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Impact of Artisanal and Small-Scale Mining on Land Degradation: A Systematic Review

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Abstract
Artisanal and small-scale mining (ASM) sustains the livelihoods of an estimated 40 million workers. It indirectly supports more than 100 million dependants globally, yet its environmental consequences, particularly land degradation, remain poorly governed and insufficiently synthesised in the literature. This systematic review, conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, analyses 33 peer-reviewed studies published between 2014 and 2025 to assess the environmental and socio-economic impacts of ASM on land degradation and affected communities. The evidence indicates that informal and illegal ASM is the dominant mode of operation (reported in 30 of 33 studies), generating severe deforestation, soil erosion, water contamination, and biodiversity loss across sub-Saharan Africa, Southeast Asia, and South America. Socio-economically, the most frequently reported impacts were livelihood disruption (54% of coded responses), chronic health risks from mercury and cyanide exposure (25%), and food insecurity (21%). Gendered and age-differentiated burdens are consistent across the literature, with women and children disproportionately affected. Governance failures, including weak enforcement, inadequate incentives for formalisation, and limited community participation, underpin persistent environmental degradation. The review identifies critical research gaps, including the geographical underrepresentation of Latin America and Southeast Asia, limited longitudinal health evidence, and insufficient empirical work on the effectiveness of restoration. Policy-relevant recommendations prioritise formalisation with incentives, co-management governance, gender-responsive regulation, and performance-based environmental finance.

Keywords
artisanal and small-scale mining (ASM), land degradation, environmental governance, socio-economic impacts, PRISMA, sustainability, gender

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1. Introduction

Land degradation currently affects an estimated 1.9 billion hectares globally, threatening food security, biodiversity, and livelihoods across regions that can least absorb these losses (UNCCD, 2022). While natural processes contribute to degradation, anthropogenic activities, particularly extractive industries operating in low-governance environments, drive the most severe and irreversible outcomes. Eswaran et al. (2019) define land degradation as a decline in productive capacity driven by the interaction of environmental and human-induced stressors. This definition directly implicates artisanal and small-scale mining (ASM) as a primary driver in resource-rich developing countries. ASM is not a marginal economic phenomenon. The sector employs approximately 40 million direct workers. It supports more than 100 million dependents worldwide (Hilson, 2019) and operates across sub-Saharan Africa, South and Southeast Asia, Latin America, and parts of the Pacific. In sub-Saharan Africa alone, ASM accounts for between 25% and 80% of total mineral production in several countries (Ofosu et al., 2020). Despite this economic significance, the sector remains predominantly informal. Unlike industrial mining, ASM operations are largely unregulated, using rudimentary extraction methods and chemical processes that generate disproportionate environmental damage relative to their economic output (Arthur-Holmes & Ofosu, 2024).

The environmental consequences of ASM are well-documented in national case studies but remain theoretically fragmented and geographically skewed in the systematic literature. In Ghana, for example, ASM has been linked to the degradation of more than 78,000 hectares of land, including forest reserves and riparian zones (Bansah et al., 2024). At the landscape scale, deforestation associated with ASM reduces carbon sequestration capacity, accelerates soil erosion, and destabilises hydrological systems (Barenblitt et al., 2021; Meutia et al., 2023). At the community level, mercury and cyanide-contaminated water sources compromise public health, particularly for women and children who depend on these resources for domestic use (Hilson et al., 2021; Engstrand et al., 2024). The sector also raises significant governance challenges. Most ASM activity occurs outside existing legal frameworks, rendering environmental regulations difficult to enforce and land rehabilitation obligations largely unenforced (Mensah et al., 2015; Bansah et al., 2024). Where formalisation efforts have been attempted, as in Ghana, Bolivia, and Indonesia, resistance from miners and weak institutional capacity have limited effectiveness (Arthur-Holmes & Ofosu, 2024; Mestanza-Ramon et al., 2022). These governance deficits directly link ASM to failures to achieve Sustainable Development Goal 15 (Life on Land), SDG 6 (Clean Water and Sanitation), and SDG 8 (Decent Work and Economic Growth) (Hirons, 2020; de Haan, 2020).

Despite the breadth of individual case studies, no recent systematic review has examined the combined environmental and socio-economic dimensions of ASM-related land degradation across global contexts, assessed the robustness of existing evidence, and connected findings to policy-actionable frameworks. This review addresses that gap. Specifically, it synthesises findings from peer-reviewed studies published between 2014 and 2025 to (a) characterise the nature and extent of ASM-driven land degradation, (b) assess associated socio-economic consequences, (c) evaluate existing governance and restoration responses, and (d) identify substantive research gaps and policy implications.

2. Methodology

2.1 Review Design and Protocol

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) to ensure methodological transparency and replicability. A prospective protocol was defined prior to database searches, specifying the research questions, eligibility criteria, search strategy, data extraction procedures, and synthesis approach. The review was registered with PROSPERO (registration pending review). The central research question was: What are the documented environmental and socio-economic impacts of ASM on land degradation, and what governance and restoration responses are evident in the peer-reviewed literature?

2.2 Search Strategy

Systematic searches were conducted across four academic databases: Google Scholar, ScienceDirect, ResearchGate, and ProQuest. Searches were conducted between 3 and 8 September 2024. The search strategy combined primary terms related to the exposure (ASM, informal mining), the outcome (land degradation, environmental degradation), and the population (local communities, rural communities), linking them with Boolean operators (AND, OR). Table 1 presents the full search strings and initial retrieval counts by database.

Table 1. Database search strings and initial retrieval counts

Database	Search String	Results
Google Scholar	("artisanal mining" OR "small-scale mining" OR "ASM" OR "informal mining") AND ("land degradation" OR "environmental degradation" OR "soil erosion" OR "deforestation") AND ("impact" OR "consequences" OR "effects") AND ("local communities" OR "rural communities")	6,550
Science Direct	("ASM" OR "small-scale mining") AND ("land degradation" OR "environmental degradation") AND ("impacts" OR "effects") AND ("local communities" OR "rural communities")	342
ResearchGate	("artisanal mining" OR "small-scale mining" OR "ASM" OR "informal mining") AND ("land degradation" OR "environmental degradation" OR "soil erosion" OR "deforestation") AND ("impact" OR "consequences" OR "effects") AND ("local communities" OR "rural communities")	100
ProQuest	("ASM" OR "small-scale mining") AND ("land degradation" OR "environmental degradation") AND ("impacts" OR "effects") AND ("local communities" OR "rural communities")	195

2.3 Eligibility Criteria

Inclusion and exclusion criteria were defined a priori and are summarised in Table 2. Studies were included if they (a) focused on communities directly involved in or affected by ASM, (b) examined environmental, socio-economic, or health impacts attributable to ASM, (c) used peer-reviewed, empirical designs (qualitative, quantitative, or mixed-methods), and (d) were published in English between 2014 and 2025. Studies on large-scale industrial mining, conference abstracts, editorials, and studies not reporting primary data were excluded.

Table 2. Eligibility criteria for study inclusion

Criteria	Inclusion	Exclusion
Study Population	Studies on communities directly involved in or affected by ASM activities.	Studies not focusing on ASM-affected communities; research focused on large-scale industrial mining.
Exposure	Studies examining environmental, socio-economic, or health impacts of ASM; consequences of land degradation attributable to ASM.	Studies that do not address environmental or socio-economic ASM impacts; research focused exclusively on technical mining processes without community-level analysis.
Study Design	Peer-reviewed journal articles, case studies, surveys; qualitative, quantitative, or mixed-methods designs.	Opinion pieces, editorials, conference abstracts, grey literature; studies lacking full data reporting.
Publication Year	2014 to 2025.	Studies published before 2014.
Language	English-language publications only.	Studies published in other languages.

2.4 Study Selection

The initial searches retrieved 7,187 records. After deduplication, 7,135 were excluded based on title and abstract screening using the eligibility criteria. Fifty-two full-text articles were assessed. Thirteen were excluded: six were duplicates identified across databases, four lacked primary empirical data, and three focused exclusively on industrial-scale mining. Thirty-three studies were retained for full synthesis. The selection process is summarised in the PRISMA flow diagram (Figure 1).

2.5 Data Extraction and Synthesis

Data were extracted from each included study using a standardised extraction form capturing: study design, geographical context, ASM characteristics, types of environmental impact, socio-economic consequences, governance responses, and restoration strategies. Extraction was conducted by two reviewers, with disagreements resolved through discussion. Synthesis followed a convergent, integrated approach: quantitative findings (frequency counts and percentages) were combined with narrative thematic analysis to identify patterns, contradictions, and gaps across the corpus. Coding was structured around ten thematic domains defined in the protocol, including the nature of ASM activity, types of environmental degradation, socio-economic impacts, governance frameworks, and restoration practices.

3. Results

3.1 Overview of Included Studies

The 33 included studies span 12 countries across four continents, with a substantial concentration in sub-Saharan Africa (n = 29; 87.9%). West Africa, particularly Ghana (n = 19), dominates the literature. Table 3 presents the geographic distribution of included studies. Publication years ranged from 2014 to 2024, with a concentration in the 2020 to 2024 period (n = 22; 66.7%), reflecting recent intensification of scholarly attention to ASM governance and environmental consequence. Study designs included case studies (n = 18), survey-based quantitative analyses (n = 8), mixed-methods designs (n = 5), and systematic or narrative review approaches (n = 2).

Table 3. Geographic distribution of included studies

Region	n	% of Studies	Primary Themes
West Africa (Ghana, Nigeria, Sierra Leone, Burkina Faso)	24	72.7	Deforestation, soil erosion, water pollution, livelihood disruption, and mercury contamination
East Africa (Rwanda, South Sudan, Ethiopia, Madagascar)	4	12.1	Land-use change, biodiversity loss, health hazards, livelihood impacts
Southern Africa (Zimbabwe)	1	3	Rural livelihood disruption, ecosystem destruction
Southeast Asia (Indonesia)	1	3	Environmental degradation, mercury pollution, and legal challenges
South America (Ecuador, Peru)	2	6.1	Amazon deforestation, water contamination, and health risks
Multi-regional / Global	1	3	Cross-regional governance and economic analysis

3.2 Nature and Scale of ASM Activities

30 of the 33 studies characterised ASM as predominantly informal or illegal in their study contexts, reflecting endemic governance deficits. Only one study described a fully regulated ASM context; two examined settings in which formal and informal operations coexisted (Ofosu & Sarpong, 2023). Informality was consistently linked to lower environmental compliance, absence of rehabilitation obligations, and restricted access to safer processing technologies. Gold was the primary mineral extracted across the majority of studies (n = 27), with smaller subsets examining diamond and coltan extraction. Extraction methods ranged from surface panning and open-cast pit excavation to hydraulic sluicing and mercury amalgamation, the latter being the predominant gold-recovery method in African and Latin American contexts (Engstrand et al., 2024; Mestanza-Ramon et al., 2022).

3.3 Environmental Impacts of ASM

3.3.1 Land Degradation and Deforestation

Deforestation and vegetation loss were the most frequently reported environmental impacts, documented in 29 of 33 studies (87.9%). In Ghana, satellite imagery analyses confirm that ASM operations have converted extensive forest and agricultural land into bare pits and spoil heaps, with Barenblitt et al. (2021) estimating a particularly large spatial footprint relative to economic output. In Indonesia, Meutia et al. (2023) document comparable deforestation at artisanal gold sites, where legal ambiguity and weak enforcement allow mining within protected forest areas. Across West Africa, riparian zones have been particularly affected: Bansah et al. (2024) report systematic clearing of riverbank vegetation in Ghana's southern regions, removing critical erosion buffers and accelerating sedimentation. Soil erosion and topsoil loss were reported in 28 studies (84.8%), with associated reductions in agricultural productivity constituting a central pathway from environmental to socio-economic impact (Mensah et al., 2015; Cudjoe et al., 2023).

3.3.2 Water Contamination

Water pollution was documented in 27 studies (81.8%) and emerged as the most structurally consequential environmental impact given its implications for human health, agriculture, and downstream ecosystem services. Mercury, used in gold amalgamation, was the most commonly identified contaminant, with concentrations in surface water bodies exceeding WHO thresholds across Ghana, Nigeria, and South Sudan (Bansah et al., 2018; Ladu et al., 2019; Kampalath & Jay, 2015). Cyanide contamination, increasingly documented in mechanised ASM operations, presents additional risks to aquatic ecosystems and potable water supplies (Engstrand et al., 2024). In Ecuador's northern Amazon, Mestanza-Ramon et al. (2022) report multi-metal contamination profiles in ASM-affected waterways, with implications for both indigenous communities and downstream agricultural systems. Sedimentation from uncontrolled erosion further degrades water quality and disrupts aquatic habitats across all regions covered in the review.

3.3.3 Biodiversity Loss and Land-Use Change

Biodiversity impacts were reported in 18 studies (54.5%), primarily through habitat destruction. Loss of forest cover eliminates nesting and foraging habitat for endemic species, while chemical contamination affects aquatic biodiversity through bioaccumulation pathways (Boadi et al., 2016; Meutia et al., 2023). Geospatial analyses using Landsat and Sentinel imagery document land-use conversion from forest and mixed agriculture to bare ground and open pits across Ghana and Nigeria (Barenblitt et al., 2021; Laniyan et al., 2024). Table 4 provides a synthesis of the frequencies of environmental impacts across the included studies.

Table 4. Frequency and nature of environmental impacts reported across included studies

Environmental Impact	n	% Studies	Key Evidence
Deforestation and vegetation loss	29	87.9	Clearing of forest cover for mining pits; loss of ecosystem services and carbon stocks (Bansah et al., 2024; Barenblitt et al., 2021)
Soil erosion and degradation	28	84.8	Topsoil removal, compaction, and reduced fertility from excavation and spoil dumping (Mensah et al., 2015; Cudjoe et al., 2023)
Water pollution	27	81.8	Mercury and cyanide contamination of surface water and groundwater (Bansah et al., 2018; Engstrand et al., 2024)
Biodiversity loss	18	54.5	Habitat destruction is reducing flora and fauna diversity (Boadi et al., 2016; Meutia et al., 2023)
Air pollution	12	36.4	Dust and gaseous emissions affecting respiratory health (Meutia et al., 2023; Ladu et al., 2019)
Land-use change	22	66.7	Conversion of agricultural and forest land to mining sites (Barenblitt et al., 2021; Laniyan et al., 2024)

4. Socio-Economic Consequences

4.1 Livelihood Impacts

Livelihood disruption was the most frequently coded socio-economic impact, appearing in 29 of 53 coded responses (54.7%). ASM provides income in economically marginalised rural areas, functioning as a buffer against poverty in contexts where alternative employment is limited (Isung et al., 2021; Brunnschweiler et al., 2024). However, land degradation progressively undermines agricultural livelihoods that coexist with or succeed mining. Ofosu et al. (2020) document systematic displacement of smallholder agriculture across ASM zones in Ghana, as mining encroaches on farmland and degrades soil fertility. Pokorny et al. (2019) reach similar conclusions in Burkina Faso, finding that the long-term livelihood calculus of ASM is negative for a substantial proportion of affected households once environmental costs are internalised.

4.2 Health Risks

Health impacts were coded in 13 responses (24.5%), with mercury exposure constituting the central hazard pathway. Communities in the vicinity of ASM operations in Ghana, Nigeria, and Indonesia record higher incidence rates of respiratory illness, neurological disorders, and dermatological conditions than control communities (Mensah et al., 2015; Meutia et al., 2023). Mercury bioaccumulation in fish consumed by local communities extends exposure beyond workers to the broader population, disproportionately affecting pregnant women and children (Kampalath & Jay, 2015; Hilson et al., 2021). The absence of occupational health infrastructure in informal ASM contexts means that exposure monitoring and clinical follow-up are largely lacking, making the true burden of disease difficult to quantify in the existing literature.

4.3 Food Insecurity

Food insecurity was coded in 11 responses (20.8%), arising from two primary pathways: direct loss of agricultural land to mining operations and water contamination affecting irrigation and aquatic food sources. Cudjoe et al. (2023) document reduced crop yields in communities adjacent to ASM operations in Ghana's Western Region, attributing the decline to soil fertility loss and reduced water availability during dry seasons. Mabey et al. (2020) report comparable food security pressures in Sierra Leone, where ASM-induced land degradation reduces household food production and increases reliance on purchased food, compounding the vulnerability of low-income households.

4.4 Gendered and Age-Differentiated Impacts

The gendered dimensions of ASM are documented across multiple geographical contexts and represent one of the most structurally significant, yet analytically underserved, dimensions of ASM impact. Women in ASM communities consistently occupy lower-income, higher-risk roles in ore processing, particularly in mercury-based amalgamation (Hilson et al., 2018; Arthur-Holmes & Ofosu, 2024). These roles expose women to acute and chronic mercury toxicity while providing minimal economic security or regulatory protection. Women also bear disproportionate health and domestic burdens from degraded water sources, as they are primarily responsible for household water collection (Hilson et al., 2021). Children face compounding disadvantages: hazardous child labour in ASM is documented across Ghana, Sierra Leone, Ethiopia, and South Sudan, with adverse effects on educational attainment and physical development (Gatsinzi, 2020; ILO, 2018). Despite the frequency of such observations, few studies operationalise gender analysis beyond descriptive reporting, constituting a substantive methodological gap in the literature.

5. Discussion

5.1 Environmental Degradation as a Governance Failure

The most consistent finding across the corpus is that the severity of ASM-related environmental degradation is not primarily a function of extraction scale, but of governance quality. Thirty of 33 studies identify informality as the dominant operational mode, and across all regional contexts, informality correlates with environmental harm (Bansah et al., 2024; Meutia et al., 2023). This pattern is consistent with the theoretical arguments of political ecology, which situates environmental degradation not as an inevitable consequence of resource extraction but as an outcome of unequal power relations, weak institutional frameworks, and the exclusion of affected communities from governance processes (Hilson, 2019; Ofosu et al., 2023). Ghana's Minerals and Mining Act, widely cited in the included studies, illustrates this dynamic: a formally robust statutory framework has yielded limited environmental outcomes due to enforcement deficits, corruption, and the absence of credible alternative livelihoods for informal miners (Mensah et al., 2015; Dumakor-Dupey & Bansah, 2017). The Indonesian case, the only Southeast Asian context included in the review, provides a comparative reference point that reinforces this interpretation. Meutia et al. (2023) document a structurally similar governance failure, in which legal ambiguity around ASM sites within protected areas enables persistent environmental harm despite formal prohibitions. That comparable dynamics emerge across vastly different institutional, ecological, and cultural contexts (Ghana and Indonesia) suggests that the drivers of ASM-related degradation are systemic rather than idiosyncratic, and that effective responses require governance reform rather than merely technical solutions.

5.2 The Socio-Economic Paradox of ASM

ASM generates a well-documented socio-economic paradox: it provides critical income to economically marginalised populations while simultaneously undermining the environmental conditions that sustain those same livelihoods over time. Brunnschweiler et al. (2024) capture this tension in their survey evidence from Ghana, which finds that household perceptions of ASM's economic benefits coexist with awareness of its environmental costs and health risks. The reviewed evidence suggests that this paradox is not resolvable through prohibition, which drives operations further underground and reduces what limited compliance exists, but through formalisation strategies that lower the cost of legal operation, provide access to cleaner technologies, and build enforcement legitimacy through community participation (Arthur-Holmes & Ofosu, 2024; Ofosu & Sarpong, 2023).

The literature on sustainability transitions offers a complementary analytical lens here. Transitions in informal extractive sectors require not only technical substitution (replacing mercury with gravity-based recovery methods, for instance) but also changes in institutional rules, social norms, and market structures (Hilson, 2019; de Haan, 2020). The "golden practices" documented by Ofosu and Sarpong (2023), which describe lower-impact ASM methods that generate competitive economic returns, demonstrate the feasibility of sustainability transitions within the sector while also highlighting the barriers to scaling these practices in low-state-capacity environments.

5.3 Gendered Governance and the Limits of Existing Analysis

This review confirms that gender inequality is a structural feature of ASM communities, shaping both the distribution of environmental burdens and the exclusion of women from governance processes. Hilson et al. (2018) and Arthur-Holmes and Ofosu (2024) demonstrate that women's roles in ASM are often both economically essential and institutionally invisible: women undertake ore processing and head porterage at high health risk while remaining outside formal licensing structures and policy discourse. This dual invisibility, as economic actors and as affected parties, reflects broader patterns of institutional exclusion documented in feminist political ecology (Rocheleau et al., 1996, as discussed in Hilson et al., 2021). The absence of gender-disaggregated data in most included studies and the limited use of feminist analytical frameworks constitute a critical methodological deficit that constrains the generation of policy-relevant evidence.

5.4 Restoration and the Limits of Current Evidence

Restoration strategies identified in the literature, including reforestation, soil amendments, water remediation, and community-led reclamation, are theoretically sound but empirically underpowered. Most included studies document restoration initiatives without providing longitudinal evidence on outcomes, ecological recovery trajectories, or cost-effectiveness. Antwi et al. (2017) provide one of the more methodologically rigorous assessments, demonstrating partial ecosystem recovery in mine-affected communities in Ghana, but note that community participation and sustained financing are necessary conditions for durable outcomes. The evidence base for the use of payment for ecosystem services as a restoration financing mechanism in ASM contexts remains nascent and requires dedicated empirical investigation.

6. Policy Implications, Research Gaps and Future Directions

6.1 Policy Implications

The findings of this review support five interconnected policy priorities, each grounded in the evidence and directly addressing the structural drivers of ASM-related land degradation. Table 5 presents these recommendations alongside their evidence base.

A cross-cutting principle emerging from the evidence is that no single policy instrument is sufficient. Formalisation without community participation generates resistance (Arthur-Holmes & Ofosu, 2024); restoration without sustainable financing yields short-term projects with no long-term impact (Antwi et al., 2017); and health interventions without governance reform fail to address exposure at the source. Integrated, multi-level policy frameworks that combine national regulatory reform with local co-management and international technical and financial support represent the most robust pathway to reducing ASM-related environmental harm while protecting the livelihoods of those who depend on the sector.

Table 5. Policy recommendations derived from the systematic review

Policy Area	Recommended Actions	Evidence Basis	Key References
Targeted Formalization	Simplify licensing; offer technology subsidies and tax relief; enforce prohibitions on the use of mercury and child labour.	Informality dominates (30 of 33 studies); incentivising compliance reduces illegality and environmental harm.	Ofosu & Sarpong (2023); Arthur-Holmes & Ofosu (2024); de Haan (2020)
Co-management Governance	Establish district-level coordination among miners, local authorities, traditional leaders, and environmental agencies.	Weak local enforcement and community exclusion were persistent findings; participatory governance improves accountability.	Mensah et al. (2015); Dumakor-Dupey & Bansah (2017); Ofosu et al. (2023)
Integrated Health Policy	Deploy mobile mercury screening; distribute PPE; link rural clinics to ASM hubs; include occupational health in mining permits.	Health impacts, especially mercury exposure, are under-regulated and disproportionately affect women and children.	Hilson et al. (2021). Meutia et al. (2023), Brunnschweiler et al. (2024). i
Restoration Finance	Implement performance bonds; establish payment for ecosystem services (PES) schemes; fund reforestation and dam restoration.	Environmental degradation was reported in 87% of studies; financial mechanisms sustain restoration beyond project cycles.	Antwi et al. (2017); Bansah et al. (2024); Ofosu et al. (2020)
Gender-Responsive Policy	Integrate gender audits into ASM licensing; establish women-led co-operatives; enforce prohibitions on hazardous processing roles.	Women face disproportionate health and economic burdens, yet remain largely excluded from formal regulatory processes.	Hilson et al. (2018). Arthur-Holmes & Ofosu (2024); Hilson et al. (2021).

6.2 Research Gaps and Future Directions

The synthesis reveals five substantive research gaps that constrain both scientific understanding and the generation of policy-relevant evidence. Table 6 summarises these gaps and proposed future directions.

Addressing these gaps requires not only expanded geographical sampling but also methodological innovation: longitudinal cohort designs for health research, quasi-experimental designs for policy evaluation, feminist political ecology frameworks for gender analysis, and remote sensing combined with field validation for degradation quantification. Cross-regional comparative studies that draw on standardised indicators would significantly enhance the generalisability of findings and strengthen the evidence base for global governance initiatives.

Table 6. Summary of research gaps and recommended directions

Gap	Nature	Recommended Focus	Key References
Geographical imbalance	Over 72% of studies are from West Africa (predominantly Ghana); Southeast Asia and Latin America are severely underrepresented.	Expand comparative studies to ASM regions in Southeast Asia (Indonesia, Philippines) and Latin America (Peru, Bolivia).	Meutia et al. (2023); Engstrand et al. (2024); Mestanza-Ramon et al. (2022)
Socio-economic and health dimensions	Focus on livelihoods; limited longitudinal analysis of chronic mercury/cyanide exposure and its health sequelae.	Conduct longitudinal cohort studies on health outcomes, including gendered exposure pathways and child developmental impacts.	Hilson et al. (2021); Brunnschweiler et al. (2024); Kampalath & Jay (2015)
Policy and regulatory effectiveness	Most papers describe frameworks without evaluating implementation outcomes or enforcement effectiveness.	Evaluate governance reforms, licensing processes, and decentralised enforcement mechanisms using before-and-after designs.	Arthur-Holmes & Ofosu (2024); Ofosu & Sarpong (2023); Bansah et al. (2024)
Environmental restoration evidence	Sparse empirical evidence on the long-term success of rehabilitation, reforestation, and the adoption of cleaner technologies.	Assess success factors of restoration projects; test low-impact technologies; explore PES as a financing mechanism.	Antwi et al. (2017). Ofosu & Sarpong (2023); Cudjoe et al. (2023)
Gendered governance analysis	Gender is noted but rarely operationalised; few studies examine women's agency or participation in ASM governance.	Develop feminist political ecology frameworks to interrogate power, agency, and governance in ASM-affected communities.	Hilson et al. (2018); Arthur-Holmes & Ofosu (2024)

7. Conclusion

This systematic review synthesises evidence from 33 peer-reviewed studies to demonstrate that ASM-related land degradation is extensive, multi-dimensional, and structurally embedded in governance failures that persist across regional contexts. Deforestation, soil erosion, and water contamination are near-universal environmental consequences of informal ASM, with cascading effects on livelihoods, health, and food security. The gendered and age-differentiated dimensions of these impacts are consistent across the literature, yet analytically underserved. The evidence clearly indicates that governance reform, including formalisation with practical incentives, community co-management, gender-responsive regulation, and performance-based restoration finance, constitutes the most viable pathway to reducing environmental harm without eliminating the livelihoods on which millions of people depend. Critically, the literature remains geographically skewed, methodologically inconsistent, and weak on longitudinal evidence, limiting the confidence with which global policy conclusions can be drawn. Addressing these gaps through internationally coordinated, methodologically rigorous research programmes is a prerequisite for evidence-based ASM governance at scale.

8. Declaration of Competing Interest

The authors declare no conflict of interest.

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References

[1] Antwi, E. K., Owusu-Banahene, W., Boakye-Danquah, J., Mensah, R., Tetteh, J. D., Nagao, M., & Takeuchi, K. (2017). Sustainability assessment of mine-affected communities in Ghana: Towards ecosystems and livelihood restoration. Sustainability Science, 12, 747–767. https://doi.org/10.1007/s11625-016-0415-7

[2] Arthur-Holmes, F., & Ofosu, G. (2024). Rethinking state-led formalisation of artisanal and small-scale mining (ASM): Towards mining licence categorisation, women empowerment and environmental sustainability. Resources Policy, 93, 105058. https://doi.org/10.1016/j.resourpol.2024.105058

[3] Asamoah, E. O., Xu, W., Huang, W., & Yang, W. (2018). Environmental impacts of artisanal gold mining: A case study of Nkaseim Community, Ghana. Journal of Environment and Earth Sciences, 8(12), 116–130.

[4] Bansah, K. J., Acquah, P. J., & Boafo, A. (2024). Land, water, and forest degradation in artisanal and small-scale mining: Implications for environmental sustainability and community wellbeing. Resources Policy, 90, 104795. https://doi.org/10.1016/j.resourpol.2024.104795

[5] Bansah, K. J., Dumakor-Dupey, N. K., Kansake, B. A., Assan, E., & Bekui, P. (2018). Socioeconomic and environmental assessment of informal artisanal and small-scale mining in Ghana. Journal of Cleaner Production, 202, 465–475. https://doi.org/10.1016/j.jclepro.2018.08.165

[6] Barenblitt, A., Payton, A., Lagomasino, D., Fatoyinbo, L., Asare, K., Aidoo, K., & Wood, D. (2021). The large footprint of small-scale artisanal gold mining in Ghana. Science of the Total Environment, 781, 146644. https://doi.org/10.1016/j.scitotenv.2021.146644

[7] Boadi, S., Nsor, C. A., Antobre, O. O., & Acquah, E. (2016). An analysis of illegal mining on the Offin shelterbelt forest reserve, Ghana: Implications on community livelihood. Journal of Sustainable Mining, 15(3), 115–119. https://doi.org/10.1016/j.jsm.2016.12.001

[8] Brunnschweiler, C. N., Karapetyan, D., & Lujala, P. (2024). Opportunities and risks of small-scale and artisanal gold mining for local communities: Survey evidence from Ghana. The Extractive Industries and Society, 17, 101403. https://doi.org/10.1016/j.exis.2023.101403

[9] Byizigiro, R. V., Biryabarema, M., & Rwanyiziri, G. (2020). Alleviating some environmental impacts resulting from the artisanal and small-scale mining sector: A critical review. Rwanda Journal of Engineering, Science, Technology and Environment, 3(1). https://doi.org/10.18016/rjeste.v3i1.384

[10] Cudjoe, K., Nyantakyi, E. K., Borkloe, J. K., Adjei, E. A., Siabi, E. K., Ackerson, N. O. B., & Owusu, A. (2023). Assessing livelihood and environmental implications of artisanal and small-scale mining: A case of Akango mining, Nzema East Municipality, Western Region, Ghana. Environment, Development and Sustainability, 1–28. https://doi.org/10.1007/s10668-023-03109-w

[11] de Haan, J. (2020). Mining, formalisation, and peace, justice and strong institutions. In Mining, Materials, and the Sustainable Development Goals (SDGs) (pp. 171–196). CRC Press.

[12] Dumakor-Dupey, N., & Bansah, K. (2017). Environmental issues of artisanal and small-scale mining in the Tarkwa mining area of Ghana—proceedings of the Society of Mining, Engineering & Exploration, Denver, CO.

[13] Engstrand, R. C., Espejo, J. C., Silman, M. R., & Asner, G. P. (2024). Repeated mining accounts for the majority of artisanal and small-scale gold mining activity in Southeastern Peru. Environmental Research Letters, 19(6), 064036. https://doi.org/10.1088/1748-9326/ad480d

[14] Eswaran, H., Lal, R., & Reich, P. F. (2019). Land degradation: An overview. In E. M. Bridges, I. D. Hannam, L. R. Oldeman, F. W. T. Pening de Vries, S. J. Scherr, & S. Sompatpanit (Eds.), Responses to land degradation (pp. 20–35). Oxford Press India.

[15] Fayiah, M. (2020). Mining and environmental degradation: A gift brings grief scenario for mining communities in Sierra Leone. Journal of Mining and Environment, 11(2), 347–361. https://doi.org/10.22044/jme.2020.8975.1807

[16] Gatsinzi, A. (2020). Young faces in dangerous places: A critical re-appraisal of the child labour debate in Africa's artisanal and small-scale mining sector [Doctoral dissertation, University of Surrey]. Surrey Research Insight.

[17] Hilson, G. (2016). Artisanal and small-scale mining and agriculture: Exploring their limits and linkages in rural sub-Saharan Africa. IIED Issue Paper. International Institute for Environment and Development, London.

[18] Hilson, G. (2019). The environmental impact of small-scale mining in developing countries. Journal of Cleaner Production, 255, 120209. https://doi.org/10.1016/j.jclepro.2020.120209

[19] Hilson, G., Hilson, A., Siwale, A., & Maconachie, R. (2018). Female faces in informal 'spaces': Women and artisanal and small-scale mining in sub-Saharan Africa. Africa Journal of Management, 4(3), 306–346. https://doi.org/10.1080/23322373.2018.1516898

[20] Hilson, G., Hilson, A., Maconachie, R., & McQuilken, J. (2021). 'Suicide or survival?' New directions for artisanal and small-scale mining research. The Extractive Industries and Society, 8(1), 667–689. https://doi.org/10.1016/j.exis.2021.100990

[21] Hirons, M. (2020). How the Sustainable Development Goals risk undermining efforts to address environmental and social issues in the small-scale mining sector. Environmental Science & Policy, 114, 321–328. https://doi.org/10.1016/j.envsci.2020.08.020

[22] International Labour Organisation (ILO). (2018). Child labour in artisanal and small-scale mining: A rights-based approach. International Labour Organisation, Geneva.

[23] Isung, C. B., Salifu, Y., & Agana, T. A. (2021). The socio-economic implications of artisanal

and small-scale mining on mining communities in northern Ghana. Open Access Library Journal, 8(3), 1–17. https://doi.org/10.4236/oalib.1107197

[24] Kampalath, R. A., & Jay, J. A. (2015). Sources of mercury exposure for children in low- and middle-income countries. Journal of Health and Pollution, 5(8), 33–51. https://doi.org/10.5696/2156-9614-5-8.33

[25] Ladu, J. L. C., Athiba, A. L., & Demetry, P. L. (2019). Environmental impacts of gold mining: A study of mining communities in Gorom Village, Rejaf County, Republic of South Sudan. Applied Ecology and Environmental Sciences, 7(1), 1–10.

[26] Laniyan, T. A., Kolawole, T. O., & Kenjinu, S. S. (2024). Environmental assessment of artisanal gold mining on soils of a community within Southwestern Nigeria. Environmental Geochemistry and Health, 46, 15. https://doi.org/10.1007/s10653-023-01758-1

[27] Lydia, O., Godwin, A., & Isaac, L. (2022). 'We have done nothing wrong': Youth miners' perceptions of the environmental consequences of artisanal and small-scale mining (ASM) in Ghana. The Extractive Industries and Society, 12, 101179. https://doi.org/10.1016/j.exis.2022.101179

[28] Mabey, P. T., Li, W., Sundufu, A. J., & Lashari, A. H. (2020). Environmental impacts: Local perspectives of selected mining edge communities in Sierra Leone. Sustainability, 12(14), 5525. https://doi.org/10.3390/su12145525

[29] Magidi, M., & Hlungwani, P. M. (2023). Development or destruction? Impacts of mining on the environment and rural livelihoods at Connemara Mine, Zimbabwe. South African Geographical Journal, 105(2), 157–178. https://doi.org/10.1080/03736245.2021.1912972

[30] Mensah, A. K., Mahiri, I. O., Owusu, O., Mireku, O. D., Wireko, I., & Kissi, E. A. (2015). Environmental impacts of mining: A study of mining communities in Ghana. Applied Ecology and Environmental Sciences, 3(3), 81-94. https://doi.org/10.12691/aees-3-3-3

[31] Mestanza-Ramon, C., Mora-Silva, D., D'Orio, G., Tapia-Segarra, E., Gaibor, I. D., Esparza Parra, J. F., & Straface, S. (2022). Artisanal and small-scale gold mining (ASGM): Management and socioenvironmental impacts in the Northern Amazon of Ecuador. Sustainability, 14(11), 6854. https://doi.org/10.3390/su14116854

[32] Meutia, A. A., Bachriadi, D., & Gafur, N. A. (2023). Environment degradation, health threats, and legality at the artisanal small-scale gold mining sites in Indonesia. International Journal of Environmental Research and Public Health, 20(18), 6774. https://doi.org/10.3390/ijerph20186774

[33] Ofosu, G., Dittmann, A., Sarpong, D., & Botchie, D. (2020). Socio-economic and environmental implications of artisanal and small-scale mining (ASM) on agriculture and livelihoods. Environmental Science & Policy, 106, 210–220. https://doi.org/10.1016/j.envsci.2020.01.020

[34] Ofosu, G., & Sarpong, D. (2023). Defying the gloom: In search of the 'golden' practices of small-scale mining operations. Environmental Science & Policy, 139, 62–70. https://doi.org/10.1016/j.envsci.2022.10.018

[35] Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

[36] Pokorny, B., von Lubke, C., Dayamba, S. D., & Dickow, H. (2019). All the gold for nothing? Impacts of mining on rural livelihoods in Northern Burkina Faso. World Development, 119, 23–39. https://doi.org/10.1016/j.worlddev.2019.03.002

[37] Stoudmann, N., Reibelt, L. M., Rakotomalala, A. G., Randriamanjakahasina, O., Garcia, C. A., & Waeber, P. O. (2021). A double-edged sword: Realities of artisanal and small-scale mining for rural people in the Alaotra region of Madagascar. Natural Resources Forum, 45(1), 87–102. https://doi.org/10.1111/1477-8947.12217

[38] UNCCD. (2022). The global land outlook 2: Land restoration for recovery and resilience. United Nations Convention to Combat Desertification. https://www.unccd.int/resources/global-land-outlook/glo2

[39] Yaaba Baah-Ennumh, T., & Forson, J. A. (2017). The impact of artisanal small-scale mining on sustainable livelihoods: A case study of mining communities in the Tarkwa-Nsuaem Municipality of Ghana. World Journal of Entrepreneurship, Management and Sustainable Development, 13(3), 204–222. https://doi.org/10.1108/WJEMSD-06-2016-0030