

Government-Led Reclamation Model for Illegal Artisanal and Small-Scale Mining in Indonesia

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ABSTRACT

Artisanal and Small-Scale Mining (ASM) conducted without adherence to best mining practices across Indonesia has resulted in the degradation of approximately 557,000 ha across 8,386 locations, characterized by soil loss, quartz sand exposure, and widespread post-mining pits. Land recovery relies on long-term natural plant succession, necessitating government-led rehabilitation due to the absence of legally responsible mining operators. This study aims to examine the processes involved in mitigating the environmental impacts of ASM activities and to propose a model for effective post-mining land restoration by Government of Indonesia (GOI). The research further analyzed the reclamation planning model applied by the government. The results indicate that government-led reclamation of former illegal mining areas begins with the identification of illegal mining site indications, followed by feasibility studies. Sites deemed feasible are then developed into detailed reclamation designs. Of the 13 selected ASM locations, only four sites were considered suitable for further reclamation design. The resulting reclamation model integrates ecological restoration through forest and plantation species with tourism-oriented landscape design. Landscape planning for restoring former illegal mining land applied a revegetation-based zoning system aligned with the development conditions of existing plant communities.

INTRODUCTION

In general, Artisanal and Small-Scale Mining (ASM) refers to the extraction of mineral resources on a smaller scale, utilizing simpler, more labor-intensive methods compared to those employed in industrial open-pit mining (Hilson 2016). ASM involves exploitation of marginal ore deposits, using rudimentary tools, which are unprofitable to mine on a large-scale (Zvarivadza 2014), and according for article 2 of Minamata Convention on Mercury 2019 that "Artisanal and small-scale (gold) mining" means (gold) mining conducted by individual miners or small enterprises with limited capital investment and production. In the Indonesian regulatory system, ASM is known as *Pertambangan Rakyat* (Community Mining) (Lusanto *et al.* 2021). ASM has been practiced throughout Indonesia for hundreds of years and is facing an even greater increase in activity in the present day. ASM actors, especially gold mining, generally operate without a license and exploit marginal gold reserves located in remote areas with hard-to-reach access, such as protected or preserved forests, or even conservation areas, have also been found to be conducted in the middle of residential areas (Meutia *et al.* 2022). This community mining is generally carried out without a permit in its activities, often known as 'Mining Without Permits/PETI' (Sugiarti *et al.* 2021).

In Indonesia, artisanal and small-scale gold mining (ASGM) operates in two forms: licensed and unlicensed. Most ASGM activities remain unlicensed, operating outside government regulations without official permits. These illegal

operations are considered harmful because they do not pay royalties, lack oversight, and cause significant environmental and health impacts, especially due to the use of mercury (Meutia *et al.* 2022). Currently, ASGM activities in Indonesia are considered illegal for two main reasons: first, they are conducted without official operating permits; and second, many involve the use of prohibited substances, such as mercury, in the amalgamation process (Meutia *et al.* 2023). Despite these issues, ASGM plays an important economic role. It is part of the informal sector and provides jobs and income for local communities. Globally, ASGM involves 10-15 million people in 70 countries and contributes 15-20% of global gold production (Krisnayanti 2018). In 2010, Bali Fokus estimated that there are 163,710 artisanal and small-scale gold miners in Indonesia. The National Overview of Indonesian ASGM (2020) estimated this number to be 179,200 (Basel and Stockholm Conventions Regional Centre 2022). In Tanzania, it is estimated that more than one million people are directly involved in artisanal and small-scale gold mining (ASGM), which is a subset of the artisanal and small-scale mining (ASM) (Rwiza *et al.* 2023). Mining, artisanal and small-scale mining (ASM) has been on the increase over the past decade, contributing significantly to the country's socio-economic development, particularly in those communities where they are practiced. Precisely, it is estimated that ASM contributes about 35% of Ghana's gold and employs about a million people. It has further been documented that the sector has seen a 941% growth since its formalization in 1984 (Stemn *et al.* 2021).

Despite the current and potentially significant socio-economic benefits of ASM, the sector presents substantial health and safety risks that may compromise its long-term sustainability if left unaddressed (Stemn *et al.* 2021). Globally, ASM is remarkably widespread, both in terms of the number of participating countries and the diversity of extracted commodities. These include high-value resources such as gold, diamonds, tin, lithium, rare earth elements, tantalum, and cobalt, as well as commonly used materials like sand, coal, and mica (Schwartz *et al.* 2021). Two types of gold mining were observed at Ity and Floleu, depending on the nature of the ore extracted. These include the artisanal exploitation of alluvium and veins (Coulibaly *et al.* 2021). The unregulated expansion of illegal ASGM, particularly using Chamfi and alluvial mining techniques, has led to significant degradation of soils, deforestation, and adverse effects on human health (Manan and Uniaty 2011). However, abandoned ASGM sites also present opportunities for ecological restoration, particularly in landscapes contaminated with mercury. Rehabilitation efforts may focus on improving soil conditions to promote the natural regeneration of early successional plant species within a relatively short time frame (Asare *et al.* 2024).

ASM activities are widespread throughout Indonesia and have significantly contributed to environmental degradation. The lack of legal permits and clearly accountable entities has hindered the government's ability to enforce post-mining land rehabilitation. Consequently, the Indonesian government has taken on the responsibility for mitigating the environmental impacts caused by ASM, including the implementation of post-mining restoration initiatives. However, due to limited financial and technical resources, these restoration efforts are currently prioritized on land owned by the central, regional, customary land and village governments. This paper aims to examine the processes involved in mitigating the environmental impacts of ASM activities and to propose a model for effective post-mining land restoration by Government of Indonesia. This study also highlights the potential of integrating regenerative design principles as a forward-looking approach to strengthen ecological recovery and long-term sustainability.

MATERIALS AND METHODS

Study Area

This research was conducted over a five-year period (2018–2022) across 13 ASM communities located in 8 provinces and multiple districts in Indonesia. The distribution of study sites by year is as follows:

- In 2018, the study was carried out in five districts across three provinces: Padang Pariaman District in West Sumatra Province; Banjarnegara District in Central Java Province;

Landak District in West Kalimantan Province; Katingan District in Central Kalimantan Province; and Wakatobi District in Southeast Sulawesi Province.

- In 2019, research was conducted at two ASM sites located in Bintan District, Riau Islands Province, and Bengkayang District, West Kalimantan Province.
- In 2020, the study included two ASM sites in West Java Province (Tuban and Magetan Districts) and one site in Musi Rawas District, South Sumatra Province.
- In 2021, the study focused on three districts: Garut and Purwakarta Districts in West Java Province, and Temanggung District in Central Java Province.

These areas were selected by Directorate of Open Access Land Damage Restoration- MoEF, results of consultations with each province.

This study describes the government-led reclamation model implemented in Bengkayang Regency, focusing on a post-mining landscape design site in Monterado Village, Monterado Subdistrict, West Kalimantan Province. The study area covers 8.77 ha and is geographically located at 0°45'18.62" N and 109°08'41.16" E. The site constitutes a former illegal gold mining area situated on land owned by Monterado Village.

Research Procedure

In examining the processes involved in mitigating the environmental impacts of Artisanal and Small-scale Mining (ASM) activities and proposing a model for effective post-mining land restoration (Byizigiro *et al.* 2020) by the Government of Indonesia (GOI), four key processes have been identified:

1) Workshop:

The process of determining the reclamation workflow for land degradation caused by illegal ASM was carried out through a series of focus group discussions (FGDs) involving the Directorate of Open Access Land Damage Restoration under the Ministry of Environment and Forestry (MoEF) and several district and city governments with significant illegal ASM activities. The main outcome of this stage was the development of a standardized flow chart outlining the steps for land damage reclamation in areas affected by illegal ASM.

2) Site Selection for Reclamation:

The selection process consisted of two main stages: a document-based proposal evaluation and an on-site field assessment. The initial screening assessed the relevance, technical soundness, and alignment of proposals with national reclamation priorities. Subsequently, shortlisted proposals underwent a field verification process, which focused primarily on land ownership status and the feasibility of implementing reclamation activities at the proposed sites. This combined assessment approach ensured that only proposals with clear legal land tenure and practical implementation potential were considered for funding.

3) Feasibility study for illegal ASM reclamation:

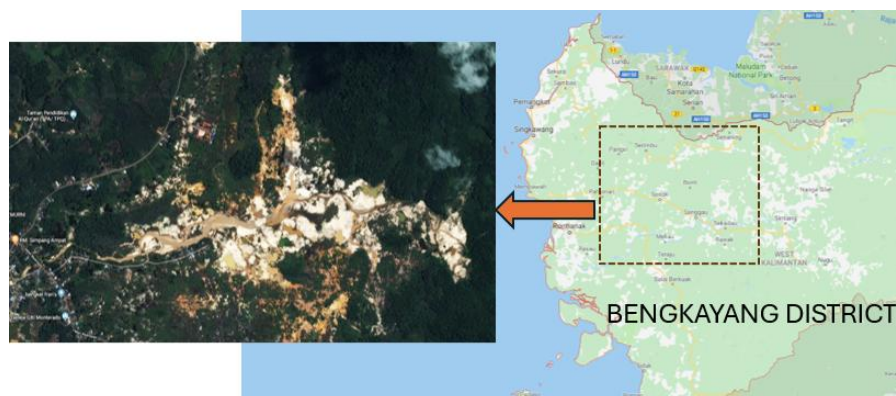


Figure 1. Study location in Monterado Village, Monterado Subdistrict, West Kalimantan Province

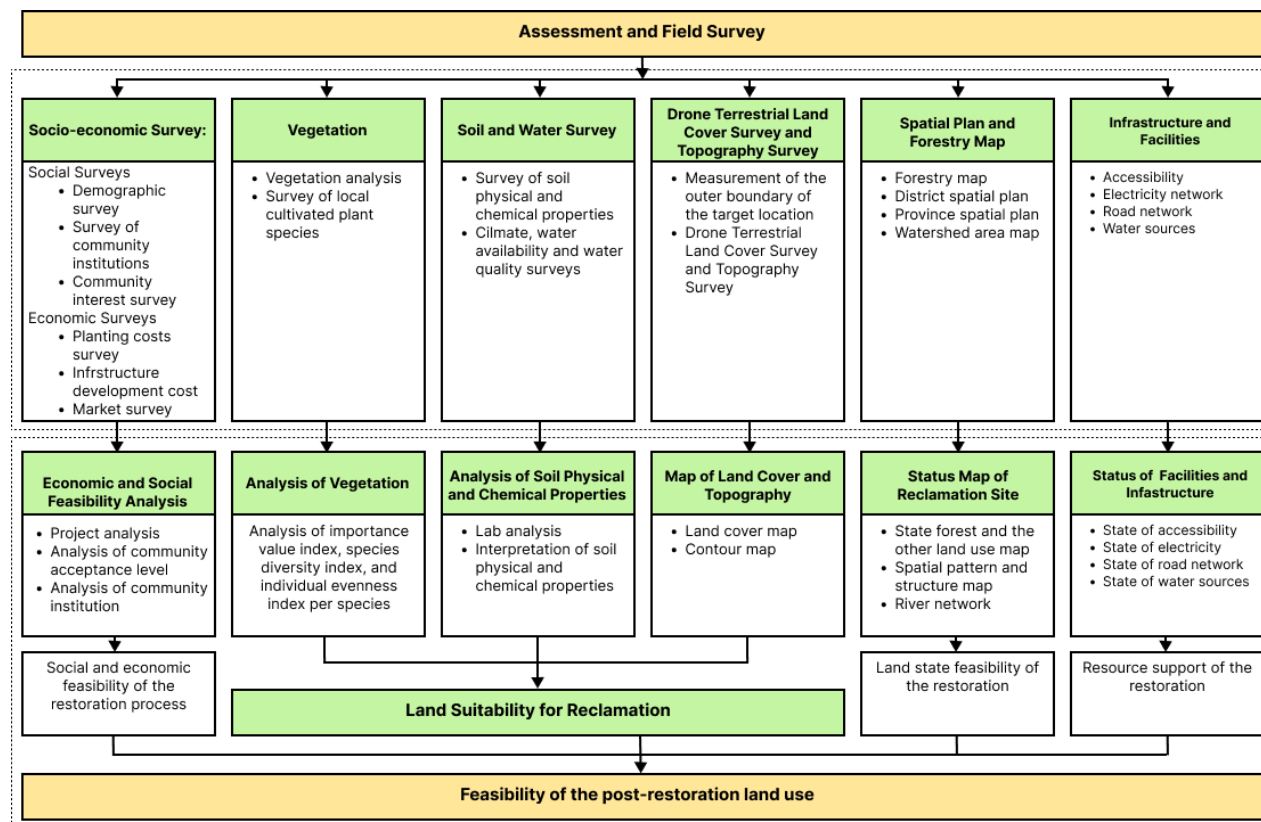


Figure 2. Assessment and field survey for feasibility study of reclamation illegal artisanal and small-scale mining

A feasibility study was conducted to evaluate the viability of government-led reclamation activities in terms of legal, environmental, and social aspects. Two dimensions were assessed: the feasibility of the restoration process and the post-restoration land use. Both primary and secondary data were utilized. Primary data included soil and water characteristics, topography, land cover, vegetation potential, and socio-economic conditions, collected through field surveys, direct measurements, and structured interviews. Secondary data, such as climate, land status and use, accessibility, infrastructure, demographics, local mining policies, and spatial planning maps were obtained through document review and data compilation from relevant agencies (Putri *et al.* 2026). The workflow of the survey and feasibility analysis is presented in Figure 1.

4) Detailed Engineering Design (DED) for illegal ASM reclamation:

This study develops a Detailed Engineering Design (DED) for reclaiming post-illegal ASM sites using a landscape architecture approach. The design process is based on the analysis of landscape characteristics, informed by prior feasibility studies and field surveys (Adesipo *et al.* 2021). These surveys assess both physical and social site conditions to guide landscape planning and design. The physical assessment focuses on the ecological condition of degraded land and surrounding environments to support integrated rehabilitation (Franco and Magalhães 2022; Dewi *et al.* 2026). Social aspects explore community involvement and future land-use preferences through interviews and purposive questionnaires (Williams and Schirmer 2012; Thani *et al.* 2016). Spatial characteristics are identified to align reclamation plans with existing regulations and land-use standards. Vegetation analysis (both existing and potential) is conducted to inform efficient planting strategies. Additional evaluations include hydrology, climate, wildlife, accessibility, infrastructure, and spatial connectivity (Tang *et al.* 2025). Legal aspects are also reviewed to ensure compliance with applicable regulations, plans, and standards relevant to post-mining land use (Kurniawan *et al.* 2025).

Vegetation, Soil and Water Sampling Method

The following activities are undertaken for the Vegetation, Soil, and Water Sampling Method to obtain the needed data:

1) Vegetation Analysis:

Vegetation data were collected using the transect line and nested plot method. Survey transects were laid out perpendicular to the contour lines (Bartha *et al.* 2022). Along each transect, a 20 m belt was established, centered on the transect line. Vegetation sampling plots measuring 20 × 20 m were placed alternately at 50-m intervals along the transect. Within each main plot, nested subplots were used to observe different vegetation strata: (1) 2 × 2 m subplots for seedlings and understory vegetation (grasses, herbs, forbs, shrubs, and epiphytes); (2) 5 × 5 m subplots for saplings; (3) 10 × 10 m subplots for poles; and (4) 20 × 20 m subplots for trees, lianas (woody and non-woody), pandan, and palms. The vegetation analysis included the calculation of the Importance Value Index (IVI), Species Diversity Index (Shannon-Wiener), and Species Evenness Index (Adeyemi 2016).

2) Soil Survey:

A very detailed soil survey was conducted through a combination of boring soil, representative profile description, and laboratory analysis. Borings were carried out to a depth of 120 cm or until the parent material was reached, with a density of two sampling points per hectare, following topographic transects. Field observations and profile descriptions adhered to the guidelines of the Soil Survey Manual (Soil Survey Staff 1951; 1961) and the Field Guidelines for Soil Observation (LPT 1969). Soil mapping and land unit classification were conducted at a very detailed scale using the terminology of the Indonesian Soil Research Center (PPT 1983), with equivalents provided based on USDA Soil Taxonomy (1977) and the FAO-UNESCO system (1985). Laboratory analyses were performed to determine key soil properties, including texture (sand, silt, and clay fractions), pH, total phosphorus (P), total potassium (K), cation exchange capacity (CEC), base saturation,

exchangeable cations (Ca, Mg, K, Na), total nitrogen (N), organic carbon (C), available phosphorus (P), as well as indicators of soil toxicity and nutrient deficiencies.

3) Climate and Hydrological Surveys:

a) Climate Data:

Climate data for the study area was obtained from the Meteorology and Geophysics Agency, covering a 10-year period. The climatic classification of the site was determined using the systems developed by Köppen, Schmidt and Ferguson, and Oldeman. Rainfall analysis included monthly precipitation patterns as well as variations in the onset and end of the dry season (Perdinan *et al.* 2017).

b) The Observed Hydrological Characteristics:

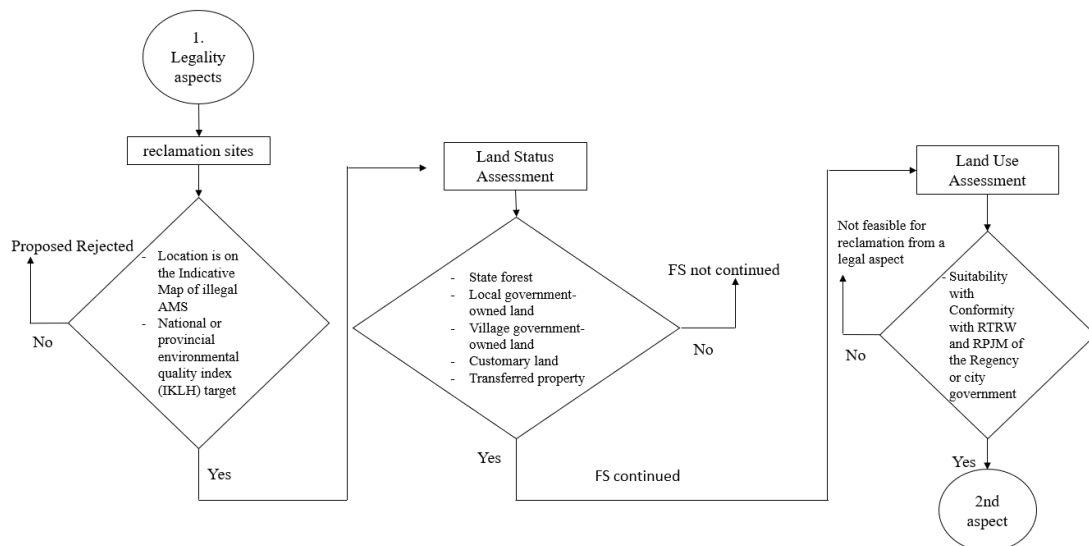
The observed hydrological characteristics included drainage conditions, major river boundaries, inundation zones, and flood-prone areas. For existing rivers or waterways, measurements of width, depth, and discharge were conducted and subsequently mapped. Flood hazard areas were assessed based on river basin data, estimated channel capacity, river morphology, and supporting information derived from topographic, soil, and land use surveys.

c) The Availability of Water Sources:

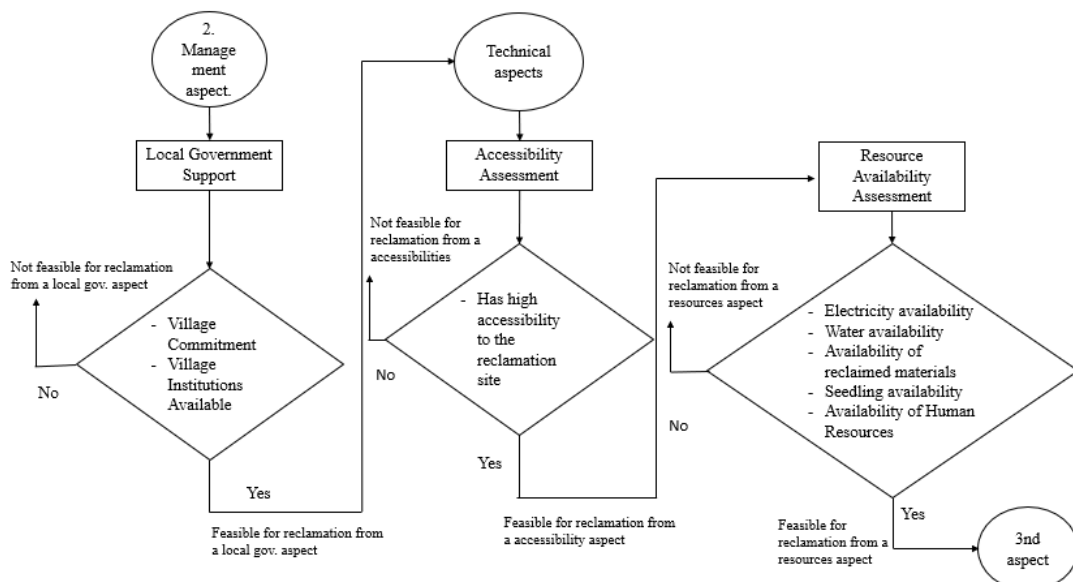
The availability of water sources in the study area was assessed through field observation and local inquiry. Potential sources of clean water include shallow groundwater wells, surface water, and rainwater harvesting systems. Groundwater quality was tested from at least two representative shallow wells within the study area. Variations in groundwater depth were identified through community interviews and direct observation of the water table. The locations of test wells and areas suitable for shallow well development were mapped as part of the hydrological assessment. Surface water sources with potential for domestic use and agricultural irrigation were also surveyed, with their locations and distribution patterns documented accordingly.

Data Analysis

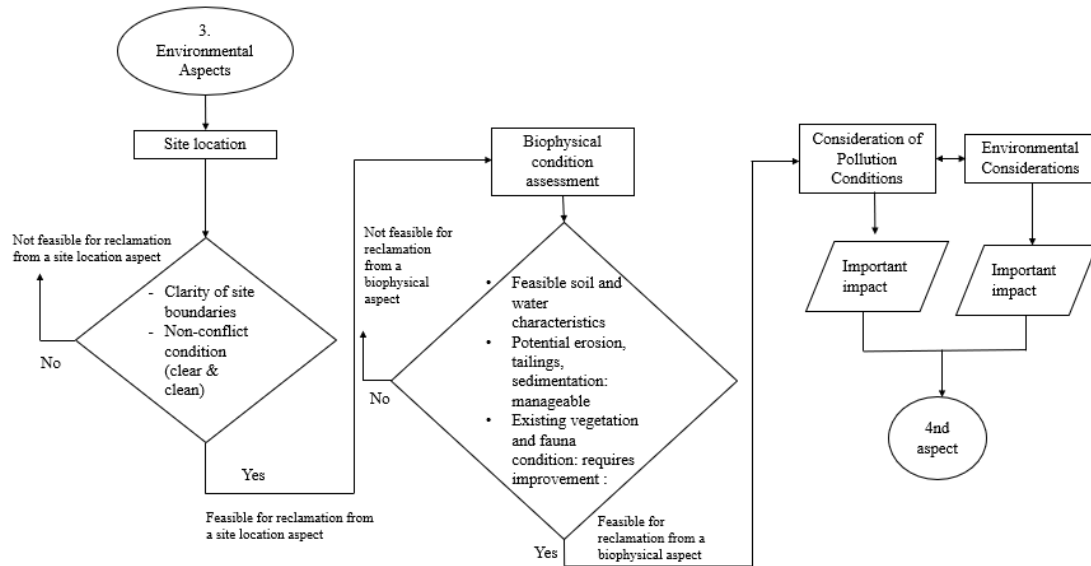
The objective of this study is to assess the feasibility of conducting land reclamation and the potential utilization of reclaimed land, which serves as a key output of the research. Data analysis was conducted descriptively by comparing the results of field and laboratory analyses with the established criteria for land restoration and post-reclamation land use at each of the proposed sites for the reclamation of former illegal



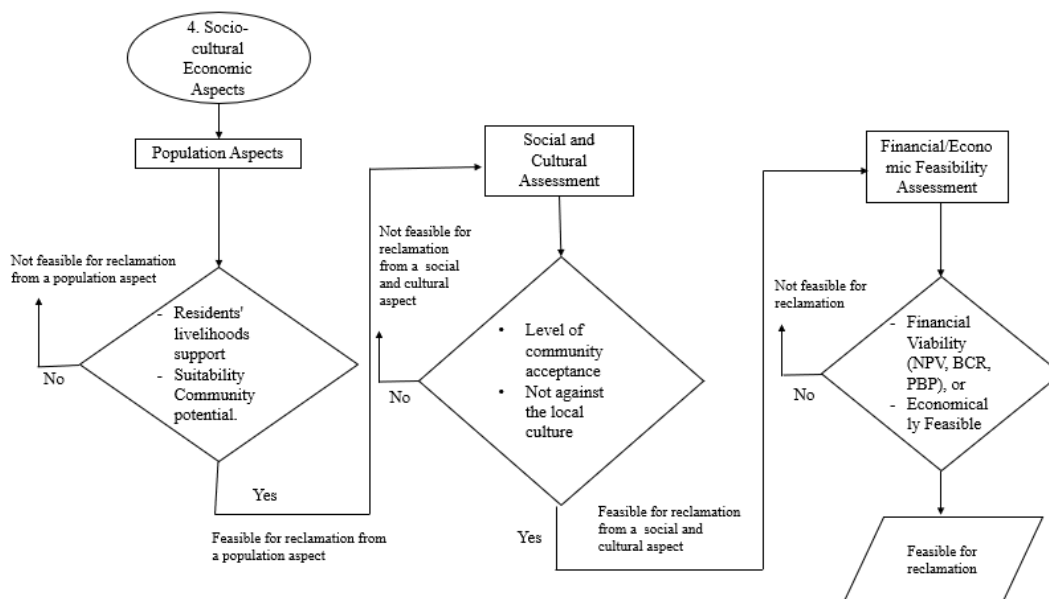
A. Feasibility study from legal aspects



B. Feasibility study from management aspect



C. Feasibility study from environmental aspect



D. Feasibility study from social-culture and economic aspect

Figure 3. Flowchart of Feasibility and Decision Making of Reclamation Process and Post-Reclamation Land Use

Source: Hernawan *et al.* 2026

ASM mining areas. The analysis aimed to determine the suitability of each site for ecological and productive recovery. The overall data analysis process followed the sequence illustrated in the flowchart (Figure 3).

RESULT AND DISCUSSION

Result

Mechanism of implementation of environmental damage reclamation due to illegal ASM by GOI

The mechanism established by the Government of Indonesia (GOI) to address environmental degradation caused by illegal ASM 15 procedural stages have been found. The process is initiated when district or city governments submit a formal proposal of environmental damage linked to illegal ASM activities to the Directorate of Open Access Land Restoration under the Ministry of Environment and Forestry. The directorate then conducts a verification process by reviewing spatial maps indicating the presence of illegal ASM and aligning the findings with the national environmental quality index targets. If the location meets the

required criteria, a pre-feasibility study (pre-FS) team is formed to conduct an initial technical and environmental assessment. The results of this assessment are documented and submitted to the Directorate. Upon approval, and if the site is deemed viable, the area is designated as a priority location for land reclamation. Following this designation, the Directorate appoints a third-party consultant to carry out a feasibility study (FS) and prepare a DED. This stage includes the preparation of technical designs, budget estimates, and implementation plans. Based on the approved DED, reclamation activities are implemented on-site to restore environmental functions previously damaged by illegal ASM operations (Figure 4).

Site Selection for Reclamation of Illegal ASM Post-Mining Areas (2018–2021)

Based on the 2017 inventory conducted by the Directorate of Open Access Land Restoration, illegal ASM activities were identified in 33 provinces across Indonesia, except for DKI Jakarta. These activities span approximately 557,000 ha and are distributed across 8,386 locations. The data reveal that the highest concentrations of illegal ASM

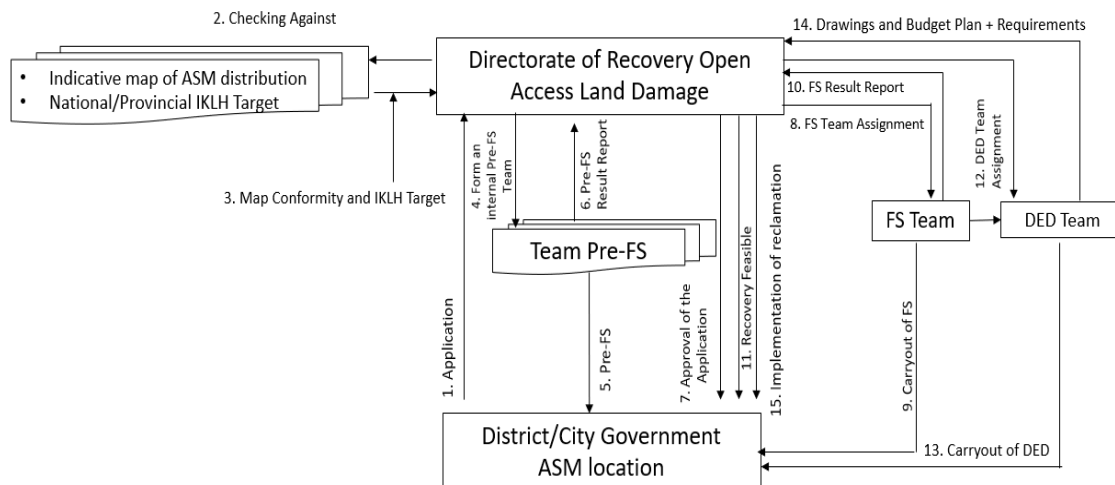


Figure 4. Mechanism of implementation of environmental damage reclamation due to illegal ASM by the government

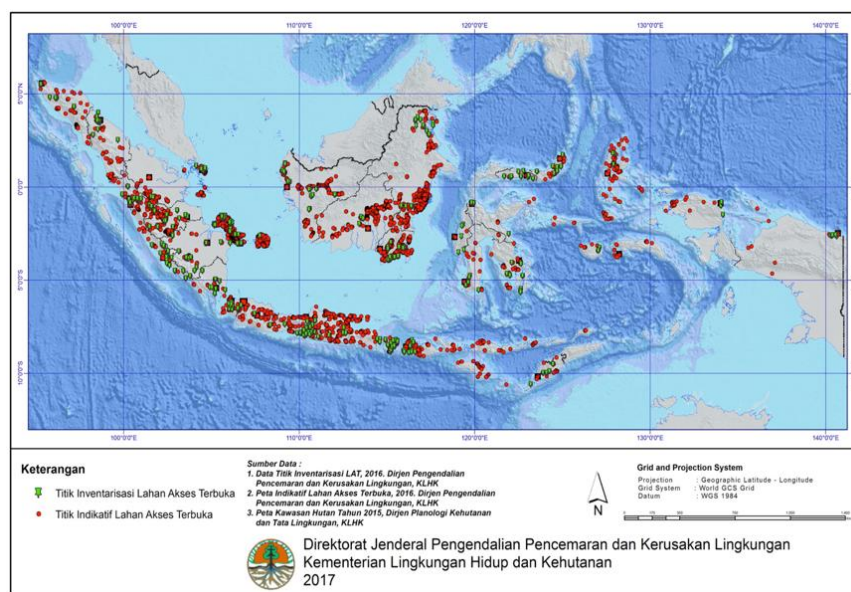


Figure 5. Map of the distribution of indicative illegal ASM sites throughout Indonesia, highlighting key hotspots and the relative scale of mining activities across different islands

Sources: Directorate General of Pollution and Environmental Damage Control, Ministry of Environment and Forestry 2017

operations are found on the islands of Java, Sumatra, and Kalimantan. This spatial distribution suggests that illegal ASM is not limited to remote or resource-rich regions but also occurs in densely populated and environmentally sensitive areas (Figure 5).

According to 2017 data from the Directorate General of Pollution Control and Environmental Damage, Ministry of Environment and Forestry, the types of mining activities conducted by illegal artisanal and small-scale mining (ASM) operations in Indonesia include sand and rock mining (37%), gold (25%), quartz sand (8%), tin (7%), coal (5%), limestone (3%), rock (2%), and other types of mining (8%). Based on the press release Number: 259.Pers/04/SJI/2022 dated July 12, 2022, accessed through the official website of the Ministry of Energy and Mineral Resources (<https://www.esdm.go.id/id/media-center/arsip-berita/pertambangan-tanpa-izin-perlu-menjadi-perhatian-bersama>), it is reported that there are more than 2,700 illegal artisanal and small-scale mining (ASM) sites across Indonesia. Of these, approximately 96 sites are associated with illegal coal mining, while around 2,645 sites involve illegal mineral extraction, according to data from the third quarter of 2021. One of the largest concentrations of illegal ASM activities is in South Sumatra Province.

Reclamation site selection between 2018 and 2021 was informed by proposals submitted by local governments, pre-feasibility study, and adjusted to state budget availability, with sites classified according to the type of mining commodity (Table 1). A total of 13 sites were designated, comprising 8 locations affected by soil, sand, and/or rock extraction; 3 by gold mining; 1 by bauxite mining; and 1 by limestone mining. These sites reflect the diverse environmental impacts associated with different types of small-scale mining activities.

Site Selection for Reclamation of Illegal ASM Post-Mining Areas (2018–2021)

1) Legal Aspect:

An assessment of the land status feasibility at the 13 post-operational sites of ASM's illegal mining activities is presented as follows. Based on the government's requirements for post-mining reclamation locations, nine sites are considered compliant: Landak Regency, Bengkayang Regency, Katingan Regency, Bintan Regency, Magetan Regency, Tuban Regency, Temanggung Regency, Purwakarta Regency, and Garut Regency. Meanwhile, four other locations—Banjarnegara Regency, Padang Pariaman Regency, Wakatobi Regency, and Musi Rawas Regency—generally meet the location criteria but

Table 1. Determination of reclamation sites for the period 2018 to 2021

No.	The types of mining activities	Location	Year prepare DED	Remarks
1	Soil, sand and/or rock mining	1. Padang Pariaman District, West Sumatra Province	2018	Site location on the river
		2. Banjarnegara District, Central Java Province	2018	Site location on the river
		3. Wakatobi District in Southeast Sulawesi Province	2018	Site location on the small island
		4. Magetan Districts, East Java Province	2020	Site location on the mainland
		5. Musi Rawas District, South Sumatra Province	2020	Site location on the river
		6. Garut Districts, West Java Province	2021	Site location on the river estuary
		7. Purwakarta District, West Java Province	2021	Site location on the mainland
		8. Temanggung District, Central Java Province	2021	Site location on the mainland
2	Gold mining	9. Landak District, West Kalimantan Province	2018	Site location on the mainland
		10. Katingan District, Central Kalimantan Province	2018	Site location on the peatland
		11. Bengkayang District, West Kalimantan Province	2019	Site location on the mainland
3.	Bauxite	12. Bintan District, Riau Islands Province	2019	Site location on the mainland
4.	Limestone	13. Tuban District, East Java Province	2020	Site location on the karst land

require further verification through the submission of supporting legal documentation. In terms of spatial planning compliance at the district and provincial levels, all sites fulfill the applicable requirements. However, in the case of Katingan Regency, the site is situated within the Forest Production Management Area (Kawasan Pengelolaan Hutan Produksi Katingan, KPHP) Katingan Hilir Unit XXX, according to SK.02/Menhut-II/2012 dated January 9, 2012, planned as a Community Development Block.

2) Management and Technical Aspect:

The feasibility of the management aspect is crucial, as the implementation and oversight of reclamation efforts—aimed at mitigating environmental damage caused by illegal ASM operations—and the subsequent post-reclamation land use depend on the active involvement of local community groups, village governments, and district authorities. In parallel, the technical feasibility assessment ensures that adequate resources are available to support both reclamation activities and long-term land management. Based on the assessment, 11 out of the 13 post-operational illegal ASM sites were found to be compliant with the management feasibility criteria. However, two sites, Banjar Negara Regency and Wakatobi Regency, were deemed non-compliant. In Banjarnegara, this is due to an ongoing boundary conflict between Kertajati Village and Purwareja Village. In Wakatobi, residents opposed the reclamation efforts because part of the area is currently used for shallot cultivation. From a technical standpoint, two sites—Katingan Regency and Wakatobi Regency—did not meet the feasibility requirements, as their remote locations present significant logistical challenges for implementing and maintaining reclamation activities. Both locations also face limitations in electricity availability, particularly from the state electricity provider (PLN), which would require the installation of long-distance power line connections.

3) Environmental Aspects:

The environmental aspect encompasses both locational and biophysical components. The locational component refers to the clarity of site boundaries in the field and the absence of land tenurial conflicts. In all assessed sites, shifts in boundary clarity and potential land disputes were observed, driven by several factors: the lack of clear demarcation between state-owned and privately-owned land (as in Katingan and Wakatobi Regencies); land ownership conflicts between adjacent villages (as in Banjarnegara Regency); and the presence of planned infrastructure development, such as a toll

road (as in Padang Pariaman Regency). In the remaining nine locations, the shifts were primarily since the site boundaries described in the initial proposals were indicative rather than definitive.

The feasibility of the biophysical component is evaluated based on the ease of reclamation, which encompasses factors such as land rehabilitation capability, surrounding environmental conditions, the level of pollution, and biodiversity at the ex-mining site. The assessment of reclamation ease is guided by the suitability of the soil for both pre-existing and target plant communities post-mining. Key soil characteristics considered in determining land suitability include chemical properties (pH, electrical conductivity [EC], and sodium adsorption ratio [SAR]), soil texture, and the capacity for water retention (Table 2). Based on Table 2, the 13 post-operational sites resulting from illegal ASM activities can be categorized into three distinct groups, namely:

- Land Suitability Good:**
Post-mining sites located in Musirawas Regency, Purwakarta Regency, and Garut Regency are classified as having good land suitability, both under current conditions and for future planting plans. The soil characteristics and water availability in these areas meet the criteria for good suitability, facilitating ease of rehabilitation efforts.
- Land Suitability Fair:**
Post-mining sites classified as having fair land suitability are in Banjarnegara Regency, Padangpariaman Regency, Temanggung Regency, Magetan Regency, and Bintan Regency. The primary limiting factor in these areas is soil texture, which includes high proportions of clay, sediment, clay sand, sandy loam, and clayey sand.
- Land Suitability Difficult:**
Former mining sites in Landak District, Bengkayang District and Tuban Regency fall under the category of poor land suitability due to significant limitations for rehabilitation. In Tuban, the main constraint is calcareous soil, which has low water retention capacity and an alkaline pH ranging from 8.5 to 9.0. In contrast, Bengkayang is limited by acidic soil conditions (pH 4.5 to 5.0) and clay-dominated texture.
- Land Suitability Expert Difficult:**
The site with the most severe limitations for reclamation is in Katingan and Wakatobi District. The dominant constraint in this area is the presence of quartz sand, which has replaced the original soil texture, making rehabilitation extremely difficult.

Table 2. Post-mining land suitability

Characteristics of soil	Good	Fair	Difficult	Expect Difficult
pH	6.1 to 8.2	5.1 to 6.1	4.5 to 5.0	less than 4.5
EC (mmhos/cm)	0 to 4	8.2 to 8.4	8.5 to 9.0	>9.0
SAR	0 to 4	4 to 8	8 to 15	>15
texture**	Sl, l, sil, scl, vfsl, fsl	5 to 10	10 to 12	>12
avail water holding	>0,10 moderate	C, sic, sc, ls, lfs	Sic, s, sc, c, cos, fs, vfs	G, vcoss
		0.05 to 0.10 low	<0,05 Very low	

**s=sand, l= loam, si= silt, c= clay, v= very, f= fine, co=coarse, g=gravel

Based on the condition of vegetation development, referring to the stages of secondary succession in disturbed areas, post-mining sites from illegal ASM activities can be classified into four succession process stages:

a) Initial Intervention Stage:

At this stage, more than 90% of the ex-mining land is characterized by bare soil, with possible colonization limited to microorganisms such as bacteria and *Cyanophyceae* algae, including *Anabaena*, *Lyngbya*, and *Symploca*. This stage is observed at the post-mining site in Katingan District and Wakatobi District.

b) Adaptation Stage:

In this phase, more than 90% of the area is covered by Cryptogamae vegetation, predominantly ferns. This stage occurs in Landak Regency, Bengkayang Regency, Padangpariaman Regency, and Wakatobi Regency.

c) Aggregation Stage:

During this stage, over 90% of the site is dominated by grasses and small herbaceous shrubs. This condition is found in Temanggung Regency and Tuban Regency.

d) Adaptation Stage:

At this stage, more than 90% of the land is covered by mature shrubs and young trees (height ≤ 15 m). Such conditions are present in Magetan Regency and Musirawas Regency.

d) Land Suitability Expert Difficult:

This is the most advanced stage of succession, where over 90% of the area is covered by tree stands exceeding 15 m in height, indicating a more stable and mature ecosystem.

Based on the environmental conditions—specifically the key soil characteristics and vegetation development, along with the visible extent of damage at the illegal ASM mining site, are presented in Figure 6.

Conceptual Design for the Reclamation Process and Post-Reclamation Land Use

The government's reclamation of land degraded by illegal ASM activities aims to restore essential environmental functions—including production capacity, water regulation, and ecological protection—while simultaneously improving community livelihoods, public health, and overall welfare. Feasibility studies conducted at 13 sites identified four locations as suitable for reclamation: Bengkayang District, Landak District, Temanggung District, and Garut District. Based on these feasibility assessments, complemented by field observations and community aspirations, site-specific reclamation design concepts were formulated. In Bengkayang District, the proposed concept is 'Arboretum Tengkawang'; in Landak District, Green Open Space (RTH) for Industrial Area; in Temanggung District, Macadamia-based Agroforestry; and in Garut District, Coastal Estuary. This study presents a conceptual landscape design for the reclamation of post-gold mining areas in Bengkayang District.

The 'Arboretum Tengkawang' concept is since the area is a producer of tengkawang nuts derived from meranti trees (*Shorea spp.*). In addition, the former mining site has

already developed as a 'grass track' tourism area, and it also contains a traditional Dayak Rarang house that is used for customary ceremonies. Accordingly, the reclamation concept for this former illegal ASM site integrates the development of a biodiversity conservation area for local West Kalimantan flora to support germplasm preservation, alongside the promotion of grass track sports activities and the development of a Dayak cultural tourism area.

As the basis for reclamation planning under the 'Arboretum Tengkawang' concept, vegetation arrangement was designed in accordance with existing environmental conditions and the designated functions of different site zones, which were classified into conservation, collection, and aesthetic vegetation areas. Conservation vegetation was allocated to areas surrounding former gold mining pits, erosion-prone zones such as steep slopes and high-gradient areas, and boundary zones adjacent to the grass track. Collection vegetation focused on tengkawang trees and other species belonging to the Dipterocarpaceae family. Aesthetic vegetation consisted of ornamental plant species intended to enhance visual appeal and serve as recreational elements to attract visitors to both the Arboretum area and the traditional cultural house area. Based on these considerations, the Block Plan and Site Plan were developed as illustrated in Figure 7.

Discussion

The increasing demand for gold, as a representative commodity, has contributed to the expansion of unregulated ASM, resulting in severe environmental degradation and the abandonment of previously productive agricultural and forested areas (Adu-Baffour *et al.* 2025). In response, the Government of Indonesia has launched initiatives to rehabilitate former ASM sites as a proactive measure to address environmental damage, particularly in cases where no responsible parties can be held accountable (Saputra *et al.* 2025). However, due to regulatory constraints governing the use of the state budget and limitations in government funding, the implementation of reclamation by the government requires a prior feasibility study. Consequently, of the 13 former ASM sites initially planned for reclamation, only four were deemed feasible for restoration (Ministry of Environment and Forestry [MoEF] 2021).

In the formal mining sector, companies are legally required to carry out post-mining reclamation. Reclamation refers to the process of restoring and rehabilitating ecosystems and the environment following mining activities so that the land can regain its intended function (Sudaryat 2025). To ensure compliance, mining companies are obligated to provide reclamation guarantee funds to the government prior to the commencement of mining operations. These funds serve as a financial assurance that the company will fulfill its post-mining environmental responsibilities. The reclamation guarantee covers both the exploration and production phases and reflects the company's commitment to restoring the land to its original condition, thereby contributing to sustainable development (Oktorina 2017). In Ghana, for instance, post-mining reclamation activities in the ASM sector have been



Figure 6. The visible extent of damage at the illegal ASM mining site

implemented through voluntary initiatives by licensed companies, such as Zenon Mining Company (Bansah *et al.* 2016). In Indonesia, however, reclamation of ASM-affected areas is typically conducted through watershed rehabilitation programs under the Leasehold License of the Forest Area (LLFA) scheme. The issuance of LLFA is governed by the Regulation of the Minister of Environment and Forestry (MoEF) No. 27/2018. As of January 2021, there were 1,089 active LLFA holders, covering a total area of 482,223.63 hectares.

Those requirements relate to spatial planning, environmental quality standards, environmental impact assessment (EIA), and licensing (Tegnan *et al.* 2023). The mechanism for implementing reclamation of environmental damage caused by illegal ASM using the state budget (APBN) comprises 15 procedural stages, beginning with proposal submission by local governments and culminating in on-site reclamation activities. Although this process is systematically structured, its implementation remains constrained by regulatory restrictions and limited budget availability,

resulting in only a portion of the planned sites being successfully reclaimed. Accordingly, feasibility studies play a critical role in determining appropriate reclamation sites by assessing legal, environmental, and socio-economic considerations. Land suitability assessments indicate considerable variability among sites: some exhibit high potential for successful reclamation, whereas others present substantial challenges, such as highly acidic soil conditions or the predominance of quartz sand. Similarly, vegetation conditions vary across sites, reflecting different stages of ecological succession ranging from early intervention to more stabilized ecosystems. These results underscore the necessity of site-specific reclamation approaches, including the strategic selection of plant species and the application of appropriate soil amelioration techniques.

Both the social and economic aspects are equally important. Effective implementation, monitoring, and sustainable post-reclamation land use requires the active participation of local communities, village governments, and district authorities. However, issues like disputes over land



Legend

Site Boundary

Circulation

X-Treme Tourism Area – Circuit Zone

Grass Track Circuit and Grandstand Area

Cultural Tourism Area

Traditional House, Amphitheater, Cottages

X-Treme Tourism Area

Hospitality Area, Garage Pit / Pit Box, Aircraft Facility, Race Room, Podium

Kalimantan Endemic Arboretum

Dry Land (Tengkawang and Ironwood) and Wetland (Nibung)

Mining Tourism Area

Selfie Spot and Park

Service Area

Management Office, Information Center, Parking Area, Food Court

(a) The spatial concept of Bengkayang Site



(b) The master plan of site in Bengkayang

Figure 7. Arboretum Tengkawang site plan in Monterado Village, Monterado Subdistrict, West Kalimantan Province

tenure and local opposition highlight the need for better communication and inclusive decision-making. The way reclaimed land is used varies; in some places, it is used for recreation, while in others, as demonstrated by the successful reclamation of coal mining areas in East Kalimantan, it supports agriculture or forest restoration (Tirkaamiana *et al.* 2024). In general, the actions undertaken by the government to recover the land that has been destroyed due to illegal ASM activities are noteworthy measures in the direction of environmental healing, however, their influence remains limited.

Implication of ASM Policy

ASM holds a vital position in the socio-economic fabric of developing countries. However, it is accompanied by considerable challenges, encompassing both its potential benefits and adverse impacts, thereby underscoring the urgency for effective policy reforms and stronger regulatory

frameworks (Abdinoor and Hussein 2025). The changes would all be a consequence of artisanal mines being morticians and by improving the incentives for accumulating the human capital necessary to achieve this higher efficiency (Sinding 2025). Consequently, the legality or licensing of ASM may incentivize ASM players to assume responsibility for post-mining reclamation efforts. The findings also showed that the one-size-fits-all mining license hinders.

- The development of appropriate environmental regulations and mine waste management practice for the various local ASM operations.
- The designing of context-specific land reclamation approaches.
- The provision of logistics, training, and technical assistance to address the divergent environmental impacts.
- The economic empowerment of women who seek to have economic visibility in the sector.

The findings further demonstrate that the current ASM formalization framework needs to be reformed through. The confluence of two factors poses a significant challenge to the reclamation efforts in former illegal ASM mining areas: the constrained state budget and the pervasive nature of illegal ASM activities.

Future Recommendation

To strengthen the sustainability and resilience of post-mining reclamation in Indonesia, future strategies should incorporate regenerative design principles. Regenerative design goes beyond conventional ecological restoration and sustainability, which primarily aim to minimize environmental damage or return land to its previous function. Instead, it emphasizes actively healing degraded ecosystems, restoring ecological processes, and enabling landscapes to continuously renew themselves (Brown *et al.* 2018; Rahmafitria *et al.* 2024). The ethos of regenerative design is to rebuild and foster new relationships between people and natural systems, so that both can co-evolve and thrive together (Toner *et al.* 2023). It emphasizes preventing further land degradation while building in-situ sources of organic matter and biodiversity. In the long term, this approach is more effective because it not only addresses immediate environmental damage but also strengthens adaptive capacity, supports biodiversity, and enhances social-ecological systems.

A key recommendation is to adopt systems that generate both ecological recovery and economic benefits, ensuring continuous motivation for long-term maintenance. Practical approaches include crop rotation to improve soil fertility and structure, mulching to prevent erosion and maintain moisture, cover crops to add organic matter and slow runoff, alley cropping, and multistrata agroforestry systems that combine species such as coconut, durian, spices, fruit trees, and legumes to stabilize soil and enhance productivity (Erfandi 2017; Pranoto and Yuni 2025). At a larger scale, a landscape-based regenerative framework designed at the watershed or ecosystem level can integrate key ecological functions such as water regulation, soil improvement, and biodiversity corridors, while also supporting human livelihoods. Techniques like composting, using biochar, and planting native vegetation accelerate soil recovery and succession (Akbar *et al.* 2020) making reclamation efforts not only ecologically restorative but also socially and economically sustainable.

Further development could focus on engaging local communities in the reclamation process to foster a sense of ownership and ensure the long-term success of regenerative projects (Syawie *et al.* 2023; Harbowoputri *et al.* 2025). This could involve training programs in regenerative agriculture, ecological restoration, and sustainable land management. By empowering communities to manage and benefit from reclaimed land, the government can ensure that reclamation efforts contribute to both environmental restoration and socio-economic development. For example, agroforestry systems could be implemented, combining timber trees with crops or livestock to provide both ecological benefits and economic opportunities (Faisal *et al.* 2022; Gege *et al.* 2023).

CONCLUSION

The study examines government-led reclamation models for illegal artisanal and small-scale mining (ASM) in Indonesia. It shows a complex interaction between environmental degradation, socio-economic factors, and regulatory challenges. ASM provides important livelihoods.

However, unregulated practices cause severe land degradation. This condition limits the government's ability to enforce post-mining rehabilitation.

The Indonesian government has taken responsibility for environmental restoration. However, these efforts are constrained by financial, technical, and regulatory limitations. Feasibility studies conducted at 13 ASM sites emphasize the need to consider legal, environmental, management, and technical aspects in reclamation planning. Land suitability for reclamation varies widely. Soil conditions and vegetation development strongly influence rehabilitation success.

Effective reclamation requires active participation of local communities. It must align with spatial planning regulations. It should also restore key environmental functions while providing socio-economic benefits. The government's reclamation mechanism follows a multi-stage process. This process starts with proposal submission and ends with on-site implementation. However, budget constraints often limit its effectiveness. As a result, only a small number of planned sites are considered feasible for reclamation.

Future reclamation should adopt a regenerative approach. This approach goes beyond basic restoration. It aims to improve ecosystem health, biodiversity, and functionality. Regenerative practices may include adding organic matter to soil, promoting native plant species, and implementing water conservation measures. Agroforestry systems can also be integrated to enhance ecological and economic value.

Local communities should be empowered to participate in planning, implementation, and monitoring. Their involvement is essential for long-term success and stewardship. By applying a regenerative framework, Indonesia can transform degraded ASM sites into productive and resilient ecosystems. These landscapes can provide ecosystem services, support local livelihoods, and contribute to a more sustainable future.

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