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Reclamation Challenges in Artisanal and Small-Scale Mining Operations in the Wassa Amenfi District of Ghana: Issues, Prospects and Sustainable Solutions

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Abstract

Artisanal and small-scale mining (ASM) has become a significant contributor to global minerals production and improvements in rural livelihoods. Despite its economic significance, ASM activities have resulted in widespread environmental degradation, raising concerns about the effectiveness of land reclamation practices. Whereas this remains a challenge, there remains a gap in literature regarding challenges faced by ASM operations during reclamation. This information is critical as it will help governments, miners, regulatory institutions, stakeholders and non-governmental agencies to plan the best strategies to be used in order to execute sustainable reclamation activities. This study contributes to scientific knowledge by examining the challenges associated with reclamation in ASM operations and proposing sustainable strategies to improve reclamation in the sector. The research adopted a mixed-method approach, integrating field studies and socio-economic surveys. Primary data was collected through structured questionnaires administered to stakeholders, such as, chiefs, regulatory agencies and local governments as well as inhabitants across 13 selected communities within the Wassa Amenfi Districts of Ghana between August 5 and August 30, 2024. Field studies were conducted in ten ASM sites using purposive and random sampling techniques. Statistical and graphical analyses were conducted using Microsoft Excel and Chi-Square tests. Key challenges identified include luck of sustainable reclamation plan, insufficient funding, weak enforcement of environmental regulations, lack of technical expertise, encroachments of illegal miners, inappropriate mining and processing techniques and no chemical analysis of the soils and water. The study recommended the adoption of a multi-stakeholder approach involving government agencies, local communities and mining operators in addressing reclamation challenges in ASM. Strengthening regulatory enforcement, ensuring compliance with reclamation policies, setting up of reclamation funds as part of the operational costs, promoting community participation, and providing technical training and expertise were identified to be critical to improving reclamation outcomes.

Keywords

Artisanal and Small-Scale Mining, Reclamation, Land Degradation, Sustainable Mining, Revegetation

1. Introduction

Reclamation is a critical component in mining operations as it ensures the environmental sustainability of the operations through the repair and preservation of the mined out lands. Mine reclamation is defined as the process of returning mined land to its natural or commercially viable state (Asiamah, 2025). Adjei (2010) also defined reclamation as the process of restoring a land into a useful state after it has suffered from environmental deterioration brought by either natural or human-caused factors. Reclamation is also defined as the process by which derelict or highly degraded lands are returned to productivity, and by which some measures of biotic function and productivity are restored (Jinger et al., 2023; Mishra et al., 2024; Rana et al., 2024). The importance of reclamation in mining operations include the restoration of fruitful ecosystems, creation of industrial resources, and the improvement of the land terrain. In addition, reclamation helps in reducing or mitigating the environmental impacts associated with mining operations. Bansah et al. (2016) highlighted that reclamation transforms mined-out pits into valuable economic resources for the local communities. Failure to reclaim land after mining poses serious safety, health, and environmental hazards, while also leading to economic losses (Salati et al., 2016; Yalley, 2024; Yalley et al., 2025a).

Reclamation objectives may be conceptualised from both theoretical and practical perspectives. Fundamentally, an effective reclamation programme should be designed to establish ecologically stable and self-sustaining conditions that facilitate the reintegration of disturbed landscapes into the surrounding ecosystem (Jinger et al., 2023; Mishra et al., 2024). Importantly, mine reclamation planning should be undertaken prior to the commencement of mining operations, even though the implementation occurs mostly during and after mine closure (Amankwah & Anim-Sackey, 2003; Aryee et al., 2003; Appiah & Osman, 2014; Basommi et al., 2015; Botchwey & Crawford, 2018; Yalley et al., 2025b). Given the heterogeneity of disturbance regimes, reclamation interventions must be site-specific and based on appropriate technical and ecological assessments. Consequently, a comprehensive reclamation plan should incorporate landform recontouring and stabilisation, topsoil replacement or the use of suitable growth media, revegetation using appropriate species assemblages, and long-term monitoring and adaptive management to ensure ecosystem recovery and functionality (Jinger et al., 2023; Mishra et al., 2024; Rana et al., 2024).

Various reclamation techniques have emerged over the years which have been classified as: Physical and Engineering technologies, Soil Amendment and Physicochemical technologies, Biological and Ecological technologies, Phytoremediation and Phytotechnologies, Geomorphic and Landscape Design approaches, Integrated and Emerging technologies, and Monitoring and Adaptive Management technologies (Castaño-Díaz et al., 2018; Xie & Zyl, 2020; Basu et al., 2025; Darko et al., 2026). The Physical and Engineering technologies involve the works of land recontouring, backfilling, topsoil layering and drainage and hydrological control. Soil amendments and physicochemical technologies involve soil stabilisation through chemical balances either through biochar application or nanoremediation. The biological and ecological technologies involve the works of revegetation through either the forestry reclamation approach, agricultural approach or the microbial remediation approach. Phytoremediation and phytotechnologies happen to be the amongst the most recent technologies which could be achieved through phytoextraction, phytostabilisation, phytovolatilisation, rhizodegradation or phytohydraulics. The Geomorphic and landscape design approaches involve the modelling and geotechnical engineering to create stable landforms with natural landscapes and resist long-term erosion.

In order to ensure sustainability in mining operations, many countries enforce reclamation in their mining laws and regulations. For instance, in Ghana the Regulation 9 of the L.I. 2182 which is the Minerals and Mining Regulations (Health, Safety and Technical Regulations, 2012) require that the Mining Operating Plan (MOP) must include an Environmental Management Plan (EMP). The EMP should contain the reclamation schedule and strategies to be implemented after mining. Moreover, Regulation 23 of the Environmental Assessment Regulations (EAR), 1999 (L.I 1652) mandates the Environmental Protection Agency (EPA) to ensure that prospective mining companies in Ghana post reclamation bonds in the form of cash into an escrow account based on approved reclamation plans before issued permits to operate. Due to the huge capital investment in Large Scale Mining (LSM), LSM operations ensure proper reclamation and strict adherence to regulations regarding reclamation in order to avoid any sanctions to their operations. Moreover, LSM operations employ technical professional who are able to provide effective and reclamation plan and strategies and efficient implementation. However, observations of ASM operations reveal gaps in the reclamation process and gaps in the adherence to the regulations regarding reclamation.

Although a substantial body of scientific literature exists on artisanal and small-scale mining (ASM) operations, a significant knowledge gap remains regarding the reclamation of ASM mined-out sites. Much of the existing research has primarily focused on documenting the adverse environmental consequences of ASM operations, with comparatively limited attention given to reclamation practices and technological advancements that could enhance environmental sustainability within the sector (Amegbey & Eshun, 2003; Eshun, 2005; Tschakert & Singha 2007; Tom-Dery et al., 2012; Ontoyin & Agyemang, 2014; Hilson & Maconachie, 2020; Dossou Etui et al., 2024; Fonshiynwa et al., 2024; Opoku et al., 2024). While ASM plays an important role in local livelihoods and broader economic development, there is insufficient understanding of the challenges associated with the reclamation of ASM sites and the sustainable strategies required to address them effectively. Addressing this gap is essential for mitigating the extensive land degradation resulting from ASM operations and promoting the long-term sustainability of the sector. Therefore, this study aims to contribute to the existing body of scientific knowledge by critically evaluating the challenges associated with ASM sites reclamation in the Wassa Amenfi Districts of Ghana and proposing sustainable solutions to improve reclamation outcomes.

2. Materials and Methods Used

This study employed a mixed-methods research approach that utilised primary data sources to comprehensively investigate the challenges associated with the reclamation of artisanal and small-scale mining (ASM) sites. Primary data were collected through field studies undertaken at 10 ASM sites, which included field observations and interviews of the 10 Mine Managers from the 10 sites. Also, there was administration of structured questionnaires to stakeholders of ASM and inhabitants of 13 selected communities within the Wassa Amenfi Districts. Amongst the stakeholders included Chiefs, Minerals Commission Officers, Environmental Protection Agency Officers and Officers of the District and Municipal Assemblies. Out of the 171 total number of respondents, 141 were inhabitants (landowners and tenants) and 30 of the respondents were the stakeholders. The data collection period spanned from 5th August 2024 to 30th August 2024. The collected primary data were analysed using graphical and descriptive statistical methods (Percentiles) to facilitate the identification of key trends and patterns. Furthermore, Microsoft Excel and Chi-Square Test were utilised for data management, interpretation, and the presentation of the primary data. The integration of these methodological approaches provided a robust framework for assessing reclamation challenges in ASM operations and for generating evidence-based recommendations for sustainable land restoration and environmental management.

2.1. Study Areas

The study was conducted in 3 Municipal and District Assemblies (MDAs) in the Wassa Amenfi area in the Western Region of Ghana. These include the Wassa Amenfi West Municipal Assembly, the Wassa Amenfi East Municipal Assembly and the Wassa Amenfi Central District Assembly. **Figure 1** shows the location of the study areas on the map of Ghana. These study areas were selected due to the high concentration and long-standing prevalence of ASM operations within the region. Furthermore, the selected locations encompass the principal forms of ASM operations, including both underground and surface mining methods, as well as the various types of mineral deposits exploited by ASM operators, namely alluvial, colluvial and hard-rock deposits. The diversity of mining techniques and geological settings represented within the study areas provide a comprehensive basis for examining reclamation challenges across different ASM contexts. Consequently, these characteristics render the study area particularly suitable for investigating ASM-related environmental and reclamation issues. Additionally, given the region's extensive history of ASM activities and their anticipated continuation in the foreseeable future, the findings of this research are expected to contribute valuable insights for the development of sustainable reclamation strategies and environmental management interventions.

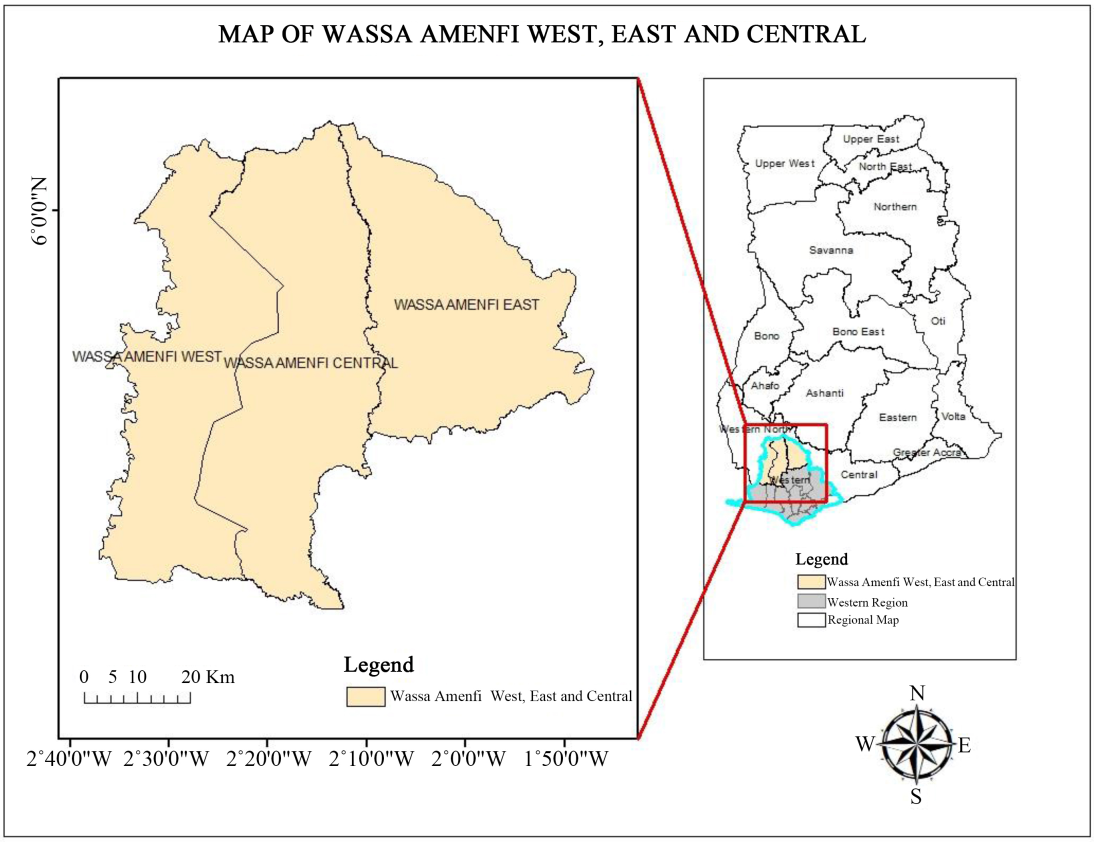

Figure 1. Map of Ghana showing the location of the study areas.

2.2. Research Methods for Field Work

The purposive sampling technique was employed to select the ten (10) ASM sites used for the field investigation. Site selection was undertaken in consultation with and based on recommendations from the District Office of the Minerals Commission in Asankragwa within the Wassa Amenfi West Municipal Assembly. The Minerals Commission is the statutory regulatory authority responsible for the licensing and regularization of mining activities, including ASM operations in Ghana. Consequently, it is the primary repository of information on registered

ASM operations and is well positioned to identify sites that are appropriate for research purposes.

Furthermore, consultations with the Minerals Commission facilitated the identification of active and operational ASM sites, as a considerable proportion of registered mining sites were found to be inactive at the time of the study. Engaging the Commission in the site selection process also enhanced access to the selected sites, as miners generally regard researchers introduced through the Commission as credible and duly authorized to conduct research activities. In total, 10 active ASM sites distributed across the 3 Metropolitan, Municipal, and District Assemblies (MMDAs) within the Wassa Amenfi area were selected for this study.

For the purposes of this study, the sites were labelled based on the located towns. The sites were chosen to represent both underground and surface ASM operations. Out of the 10 selected sites, 8 sites were located in the Wassa Amenfi East Municipal Assembly, 1 site was located in the Wassa Amenfi West Municipal Assembly and 1 site was located at Wassa Amenfi Central District Assembly. The selected sites within the Wassa Amenfi East Municipal Assembly include the sites at Botwekrom, Adamanso, Gyapa, Dompoase, Nanakaw, Dadieso, Adiembra and Nkyiase. The selected sites in the Wassa Amenfi Central District Assembly and the Wassa Amenfi West Municipal Assembly were in Hiawa and Asankragwa respectively. Figure 2(a)-(d) show the surface ASM operations and Figure 3(a), Figure 3(b) show the underground ASM operations.

At the various sites observations were made regarding the mining methods and processing methods used, the operational challenges and the reclamation challenges. In addition, the mine managers were asked to also outline their operational challenges and reclamation challenges. The information was gathered to show their general challenges and the likelihoods of them affecting reclamation.

Figure 2. Selected surface ASM sites at (a) Asankragwa (b) Adamanso (c) Gyapa (d) Hiawa.

Figure 3. Underground ASM sites at Dompoase showing (a) Underground Mine Set-up (b) A Typical Inclined Tunnel.

2.3. Sampling of Respondents for the Interviews and Questionnaire Administration

For this study, a total of 3 sets of respondents were used for the interviews and questionnaire administration. These include the interviewees for the field studies, questionnaire administration to the stakeholders including the chiefs, Minerals Commission officials, the Environmental Protection Agency (EPA) officials and the District Assembly officials. The third category of respondents were the inhabitants of the communities for the questionnaire administration.

2.3.1. Sampling of Interviewees

The purposive sampling techniques was employed in selecting the interviewees at the various mine site. This technique was employed because the questions relating to the reclamation challenges being faced by the mine could only be answered by top management who understood the obligations of the mine in terms of reclamation. As such, the mine managers were specifically chosen as they had that knowledge. Besides, they were the ones responsible for reporting the activities of the operations to the regulatory bodies including their environmental management practices. At best, the Environmental engineers should have also been interviewed but all the operations did not have such engineers on site. As such, the interviews were limited to only the 10 mine managers from the 10 selected mine sites.

2.3.2. Sampling of Households and Stakeholders for the Questionnaire Administration

Sampling of the respondents for the questionnaire administration was done using both purposive and simple random sampling techniques. Clustering the Wassa Amenfi corridor according to the administrative division of Municipal and District Assemblies (MDAs) was the first step in the sampling process. The 3 MDAs are the Wassa Amenfi East, Wassa Amenfi Central and Wassa Amenfi West districts with stakeholders and household surveys conducted across the three districts. These districts are known for their significant ASM operations, making them ideal for investigating the challenges regarding reclamation in the area.

A combination of purposive and simple random sampling techniques was employed in the selection of the communities. First, purposive sampling was used to select 13 communities from the three districts; Nine communities—Nanankaw, Abreshia, Dadieso, Gyapa, Adiembra, Domapoase, Nkyiase, Adamanso and Botwekrom were encompassed in the Wassa Amenfi East Municipality. Three communities—Hiawa, Wassa Bekwai and Ampongtengkrom were encompassed by the Wassa Amenfi Central District. Furthermore, it was discovered that just one settlement in the Wassa Amenfi West Muncipality; Asankrangwa hosted ASM operations and were reported on. These communities were selected based on their proximity to mining activities and their exposure to the effects of ASM operations. The purposive approach ensured that the selected communities would provide relevant data on the impact of mining.

Once the communities were selected, a simple random sampling technique was applied to select households for the survey. The purposive sampling technique was used in selecting the stakeholders for the survey. A total of 200 respondents (30 stakeholders and 170 inhabitants) were targeted for the questionnaire administration. The targeted stakeholders included 21 chiefs from the communities, 3 officials from the MDAs, 3 officials of the Minerals Commission and 3 EPA officials. The officials from the EPA and the Minerals Commission were all based in Asankragwa in Wassa Amenfi West Municipality. The other MDAs did not have Minerals Commission and EPA there and were all being supervised by the offices in Asankragwa. All 30 stakeholders responded but only 141 inhabitants responded. Thus, bringing the total number of responses to be 171 representing 85.5% response rate.

The data collection instrument used for the survey was a structured questionnaire administered to household heads. The questionnaire covered key areas including demographic information, perceptions of mining activities, the socio-economic impacts of ASM, environmental concerns, and the households' awareness of and involvement in reclamation efforts. In cases where the household head was unavailable, the survey was conducted with the most knowledgeable adult present in the household. To ensure the availability of household heads and increase response rates, data collection was scheduled within days when most households were likely to be at home. This approach helped to minimise non-responses and improve the accuracy of the data. Ethical considerations were a crucial part of the data collection process. All participants were fully informed about the purpose of the study, and their consent was obtained before administering the questionnaire. They were assured of the confidentiality of their responses, and participation in the survey was entirely voluntary.

2.3.3. Analysis of Interviews and Questionnaire Data

The collected data was analysed using Microsoft excel and further represented on graphs and tables to show the trends of the responses. The data from the field studies were analysed using tabular representations to show the trends of operations and the reclamation challenges faced by the various operations. Descriptive statistics particularly percentiles were used to analyse the responses from the questionnaire. The questionnaire responses from the stakeholders and the inhabitants were combined and analysed to provide an overview of their perceptions regarding the effects of ASM activities and reclamation efforts across the three districts. A Chi-square test of independence was performed to examine the relationship between participation in reclamation efforts and perception of mining impact. The test was conducted with Pearson's Chi-squared test with Yates' continuity correction in R studio.

3. Results and Discussions

The results from the study have been classified into 2 sections comprising of the results from the field studies, results from the interviews of the mine managers and the results from the questionnaire administration.

3.1. Results from the Field Studies

The results from the field studies include the information gathered through the observations at the 10 mining sites and the information gathered from interviews with the Mine Managers of the various sites. Ideally information should have been sort from both the Environmental engineers and the Geotechnical engineers as well since proper reclamation process requires the input of these engineers. However, all the operations did not have such technical personnel working for them, as such the study had to limit the information gathering to only the respective mine managers. Table 1 summarises the observations on mining operations and challenges regarding reclamation at the various sites. Figure 4 shows a failed reclamation site due to the encroachments of illegal miners at Botwekrom. Figure 5 shows a failed reclamation exercise at due to the poor reclamation technique used.

Figure 4. Post-reclamation encroachment by illegal miners at the Botwekrom mine site.

Figure 5. Failed Reclamation at the Nanakaw site.

Table 1. Mining operations and reclamation challenges at the various ASM site.

ASM Mine Site	Mining Methods and Processing Techniques	Operational Challenges	Reclamation Challenges
Wassa Gyapa site	Hard rock deposits being exploited with no alluvial deposits. Open pit mining method employed in mining. Mercury amalgamation technique used in the mineral processing. A total of 27 Hammer mills (Changfa), 4 Hydraulic backhoe excavators, 2 water pumps, 27 Sluice boards, hand-held pickaxes and shovels were used in the operations.	Evidence of land degradation on site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area. Poor housekeeping at the site.	Concurrent backfilling was being done with mining but the excavation of the topsoil together with the overburden materials made it difficult for revegetation to take place in the backfilled areas. Insufficient funds for the operations lead to insufficient funds for carrying out proper reclamation.
Wassa Dadieso site	Hard rock deposits being exploited with no indications of alluvial deposits mining. Mining method not clearly defined with crushing and milling ongoing nearer to the active mining area. Ball mill was being loaded directly with a Hydraulic backhoe excavator. Mercury amalgamation technique used in the mineral processing. A total of 40 Hammer mills (Changfa), 1 Ball mill, 6 Hydraulic backhoe excavators, 5 water pumps, 40 Sluice boards, hand-held pickaxes and shovels were used in the operations.	Evidence of land degradation on site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area.	Concurrent backfilling was being done with mining but the excavation of the topsoil together with the overburden materials made it difficult for revegetation to take place in the backfilled areas. No proper reclamation plan prepared.
Wassa Nanankaw site	Hard rock deposits with open pit mining method being employed. Excavators excavating the materials from the pit and loading materials directly into the crusher. Mercury amalgamation technique used in the mineral processing. A total of 5 Hammer mills (Changfa), 1 Hydraulic backhoe excavators, 2 water pumps, 5 Sluice boards, hand-held pickaxes and shovels were used in the operations.	Evidence of land degradation on site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area. Poor housekeeping at the site	Concurrent backfilling was being done with mining but the excavation of the topsoil together with the overburden materials made it difficult for revegetation to take place in the backfilled areas. Insufficient funds for the operations lead to insufficient funds for carrying out proper reclamation.

Continued

Asankrangwa site	Both alluvial and hard rock deposits being exploited. Open pit mining method employed in mining the hard rock deposits. Dig and wash method used in exploiting the alluvial deposits. Hard rock materials were fed into the hammer mills using the excavators. Mercury amalgamation technique used in the mineral processing. A total of 15 Hammer mills (Changfa), 1 Hydraulic backhoe excavators, 2 water pumps, 17 Sluice boards, hand-held pickaxes and shovels were used in the operations.	Evidence of land degradation on site. Tailings and waste water was management was a challenge at the site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area.	Reclamation already done in some of the pits. Topsoil lumped with overburden materials made revegetation difficult. Poor waste water management leading to accumulation of water everywhere on the mine. Insufficient funds for revegetation.
Adiembra site	Hard rock deposits being exploited with no alluvial deposits. Open pit mining method employed in mining. Excavators loaded materials into dump trucks which hauled it over 50 m distance to the processing site. Semi-mechanised mineral processing system using crushing and milling equipment. Hammer mills (Changfa), Hydraulic backhoe excavators, Dump trucks, water pumps, Sluice boards, hand-held pickaxes and shovels were used in the operations but the total numbers not given.	Poor housekeeping at the site.	Concurrent backfilling was being done with mining but the excavation of the topsoil together with the overburden materials made it difficult for revegetation to take place in the backfilled areas.
Dompoase site	Hard rock deposits being exploited with no alluvial deposits mining. Underground mining using a tunnel as the main entry point. Mechanised mineral processing using crushers and milling equipment. Mercury amalgamation process employed in mineral processing. Trommel, Generator plant, lighting towers, washing plant and water pumps used in operations.	Negative effects of open burning of mercury gold amalgam. Dust pollution at milling points. Noise from washing plant/ Trommel machine.	Backfilling concurrently done with mining in the underground excavations. Topsoil was lumped with the overburden during the development stage of the operations.
Adamanso site	Hard rock deposits being exploited with no alluvial deposits. Open pit mining method employed in mining. Excavators loaded materials into dump trucks which hauled it over 100 m distance to the processing site. Semi-mechanised mineral processing system using crushing and milling equipment. Mercury amalgamation technique employed in the mineral processing. A total of 3 Hydraulic backhoe excavators, 1 Crusher, Dump trucks, 2 water pumps, 2 Sluice boards, hand-held pickaxes and shovels were used in the operations.	Evidence of land degradation on site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area.	Pit actively being mined with no reclamation attempts made yet.

Continued

Hiawa site	Hard rock deposits being exploited with no alluvial deposits. Open pit mining method employed in mining. Excavators loaded materials into dump trucks which hauled it over 100 m distance to the processing site. Semi-mechanised mineral processing system using crushing and milling equipment. Mercury amalgamation technique employed in the mineral processing. Hydraulic backhoe excavators, Crusher, Dump trucks, water pumps, Sluice boards, hand-held pickaxes and shovels were used in the operations but the total number was not given.	Evidence of land degradation on site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area. Poor housekeeping at the site.	Concurrent backfilling was being done with mining but the excavation of the topsoil together with the overburden materials made it difficult for revegetation to take place in the backfilled areas. Insufficient funds for the operations lead to insufficient funds for carrying out proper reclamation.
Nkyiase site	Colluvial deposits being exploited with no alluvial deposits. Open pit mining method employed in mining. Excavators loaded materials into dump trucks which hauled it over 100 m distance to the processing site. Semi-mechanised mineral processing system using crushing and milling equipment. Mercury amalgamation technique employed in the mineral processing. Hydraulic backhoe excavators, Crusher, Dump trucks, water pumps, Sluice boards, hand-held pickaxes and shovels were used in the operations but the total number was not given.	Evidence of land degradation on site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area. Poor housekeeping at the site.	Concurrent backfilling was being done with mining but the excavation of the topsoil together with the overburden materials made it difficult for revegetation to take place in the backfilled areas. Insufficient funds for the operations lead to insufficient funds for carrying out proper reclamation.
Botwekrom site	Both alluvial and colluvial deposits being exploited. Dig and wash method used in exploiting the deposits. Mercury amalgamation technique used in the mineral processing.	Evidence of land degradation on site. Tailings and waste water was management was a challenge at the site. Open burning of mercury amalgam highly hazardous. Dust and noise pollution from the crushing and milling area.	Reclamation already done in some of the pits. Topsoil lumped with overburden materials made revegetation difficult. Poor waste water management leading to accumulation of water everywhere on the mine. Insufficient funds for revegetation.

Reclamation Challenges from the Field Studies

Results from the field studies reveal that the major challenges faced by ASM operations in reclamation include: the luck of a sustainable reclamation plan; insufficient funding for reclamation; inappropriate excavation procedure and mineral processing techniques; luck of expertise or professionals; No chemical testing of the soils and water after mining; and encroachments from illegal miners. Firstly, any proper and sustainable reclamation should be well planned and executed. However, throughout all the 10 mining sites visited, it was seen that the operations did not have any reclamation plan. It appeared that the miners considered reclamation as a spontaneous and transient activity that did not require much attention. However, contrary to that reclamation actually forms an integral and important part of mining sustainability, which consumes time and is also capital intensive. Therefore, a detailed reclamation plan should be outlined at the feasibility stage of the operations, with the cost included in the operations cost before the economic viability of the operations are determined. Moreover, insufficient funding for reclamation was hindering the execution of a sustainable reclamation. The managers of the ASM sites visited indicated that there was not enough funding for reclamation. This is because the process was not envisaged to be as expensive only until they begun the process. As such, even though its reclamation was being undertaken, it was not properly done.

Furthermore, in all cases, there was no chemical assessment of the soils and water before and after mining. It is important for the chemical composition of soils to be tested before and after mining so that the chemical compositions beyond the acceptable limits could be remedied. This forms the basics of the exact vegetation to be used for the reclamation. But since none of these were not done, it clearly shows as the supposed reclaimed sites where not thriving as it could be a case of the vegetation may not be the best for those types of soils. In addition, inappropriate excavation techniques or procedure and the poor mineral processing techniques also resulted in difficulty in reclamation. In the excavation, the correct procedure should have been that the topsoils are stripped and stockpiled before the overburden materials are also removed. That way after mining, the overburden will be used to backfill the area and the topsoil spread on it to support the vegetation growth. However, the lumping of the overburden together with the soils using the hydraulic excavators makes it difficult for revegetation after backfilling since there will be the absence of topsoil to support vegetation growth. Also, the use of the mercury amalgamation technique and the open burning of the mercury during smelting could lead to the accumulation of the liquid mercury in the atmosphere which could eventually be released into the soil when it rains.

In addition, the encroachments from the illegal miners also challenged the reclamation process. In many cases, the illegal miners encroach the already reclaimed areas, excavating and abandoning those areas. Others, also encroached the already mined out pits which were being prepared for reclamation. These completely degrade the already reclaimed lands and also frustrate the registered ASM sites if they want to reclaim their lands. Lastly, the luck of the expertise in terms of environmental engineers and geotechnical engineers makes reclamation quite difficult for the miners. As there will be the need to have those engineers on the sites to guide the reclamation procedure and ensure compliance to standards.

3.2. Results from Questionnaire Administration

Out of the 200 targeted number of respondents for the questionnaire administration, 171 responses were received, thus representing an 85.5% response rate. The targeted respondents included chiefs, houseowners, inhabitants, officers from the Minerals Commission, officers from the Environmental Protection Agency (EPA) and officers from the MDAs. The questionnaire focused mainly on 4 key areas to analyse the respondents' views on reclamation in ASM operations. The questions were centered on whether ASM operations have positive or negative impacts; whether they are aware that ASM operations undertake reclamation; whether they had been involved in any ASM mine site reclamation activities and: whether ASM operations were contributing to environmental degradation. The designation of the respondents and the total number of individuals across the 3 MDAs is shown in Table 2. The results from the questionnaire administration is shown in Table 3.

Table 2. Designation of respondents and their total number.

Districts	Designations	Respondents	No of Respondents	Total
Wassa Amenfi East	Stakeholders	Chiefs	10	83
		District Assembly	1	
	Community Members	Landlords	27	
		Inhabitants	45	
Wassa Amenfi Central	Stakeholders	Chiefs	7	48
		Municipal Assembly	1	
	Community Members	Landlords	15	
		Inhabitants	25	
Wassa Amenfi West	Stakeholders	Chiefs	4	40
		Municipal Assembly	1	
		Minerals Commission	3	
		Environmental Protection Agency	3	
	Stakeholders	Landlords	10	
		Inhabitants	19	
Total			**171**	**171**

Table 3. Results from the questionnaire administration.

Variable	Wassa Amenfi East	Wassa Amenfi Central	Wassa Amenfi West	Total
Total Households Surveyed	83	48	40	171
Perception of ASM Impact on Livelihood				
- Positive Impact (%)	45%	40%	35%	40%
- Negative Impact (%)	55%	60%	65%	60%
Awareness of Reclamation Activities in ASM				
- Yes (%)	25%	20%	15%	20%
- No (%)	75%	80%	85%	80%
Participation in Reclamation Efforts				
- Yes (%)	10%	8%	5%	8%
- No (%)	90%	92%	95%	92%
Perception of Environmental Degradation				
- Severe Degradation (%)	70%	75%	80%	75%
- Moderate Degradation (%)	25%	20%	15%	20%
- No Degradation (%)	5%	5%	5%	5%

3.2.1. Impacts of ASM Operations on Livelihoods

In the Wassa Amenfi East Municipality, 45% of the respondents indicated that ASM operations had positive impacts on their livelihoods whereas 55% indicated that it impacts negatively on their livelihoods. In the Wassa Amenfi Central, 40% of the respondents indicated that ASM operations impact positively on their livelihoods whereas 60% indicated that the operations impact negatively on their livelihoods. In the Wassa Amenfi West, 35% of the respondents indicated that ASM operations impact positively on their livelihoods whereas 65% indicated that ASM operations impact negatively on their livelihoods. In effect an average of 40% of the respondents indicated positive impacts of ASM and 60% of the respondents indicated that ASM impacts negatively on their livelihoods. This clearly shows that majority of the respondents did not actually the significance of ASM to them. This could be as a result of the consequences that they were facing from land degradation resulting from the failed reclamation efforts by the miners. Figure 6 is a graph showing the responses regarding ASM operations impacts on their livelihoods.

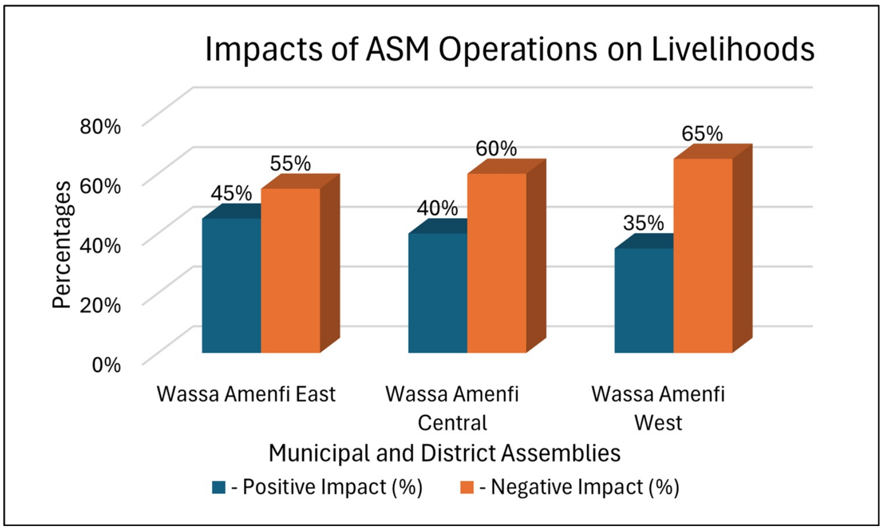

Figure 6. Graph showing responses regarding ASM operations impacts on livelihoods.

3.2.2. Awareness of Reclamation in ASM

The respondents were asked to indicate their awareness about reclamation in ASM as a way of curbing environmental degradation. In the Wassa Amenfi East Municipality, 25% of the respondents indicated that they are aware that ASM operations undertake reclamation ASM whereas 75% of the respondents indicated that they were not aware that ASM operations undertake reclamation. In the Wassa Amenfi Central, 20% of the respondents indicated that were aware of reclamation in ASM operations whereas 80% of the respondents indicated that they were not aware of reclamation in ASM operations. In the Wassa Amenfi West, 15% of the respondents indicated that their awareness of reclamation in ASM whereas 85% indicated that they were not aware that ASM operations undertake reclamation. Figure 7 is a graph showing the responses regarding the awareness of reclamation in ASM operations.

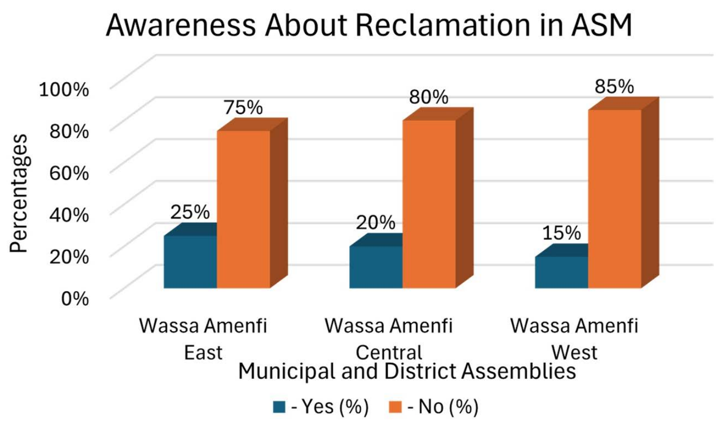

Figure 7. Graph showing responses regarding awareness of reclamation in ASM.

3.2.3. Participation of Respondents in ASM Reclamation

In assessing the reclamation challenges encountered by ASM operations, respondents were further asked whether they have been engaged or participated in any reclamation in ASM operations before. In the Wassa Amenfi East Municipality, 10% of the respondents indicated that they have participated in reclamation before whereas 90% indicated that they have never participated in any reclamation exercise before. In the Wassa Amenfi Central, 8% of the respondents indicated that they have participated in reclamation exercise whereas 92% indicated that they have never participated in reclamation. In the Wassa Amenfi West, 5% of the respondents indicated that they have participated in reclamation before whereas 95% of the respondents indicated that they have not participated in reclamation before. Figure 8 is a graph showing the responses regarding participation in reclamation.

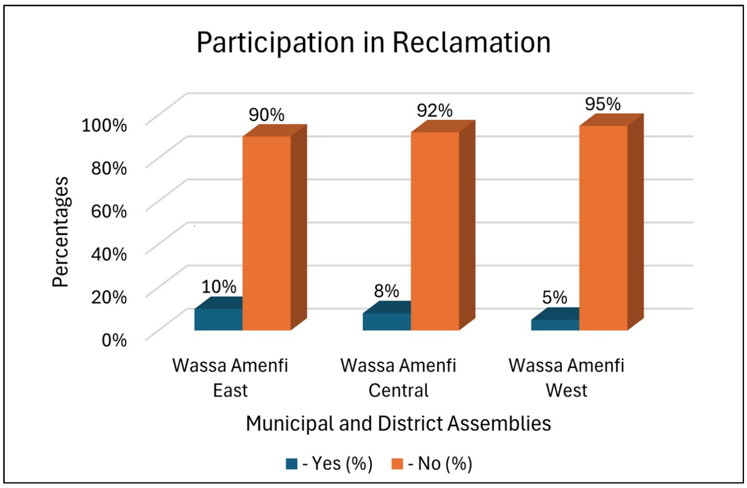

Figure 8. Graph showing the responses regarding participation in reclamation.

3.2.4. Perceptions of Environmental Degradation

The respondents were asked to rate the levels of environmental degradation from ASM operations in their respective communities. Out of the 85 respondents from the Wassa Amenfi East Municipality, 70% indicated that ASM operations lead to severe environmental damage, 25% indicated moderate environmental degradation whereas 5% indicated no degradation at all. In the In the Wassa Amenfi Central, 75% of the respondents indicated that it contributes to severe environmental degradation, 20% indicated that it leads to moderate degradation whereas 5% indicated no environmental degradation. In the Wassa Amenfi West, 80% of the respondents indicated that ASM operations within their communities lead to severe environmental degradation, 15% indicated moderate degradation whereas 5% indicated no degradation at all. Figure 9 is a graph showing the responses regarding perceptions of environmental degradation.

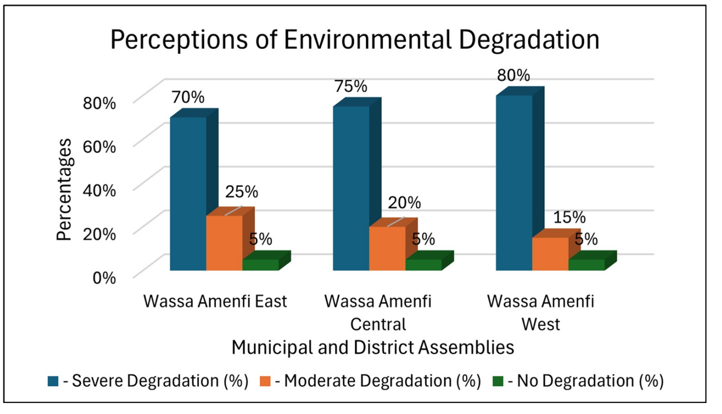

Figure 9. Perceptions of environmental degradation from ASM operations.

3.3. Chi Square Test on Reclamation Challenges in the Wassa Amenfi Area

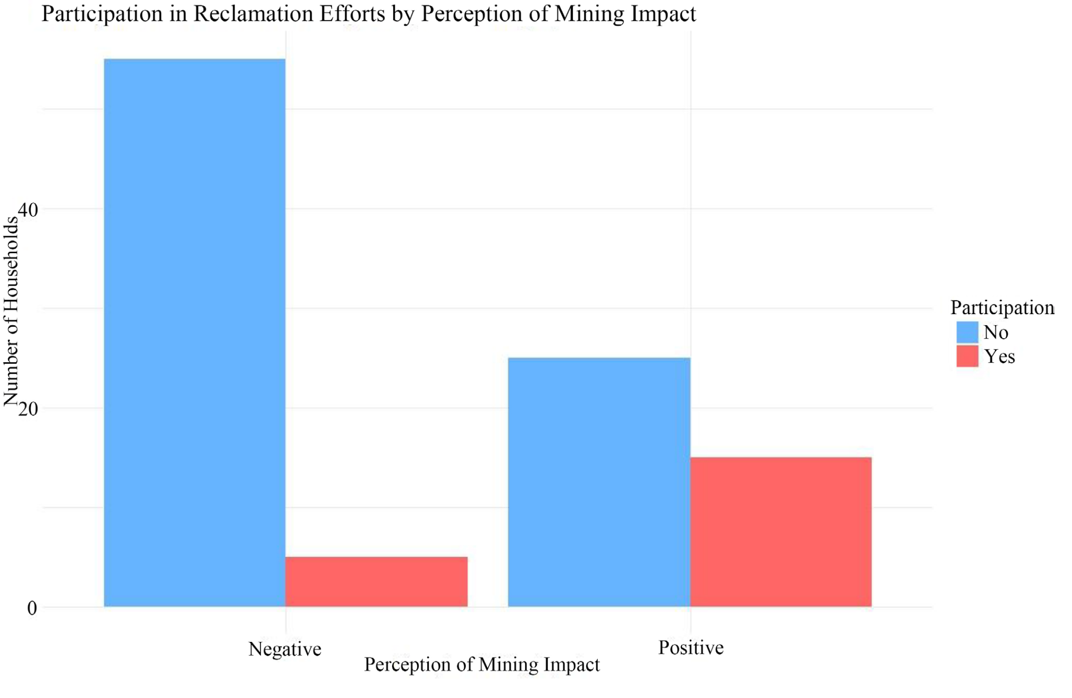

Figure 10. Chi-square test visualisation.

A Chi-square test of independence (**Figure 10**) was performed to examine the relationship between participation in reclamation efforts and perception of mining impact. The test was conducted with Pearson's Chi-squared test with Yates' continuity correction in R studio. Results indicated a Chi-squared value of 11.003 with 1 degree of freedom and a p-value of 0.0009098, indicating a statistically significant association between these two variables. Specifically, respondents with negative perceptions of mining were significantly less likely to participate in reclamation efforts compared to those with positive perceptions. This finding highlights a major challenge: overcoming negative perceptions of mining, which could hinder community involvement in reclamation activities.

4. Strategies to Promote Sustainable Reclamation in ASM Operations

In promoting sustainable Reclamation practices in ASM operation, it is important that during the licensing and permitting stage of the operations, the miners are made to produce a thorough reclamation plan. In order words, the operations can only be issued licences if they provide a good reclamation plan to either the regulatory bodies or licencing institutions in the respective countries. Moreover, the laws regarding environmental protection should be implemented efficiently by the regulatory bodies. In Ghana, even though the EPA laws insist on the provision of a reclamation bond before the EPA permits are issued by the mining operations, the 10 mining operations visited could not clearly indicate that they paid such bonds even though they are registered operations. If the miners had paid the bonds at the initial stage, they would have paid serious attention to reclamation and would have made it an integral part of their operations.

Furthermore, there will be the need to employ technical expertise such as geotechnical engineers, surveyors and environmental engineers in the reclamation process. Such experts could be contracted during the reclamation phase of the operations if a single operation cannot afford to permanently employ them. Better still, a group of ASM operations may come together and employ such experts to service their respective operations. Then the respective operations contribute to pay them, in that way the financial commitment from the respective operations will be affordable. Also, there should be chemical analysis of the soils and water in the concessions before and after mining. This will guide the reclamation process to know the chemicals or metals occurring in higher concentrations beyond set standards. This will eventually guide the vegetation or remediation techniques to use to ensure healthy soils and safe water.

Additionally, the mining excavation techniques and mineral processing techniques employed in ASM should be given attention. It is important that topsoils are removed and stockpiled separate from the overburden materials. Moreover, miners should cease from the practice of processing the minerals within the pit in which excavation is ongoing or just close to the pit. There should be a designated area for mineral processing away from the pit and the water from the process plat should be contained and reused using the 3-pond purification system. In addition, as much as possible, the mercury amalgamation technique should be stopped and replaced with mercury-free processing techniques such as direct smelting, gold kacha. Moreover, training and sensitisation of the miners and the communities on reclamation will be required. As much as possible, the community should be educated on the importance of reclamation and the need for them to insist on reclamation from any single unit ASM operation. Illegal miners should be sensitised to ward off from the registered sites. The recalcitrant illegal miners caught on registered sites should be arrested and prosecuted with hard terms in order to ensure that others do not do that to degrade the already reclaimed mine sites.

5. Conclusions

This study examined the reclamation challenges associated with artisanal and small-scale mining (ASM) operations in the Wassa Amenfi area of Ghana using field investigations, stakeholder surveys, and spatial assessment techniques. The findings demonstrate that although ASM contributes to local livelihoods, reclamation practices within the sector remain inadequate and largely unsustainable. Field investigations across ten ASM sites revealed that reclamation efforts are constrained by the absence of comprehensive reclamation plans, inadequate financial resources, poor excavation and mineral processing practices, limited access to technical expertise, lack of soil and water quality assessments, and the persistent encroachment of illegal miners on disturbed and reclaimed lands. These challenges have resulted in ineffective land restoration and prolonged environmental degradation. The household survey further revealed that 60% of respondents perceived ASM activities as having a negative impact on their livelihoods, while 75% considered ASM operations to be a major source of severe environmental degradation. Public awareness of reclamation activities was low, with only 20% of respondents aware of reclamation initiatives, and community participation in reclamation activities remained extremely limited at 8%. The Chi-square analysis confirmed a statistically significant relationship between perceptions of mining impacts and participation in reclamation activities, suggesting that negative perceptions of mining can hinder community involvement in land restoration efforts. Overall, the study concludes that the sustainability of ASM operations in the Wassa Amenfi area depends largely on the integration of reclamation into the mining life cycle, stronger regulatory enforcement, improved technical capacity, and enhanced stakeholder participation. Without addressing these challenges, ASM activities will continue to contribute to land degradation, biodiversity loss, and declining ecosystem services. Conversely, the adoption of sustainable reclamation practices can transform degraded mining landscapes into productive ecosystems that support both environmental restoration and community development.

6. Recommendations

The findings of this study highlight the need for a comprehensive and integrated approach to improving reclamation outcomes in artisanal and small-scale mining (ASM) operations. Effective reclamation requires not only regulatory compliance but also the adoption of sound technical practices, adequate financial provisions, and active stakeholder participation throughout the mining lifecycle. A critical priority is the institutionalization of mandatory reclamation planning and financial assurance mechanisms. Regulatory authorities should require all ASM operators to prepare detailed reclamation plans as a prerequisite for licensing. Such plans should clearly outline land restoration objectives, implementation strategies, monitoring frameworks, and post-mining land-use goals. Furthermore, reclamation costs should be incorporated into project feasibility assessments, and the enforcement of reclamation bonds or dedicated reclamation funds should be strengthened to ensure the availability of financial resources for post-mining restoration activities.

Strengthening regulatory oversight is equally important for promoting responsible mining practices. The Minerals Commission, Environmental Protection Agency (EPA), and relevant District Assemblies should intensify monitoring and inspection activities at ASM sites to ensure compliance with environmental management and reclamation requirements. Regular audits, coupled with the consistent application of penalties for non-compliance, would enhance accountability and encourage adherence to environmental standards. The study also underscores the importance of improving the technical capacity of ASM operators. Access to qualified environmental engineers, geotechnical engineers, surveyors, and reclamation specialists would significantly enhance the planning and execution of reclamation programmes. The establishment of shared technical support services through ASM cooperatives or government-supported extension programmes could provide cost-effective solutions for small-scale operators while improving the overall quality of reclamation outcomes. In addition, mining and mineral processing practices should be improved to minimize environmental degradation and facilitate successful land restoration. Operators should adopt proper topsoil management practices, including the stripping, storage, and preservation of topsoil before excavation activities commence. Such measures would enhance soil fertility and vegetation establishment during reclamation. Moreover, the continued reliance on mercury-based gold processing methods should be progressively reduced and replaced with environmentally sustainable alternatives, such as mercury-free gold recovery technologies and direct smelting techniques.

The implementation of comprehensive soil and water quality assessment programmes is also essential. Baseline and periodic monitoring of soil, surface water, and groundwater quality should be conducted before, during, and after mining operations. These assessments would provide critical scientific data for evaluating environmental impacts and informing the selection of appropriate remediation, revegetation, and ecosystem restoration strategies.

Community engagement should be recognized as a fundamental component of successful reclamation programmes. Local communities should be actively involved in the planning, implementation, and monitoring of reclamation activities. Increased stakeholder participation can enhance transparency, improve local ownership of restoration initiatives, and contribute to the long-term sustainability of reclaimed landscapes. Environmental education and awareness campaigns should therefore be intensified to improve public understanding of the environmental, social, and economic benefits associated with effective mine reclamation.

The findings further indicate the need for stronger measures to address illegal mining activities that undermine reclamation efforts. Government agencies should strengthen surveillance systems and enforcement mechanisms to prevent illegal miners from encroaching on active and reclaimed ASM concessions. Community-based monitoring initiatives and reporting mechanisms could complement official enforcement efforts and help safeguard restored lands from renewed disturbance. Finally, further research is required to advance knowledge and improve reclamation practices in ASM environments. Future studies should investigate the effectiveness of emerging reclamation technologies, including phytoremediation, ecological engineering approaches, and nature-based restoration solutions suitable for tropical mining landscapes. Long-term monitoring studies are also necessary to evaluate ecosystem recovery trajectories, assess reclamation success, and provide evidence-based guidance for policy development and environmental management within the ASM sector.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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