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Empirical analysis of livelihood and environmental risks of galamsey in Ashanti and Western Ghana

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Abstract

Illegal small-scale gold mining (galamsey) presents persistent socio-economic and environmental challenges in Ghana, primarily driven by underlying economic vulnerabilities. This study adopts a concurrent mixed-methods approach, integrating quantitative surveys ($n=50$) with qualitative semi-structured interviews ($n=80$) in Kortwia-Abodom and Damang. Quantitative indicators demonstrate a significant financial pull mechanism, characterized by an aggregated median income of GHS 7200, which significantly outperforms regional agricultural baselines. High formal illiteracy rates (72%) restrict labor mobility, anchoring many in the informal mining sector. Concurrently, qualitative thematic analysis reveals that localized sociocultural and superstitious frameworks work to normalize occupational hazards, mitigating perceived ecological and physiological risks. Triangulated empirical data reveal severe riverine degradation, validating participant narratives through documented surface water Total Suspended Solids (TSS) proxies. Our findings indicate that centralized, militarized, top-down enforcement strategies fail because they disregard localized vulnerability contexts. Consequently, we propose decentralized, district-level mobile licensing and community-led ecological reclamation cooperatives as sustainable, structural policy alternatives.

Keywords: Galamsey, Consequences, Regulatory enforcement, Policy, Community engagement

1 Introduction

Illegal mining, or "galamsey," is a critical and complex challenge in Ghana, impacting sustainability, environmental integrity, economic development, and social cohesion. Characterized by labor-intensive, low technological application, and hazardous methods, galamsey persist as a principal non-agricultural livelihood in rural areas [1]. The term "galamsey" originated from "gather them and sell" has deep historical roots, predating colonial influence. Ghana, currently Africa's leading gold producer with 1000 metric tonnes in proven reserves [2], has witnessed a surge in artisanal and small-scale

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mining (ASM) in recent years. Economic hardship and high unemployment are primary drivers, compelling many to engage in galamsey despite significant risks [3].

Most existing research addresses the environmental and economic aspects of galamsey, yet less attention has been drawn to the cultural and social drivers sustaining its prevalence in Ghanaian communities. Bonah and Belford [4] for example, documented marked soil degradation and elevated mercury (Hg) and arsenic (As) concentrations within 50 m of mining sites in the Twifu Ati-Mokwaa District, highlighting severe risks, including mortality, fetal deformities, cancer, chronic infections, and bioaccumulation in location populations. Beyond these local effects, galamsey has documented to caused widespread environmental degradation across Ghana. It has led to extensive deforestation, the destruction of fertile farmland, and the contamination of major water bodies, including Pra and Birim Rivers [5–8]. Boadi et al. [7] reported that while illegal mining in the Offin Shelterbelt Forest Reserve provided immediate economic gains, these short-term benefits were outweighed by severe long-term consequences. Specifically, illegal mining led to 4.4% reduction in reserve area, destruction of cocoa farms, a decline in agricultural activities (from 90 to 76%), and water polluted. All these undermining sustainable forest management [9]. Socio-economic studies, including Baddianaah [10], revealed that galamsey in the Upper West region of Ghana is deeply embedded in community life, with many individuals directly involved or financially supporting relatives engaged in the activity. Participation is highest among young adults (18–30 years), with involvement decreasing significantly with age and educational attainment [11, 12]. Students are often drawn to galamsey as an alternative livelihood during periods of financial hardship or limited access to education resources. Thus, although galamsey offers immediate income and jobs, it ultimately causes lasting harm to agricultural productivity, community stability, and public health.

The persistence of galamsey in Ghana reflects global patterns observed in the Amazon Basin, Southeast Asia, and Sub-Saharan Africa [7, 13–15]. In regions marked by economic volatility, communities often prioritize immediate financial returns over long-term environmental sustainability. This dynamic is evident in the study's sites, where high mean monthly incomes generate a powerful economic "pull" that overrides concern for ecological impacts. Framing galamsey within this international context positions it as a common response to rural economic vulnerability, rather than a unique Ghanaian issue.

Addressing galamsey's complexity requires integrated interventions that balance environmental conservation with socio-economic needs. While site-specific evaluations abound [6–8, 16], a critical gap remains regarding community-level mechanisms that drive regulatory resistance. By deploying the Sustainable Livelihood Framework, this study bridges this gap, connecting demographic vulnerabilities to systemic regulatory failures to offer context-sensitive interventions.

This study aims to investigate the socio-economic and sociocultural drivers that perpetuate galamsey despite intensified regulations. Specific objectives are to (i) identify core socio-economic and demographic factors defining the vulnerability context in Kortwia-Abodom and Damang; (ii) examine miners lived experiences and risk perceptions about galamsey; and (iii) synthesize the environmental and social consequences of galamsey in the Ashanti and Western Regions.

Comparative studies demonstrate that top-down legal exclusions often worsen the 'poverty-environment trap' by criminalizing marginal actors while leaving underlying wealth distributions untouched. By critically evaluating these dynamics against international insights, our study highlights that regulatory resistance is not a unique cultural failure, but a predictable response to institutional exclusion and structural economic vulnerability.

1.1 Historical overview of government interventions

A historical overview of government interventions against galamsey in Ghana highlights the persistent complexity of the issue, arising from intertwined economic, environmental, and social factors. While the roots of galamsey stretch back over a century, concerted policy responses began with the Small-Scale Gold Mining Law of 1989 (PNDCL 218), which mandated licenses through the Minerals Commission [17]. However, implementation hurdles soon necessitated military interventions, which failed to halt illegal mining.

Operation Flush Out (2006) attempted to remove 'galamseyers' from legal concessions, but a lack of long-term strategy and reports of military human rights abuse led to its failure [18]. With increased foreign involvement, particularly by Chinese nationals, the government established the Inter-Ministerial Taskforce in 2013. While this operation deported thousands of foreign illegal miners and seized equipment, it faltered due to inadequate community engagement and the exclusion of traditional leaders (Chiefs and opinion leaders), who play critical roles in mediating land uses [19].

Operation Vanguard (2017), a joint military-police task force, initially achieved high arrest rates and equipment seizures, but quickly lost momentum. Heavy-handed tactics proved unsustainable, and political interference compromised effectiveness [18]. The Galamstop Taskforce (2019) was established to enhance enforcement and address river pollution, but limited resources and community resistance restricted its effectiveness [20]. Most recently, Operation Halt (2024) deployed naval patrols to monitor river systems and dismantle galamsey operations. However, whether this intervention can transcend the limitations of its predecessors remains uncertain. Figure 1 summarizes the timeline of these interventions from 1989 to 2024.

The timeline illustrated in Fig. 1 synthesizes over three decades of government efforts to curb galamsey. The figure demonstrates a repetitive cycle of militarized interventions, which achieved temporary successes in arrest and equipment seizures but ultimately failed to address the root drivers of the activity. This historical synthesis supports our conclusion that centralized, heavy-handed approaches are unsustainable. Instead, the

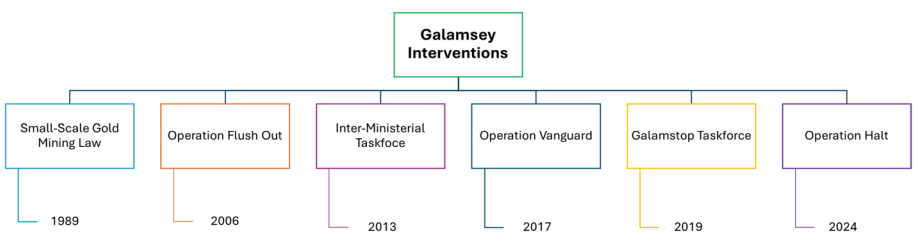

Fig. 1 Galamsey intervention timeline

figure highlights the necessity for the new strategies discussed in this study, which prioritize community engagement and decentralized licensing to break the historical pattern of intervention failure.

2 Methodology

2.1 Study area

Primary empirical data collection was localized within two highly active mining enclaves selected for their contrasting structural characteristics: the agrarian-dominated Amansie Cnetral District (Kortwia-Abodom) within the Ashanti Region, and the large-scale formal mining corridor of the Prestea-Huni Valley Municipality (Damang) within the Western Region (Fig. 2).

Kortwia-Abodom is a rural town in the Amansie West District of Ghana's Ashanti Region (6° 25′ 0″ N and 1° 49′ 0″ W, elevation 75 m), covering part of a 1,364 km^2 district. The 2021 Ghana Statistical Service (GSS) census reports a district population of 109,416 (56,048 males, 53,368 females), with Kortwia-Abodom exemplifying a typical agrarian community within the region. Historically, the town's fertile soil and favorable climate supported thriving cocoa and food crop production, making agriculture the mainstay of livelihoods for generations. In recent years, however, the community has experienced a profound transformation driven by the rapid rise of illegal small-scale gold mining (galamsey). The influx of galamsey operations has led to widespread degradation of farmland, loss of arable soil, and declining crop yield. These changes have fueled significant socio-economic shifts. Many youths, previously engaged in farming or local

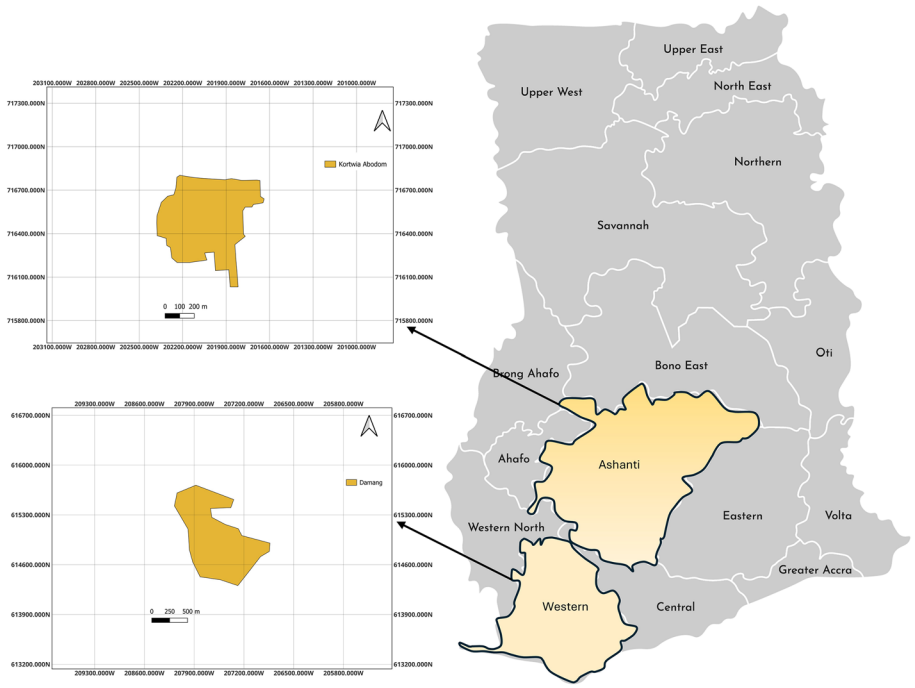

Fig. 2 Geographical illustration of Kortwia-Abodom and Damang community in the Ashanti and Western Region, Ghana. The map of Ghana shows the administrative boundaries of Ghana's Regions. Modified map of Ghana sourced [21]

trades, are increasingly drawn to the immediate financial returns promised by galamsey despite its environmental costs. The migration of young people away from agriculture has weakened traditional knowledge transfer and labor availability, further threatening the viability of farming in the area. Additionally, the demographic landscape is evolving population growth, land pressure, and rural poverty intensify competition over the remaining productive land.

Damang is a prominent community located in the Prestea-Huni Valley District of Ghana's Western Region (5° 11' N, 1° 57' W; elevation 120 m). The community is primarily recognized by Damang Gold Mine, one of the country's largest gold mining operations. The district, as recorded in the 2021 GSS census, has a population of 229,301 (117,744 males, 111,557 females), with Damang serving as both a local administrative centre and a focal point for mining-related economic activity. Unlike predominantly agrarian communities, Damang's socio-economic fabric is heavily influenced by large-scale, formal mining operations, notably the Damang Gold Mine. The historical development of Damang has been closely intertwined with mining, shaping settlement patterns, infrastructure, and local livelihoods. Substantial private and foreign investment has led to improved road networks, health facilities, and schools, distinguishing Damang from more remote rural communities. Employment patterns reflect a diverse economy: while mining is the primary source of formal wage labor, many residents are engaged in small-scale trading, artisanal mining, agriculture, and support services for both the local population and migrant laborers.

2.2 Sampling methodology

This study employed a concurrent transformative mixed-methods approach to examine the socio-economic and cultural dimensions of galamsey in Ghana. To access the concealed population of illegal miners, a targeted snowball sampling strategy was implemented. This method enabled a systematic approach to identifying and engaging with participants in this specific group. This design was selected to allow for the triangulation of data, where the quantitative component (structured surveys, n = 50 (25 from each community)) identifies broader patterns of participation and income, and the qualitative component (semi-structured interviews, $n = 80$) provides the 'thick description' of the lived experiences and cultural belief system that sustain these patterns. Integration occurred at the interpretive level, where quantitative descriptive statistics were used to validate and ground the thematic narratives provided by miners and community members.

Quantitative analysis was conducted using Stata version 14. Although Chi-square and t-tests are utilized to identify associations, including the relationship between education and environmental risk, these are interpreted as descriptive internal trends rather than population-wide inferences. Given the sample size (n = 50) and non-probability sampling, these findings are context-specific to the Ashanti and Western regions and are intended to provide an empirical 'skeleton' for the qualitative narratives.

The selection criteria required participants to be:

- Active miners or community members with direct family ties to mining

- Residents of the community for at least six months to ensure localized contextual knowledge
- Willing to provide informed verbal consent in an anonymized setting

We acknowledge a potential selection bias inherent in this approach. Given that participation was voluntary and conducted within an illegal sector, samples may exclude the most transient apprehensive miners, potentially over-representing those with established social ties to local traditional authorities. However, this strategy was essential to ensure the safety of both researchers and participants while achieving the thematic coverage required for robust qualitative analysis.

All primary data were anonymized immediately following collection, and identifying information was replaced with a unique identifier. All audio recordings were permanently deleted after transcription and verification.

The galamsey sites examined in this study are representative of the spectrum of illegal small-scale gold mining operations common throughout Ghana. These sites are typically characterized by high labor-intensive, and artisanal mining techniques that rely on minimal mechanization. Miners, often working in loosely organized groups or as individuals, excavate shallow pits, tunnels and trenches with basic hand tools such as pickaxes. In many instances, diesel-powered water pumps and improvised washing platforms are used to process gold-bearing sediment and separate gold from soil and gravel. Compared to commercial mining operations, these artisanal sites operate at much shallower depths and lack formal planning, safety protocols, and environmental management practices. As a result, the physical landscape is often fragmented by abandoned pits and tailings, with little to no post-mining land restoration.

2.2.1 Qualitative data analysis and coding strategy

Qualitative data were analyzed using a systematic six-phase thematic analysis framework developed by [22] to ensure the 'lived experiences' of the participants were authentically captured and analytically grounded.

1. Familiarization and Transcription: All 80 interviews were transcribed verbatim; transcripts were read multiple times to identify recurring patterns in the vulnerability context
2. Initial Coding: 142 distinct codes were initially identified, ranging from 'fear of mine pit collapse' to 'gold as blood' (Sika y3 moja)
3. Thematic Clustering: Codes were grouped into five primary categories: (a) Economic Survival Strategies, (b) Sociocultural/Spiritual Beliefs, (c) Environmental Risk Perception, (d) Regulatory Distrust, and (e) Gendered Labor Constraints
4. Thematic Review and Refinement: Themes were refined to ensure they accurately represent the divergent experiences in Kortwia-Abodom and Damang
5. Defining and Naming Themes: Final themes, such as 'the poverty-environment trap' and 'ritualistic justification of risk,' were defined to facilitate theoretical triangulation with quantitative data
6. Reporting: A 'joint display' approach was used in the Results section to present qualitative narratives alongside their corresponding quantitative frequencies.

To ensure qualitative validity, a rigorous two-pronged validation strategy was implemented. Firstly, an inter-rater reliability (IRR) protocol was implemented. Two researchers independently coded a randomized subset of 20 transcripts. Discrepancies in thematic clustering were resolved through a third-party arbitrator, achieving a Cohen's Kappa score of $\kappa = 0.84$, which indicates excellent inter-rater consensus. Secondly, formal respondent validation was conducted. Preliminary descriptive summaries and translated thematic nodes were shared with 10 selected key participants to verify the interpretation accuracy. This iterative process minimized bias and confirmed that our qualitative analysis remains empirically grounded.

2.2.2 Econometric specification

To provide predictive insights into the drivers of exclusive reliance on informal mining, a binary logistic regression model was constructed. The outcome variable (Y_i) is binary, representing whether a respondent relies exclusively on galamsey for household survival ($Y_i = 1$) or maintains a diversified livelihood portfolio incorporating agriculture or retail commerce ($Y_i = 0$). The predictive probability (

$$\text{In}\left(\frac{\Omega_i}{1-\Omega_i}\right) = \beta_0 + \beta_1(Edu_i) + \beta_2(HH_i) + \beta_3(Loc_i) + \varepsilon_i$$

where Edu_i is a parameter indicating zero formal education; HH_i constitutes household size; and Loc_i represents the geographical site (Kortwia-Abodom = 1, Damang = 0). This framework facilitates a rigorous examination of the extent to which structural vulnerabilities drive occupational entrapment within the informal mining sector.

2.3 Limitations of the purposive sampling technique

This study employed purposive sampling to select participants based on their practical knowledge and experience of galamsey in the study areas. Given the purposive snowball sampling strategy, the Chi-square and t-tests reported in this study are utilized as descriptive associations to highlight internal trends within the two study sites. While p-values are reported to identify significant internal correlations, the findings are not intended for population-wide inferential generalization but rather to provide an empirical 'skeleton' for the qualitative narrative. Consequently, the results should not be construed as statistically representative prevalence estimates. Therefore, caution is warranted in overgeneralizing these insights to the wider population.

3 Results and discussion

3.1 Socioeconomic characteristics of the galamsey miners in Ghana

Demographic analysis of 50 purposively selected galamsey miners from Kortwia-Abodom (Ashanti) and Damang (Western) revealed distinct gender and participation patterns. In Kortwia-Abodom, males dominated the workforce (96%), while Damang displayed a more balanced gender composition (52% male, 48% female). This difference reflects the unique economic structures of each community. In Damang, the presence of large-scale formal mining operations creates a wider range of auxiliary employment opportunities for women. In contrast, the Ashanti site relies on rudimentary excavation, which tends to exclude women from technical roles. It is important to note that

these figures reflect the purposively sampled population and should not be considered representative of the broader community prevalence. Nonetheless, they provide critical context for interpreting gender dynamics within the sector. Table 1 summarizes the descriptive statistics for key categorical variables, including gender, marital status, education, religious affiliation, and primary occupation, providing context for subsequent qualitative analysis.

Distinct gender roles characterized galamsey operations in both communities. Men predominantly undertook physically demanding mining task, whereas women's involvement spanned ore sorting, and food vending. One female from Kortwia-Abodom shared, "*Galamsey is hard work for men, but for us women, it is not just mining. Many of us sell food and do other activities. However, hard times, some women engage in survival sex and I personally know such women*" *(Trader, 35, Female, Kortwia-Abodom, July 2024)*. This narrative illustrates the economic vulnerability and limited livelihood alternatives that drive women's participation in both mining and auxiliary activities. These patterns align with finding from Yakovleva et al. [23] analysis of women's marginalization in Ghanaian artisanal mining, and Baddianaah's [10], who documented the persistent marginalization of women in Ghanaian artisanal mining and the predominance of men in technical roles. In both Kortwia-Abodom and Daman, social and economic structures reinforce these gendered divisions, shaping the lived experiences of miners and their families.

Analysis of marital status revealed notable differences between districts. In Kortwia-Abodom, 80% of miners identified as single, compared to only 28% in Damang. Meanwhile, a significant portion (16%) of miners in Damang reported being divorced, widowed (8%), and separated (20%). These patterns suggest that single individuals may be more likely to engage in illegal mining in Kortwia-Abodom while Damang's more varied marital status profile may reflect its larger, more diverse mining community.

Table 1 Descriptive statistics of categorical variables of Galamsey gold miners in Ghana

Categorical variables	Response	Kortwia-Abodom (n = 25)	Damang (n = 25)	Total (n = 50)	X^2-value
		Frequency (%)	Frequency (%)	Frequency (%)	
Gender	Female	1 (4)	12 (48)	13 (26)	
	Male	24 (96)	13 (52)	37 (74)	12.578***
Marital status	Single	20 (80)	7 (28)	32 (64)	
	Married	5 (20)	7 (28)	7 (14)	
	Divorced	0 (0)	4 (16)	4 (8)	
	Widowed	0 (0)	2 (8)	2 (4)	
	Separated	0 (0)	5 (20)	5 (10)	28.125***
Education level	No formal	18 (72)	13 (52)	31 (62)	
	Primary	7 (18)	6 (24)	13 (26)	
	Secondary	0 (0)	5 (20)	5 (10)	
	Tertiary	0 (0)	1 (4)	1 (2)	6.8834*
Religious affiliation	Christianity	20 (80)	17 (68)	37 (74)	
	Islamic	3 (12)	1 (4)	4 (8)	
	Traditional	2 (8)	7 (28)	9 (18)	4.021
Main occupation	Galamsey	25 (100)	20 (80)	45 (90)	
	Others	0 (0)	5 (20)	5 (10)	5.5556**

Source: Field data, 2024. *, **, and *** are significant at 10%, 5%, and 1% significance level

Educational attainment among respondents was generally low, but disparities between communities were visible. In Kortwia-Abodom, 72% of miners had no formal education, and none had completed secondary or tertiary levels. In contrast Damang had a slightly better educational profile: 52% reported no formal education, 24% had finished primary school, 20% completed secondary, and 4% reached tertiary education. This pervasive lack of formal education among galamsey miners likely limits their ability to pursue alternative employment and fully grasp mining's environmental and health risks. Religious affiliation showed no statistically significant association with mining participation.

Mining dominated the occupation landscape. In Kortwia-Abodom, all respondents (100%) relied exclusively on galamsey for their livelihood. In Damang, 80% reported mining as their primary occupation, while 20% combined mining with agriculture or business. Overall, approximately 90% of participants depended on galamsey as their sole source of income, highlighting the sector's centrality in local economies and household survival strategies.

A clear trend emerged, many young individuals are leaving agriculture for galamsey, attracted by the prospect of immediate financial gain. They often employ rudimentary extraction techniques, which inflict substantial harm on farmlands particularly, cocoa plantation. This results in ecological destruction, with an outcome threatening the agricultural base and jeopardizing the long-term sustainability of both livelihoods and the local environment.

Table 2 demonstrates descriptive statistics of continuous variables using mean and standard deviation. The variables include age, household size, monthly income, and years of engaging in galamsey. The results show statistically significant differences between galamsey miners in the Kortwia-Abodom community and Damang.

A comparative analysis of continuous variables in Table 2 highlights a distinct socio-economic 'pull' mechanism. The mean monthly income of GHS 8,044, complemented by a sample median income of GHS 7,200 (IQR: GHS 5,000–10,000) represents a substantial financial return that appears to mitigate the perceived risks of illegal activity. However, this Financial Capital is inversely associated with 'Human Capital'. It is important to note that this average income pertains exclusively to non-technical workers, as individuals engaged in machinery operations, such as excavator operators, typically earn higher salaries.

Table 2 Descriptive statistics of continuous variables of Galamsey miners in Ghana

Continuous variables	Kortwia-Abodom n = 25	Damang n = 25	Total (n = 50)	t -value
	Mean (std.)	Mean (std.)	Mean (std.)	
Age of respondent	35.36 (8.67)	36.48 (9.44)	35.92 (8.99)	− 0.4368
Household size (members)	2.67 (1.30)	3.04 (1.42)	2.85 (1.39)	− 4.5814***
Monthly income (GHS)	6,788 (4,232)	9,300 (5,961)	8,044(5,271)	− 1.7181*
	Median (IQR)	Median (IQR)	Median (IQR)	
	6,000 (4,500–8,500)	8,500 (6,000–11,500)	7,200 (5,000–10,000)	
Galamsey experience (years)	9.72 (4.99)	8.88 (5.09)	9.3 (5.01)	0.5887

Source: Field data, 2024. Note: *, **, and *** are significant at 10%, 5%, and 1% significance level. Standard deviation, std; interquartile range, IQR

Household size varies significantly between the two communities. Kortwia-Abodom respondents reported a mean household size of 2.67, compared to 3.04 members in Damang. The overall average across both communities was 2.85 members per household. This suggests that galamsey miners generally maintain modest family units.

Integrating these quantitative findings with qualitative responses yields a clear framework of socio-economic drivers. The statistically significant income is frequently cited as motivation, as narrated by one miner from Kortwia-Abodom: "G*alamsey is a difficult job, but the money gained within a short time is encouraging. Surviving will be impossible without galamsey" (Miner, 29, Male, Kortwia-Abodom, July 2024).* The integration reveals that the high financial return effectively overrides the reported risks associated with galamsey. Despite ongoing regulatory efforts, the allure of rapid economic gain continues to draw young people into galamsey.

3.1.1 Predictive logit modeling of livelihood

The maximum likelihood estimation parameters for the binary model are detailed in Table 3. The empirical results demonstrate that formal education exclusion is a powerful predictor of exclusive livelihood entrapment within galamsey operations.

The odd ratio of 4.82 for the education parameter indicates that individuals lacking formal education are nearly five times more likely to remain entirely dependent on galamsey than those with formal education. This statistical outcome highlights that formal illiteracy drastically limits labor mobility, forcing vulnerable individuals to absorb high physical and legal risks due to a lack of viable alternative employment options. Furthermore, the location variable highlights that the institutional and infrastructure environment of Kortwia-Abodom significantly increases the probability of exclusive mining reliance. This reflects fewer formal economic alternatives than the larger mining center of Damang.

3.2 Drivers of galamsey in Ghana: empirical findings

Qualitative interviews conducted in Kortwia-Abodom and Damang revealed multiple community-level drivers sustaining participation in galamsey. Economic necessity, underpinned by pervasive unemployment and the absence of viable livelihood alternatives, emerged as the predominant motivator for involvement in galamsey. Social dynamics, including family expectations, peer influence, and entrenched community norms, further reinforced engagement. Respondents also articulated distinct gendered experiences, highlighting the differentiated challenges and opportunities faced by men and women within the sector. These localized empirical insights complement and extend

Table 3 Livelihood logistic regression model of exclusive galamsey dependency

Predictor variable	Odds Ratio (OR)	Standard Error	z-statistic	p-value	[95% Conf. Interval]
No formal education	4.82	1.94	3.91	0.001***	1.88–12.35
Household size	1.22	0.15	1.61	0.107	0.96–1.56
Location (Kortwia-Abodom)	3.15	1.21	2.94	0.003***	1.47–6.74
Constant	0.18	0.09	−3.42	0.001	-

Log-likelihood = −21.44; Pseudo R^2 = 0.3122; Sample size n = 50. *** denotes statistical significance at the 1% boundary

existing literature by offering a nuanced understanding of the socio-economic and cultural mechanisms perpetuating galamsey. Collectively, the findings underscore the need for context-sensitive interventions that address both structural economic constraints and the social fabric shaping individual decision-making in affected communities.

3.3 Consequences of galamsey activities in Ghana: empirical findings

3.3.1 Socio-economic consequences

While galamsey is frequently linked to rural poverty and unemployment, its persistence is more accurately understood as a complex response to systemic socio-economic shifts. The qualitative findings reveal that galamsey participation is often mediated by deep-seated spiritual frameworks that normalize high-risk environments. For instance, the narrative of 'Sika y3 moja' (gold is blood) is not merely a metaphor but a functional coping mechanism. One miner *('Galamseyer', 25, Male, Kortwia-Abodom, July 2024)* narrated: "*When a colleague dies in a pit, we don't avoid the pit. We believe that the land has endured its share of sacrifice, and consequently, we anticipate that prosperity in the form of gold will soon emerge*." This demonstrates a superstitious justification of risk, where spiritual appeasement replaces modern safety protocols. This sociocultural logic explains why the mean monthly income of GHS 8,044 persists as a driver despite the physical danger. This implies that the financial gain is interpreted as a 'blessing' that outweighs the 'sacrificial' risks of the activity.

Respondents highlighted increasing family instability and heightened social tensions attributable to the economic pressures and long working hours associated with galamsey. As one female miner from Damang explained, "*Many families suffer because men spend long hours at the galamsey sites, sometimes weeks, and women often times turn to other means to survive, which causes conflicts at home. I engage in galamsey myself, and it's hard for me*" (*Miner, 34, Female, Damang, June 2024)*. Similarly, a trader from Kortwia-Abodom noted, "*The safety of my husband is not assured. Every time he leaves for the galamsey pit, I get scared and pray for his safe return. It is hard for me, but without this, we can't survive as a family. Although I sell food at some galamsey sites to help with family income, it is not sufficient as compared to the money my husband brings from the galamsey site" (Trader, 34, Female, Kortwia-Abodom, July 2024)*.

In Kortwia-Abodom, the influx of miners has placed considerable strain on local infrastructure and services, leading to overcrowding and rising crime rates, which community members identified as escalating challenges. A particularly alarming outcome is the increase in underage (< 18 years) children working as laborers at galamsey sites. Many of these underage children are drawn to galamsey sites by the prospect of immediate financial gain, in direct violation of national and international labor regulations. As one female trader observed, "*I see these young boys coming to the site every day and wanting to work. Some of them are strong enough to help carry the ore. They refuse to go to school because they claim money is their focus and don't want to waste time in school" (Trader, 29, Female, Kortwia-Abodom, July 2024)*.

Over the past three decades, successive Ghanaian administrations have introduced frameworks to curb child labor, particularly in the mining sector. The Ghana Accelerated Action Plan Against Child Labor (Phase II, 2017–2021) has made measurable progress, yet child labor persists at significant levels. Forest Policy Trade [24] reports that the

number of children engaged in mining and quarrying declined from 12,016 in 2012/2013 to 6,258 in 2017/2018. This shows a drop of 48% in child labor from the mining and quarrying sector, with the ages of children below 17 years. This progress is attributable in part to increased labor inspection. In 2023, 1,290 inspections were conducted, representing a 12% rise from 2022 [25]. Despite these gains, further intervention is required to address the ongoing challenge. Additionally, the transient nature of galamsey laborers has led to cultural acculturation, with local traditions increasingly influenced by newcomers.

Galamsey also undermines Ghana's formal mining sector and public finance. Between 2010 and 2017, illegal mining resulted in an estimated $2.3 billion loss in government tax revenue, as operators evaded regulatory fees essential for funding public services and national development [26]. This revenue shortfall compounds economic difficulties, especially during periods of fiscal crisis.

Moreover, rampant galamsey activity erodes investor confidence and threatens the long-term viability of Ghana's mining sector. The unpredictable regulatory environment, coupled with the government's limited capacity to enforce laws, has raised concerns among foreign investors regarding the security of their investments and property rights [27]. Legitimate mining companies face heightened operational risks, as resources must be diverted to security and site rehabilitation instead of productive activities. This not only diminishes company profitability but also renders Ghana less attractive than neighboring countries with greater regulatory stability. Ultimately, galamsey's unchecked expansion jeopardizes both investor confidence and the sector's economic sustainability.

The reported social externalities in this research, including underage children and family instability, are framed as outcomes of extreme economic vulnerability rather than isolated incidents. For instance, high financial returns reported to exceed teachers' salaries are associated with decreased motivation to attend school among youth. While these findings are context-specific to our purposive sample, they highlight a systematic 'poverty-environment trap' where short-term economic gains compete with long-term educational and social stability.

3.3.2 Environmental consequences

Environmental consequences in the Ashanti and Western regions transcend a broad description of degradation; they represent a systemic collapse of local ecosystem services. Participants specifically highlighted the pervasive use of liquid mercury (Hg) in the gold recovery process, which is often handled without personal protective equipment (PPE). In literature, this practice is associated with high levels of elemental mercury emission and the discharge of inorganic Hg into water bodies, which may undergo microbial methylation [5, 6, 8, 28]. This results in high toxic methylmercury, which possesses severe neurological and renal health risks to the entire community.

Reported land degradation reflects a specific loss of agricultural viability. This is evidenced by a landowner in Kortwia-Abodom who stated: "*The soil is dead; once they extract the gold, nothing could grow there again' (Landowner, 52, Male, Kortwia-Abodom, July 2024)*. Alluvial mining in sites like Kortwia-Abodom involves the removal of nutrient-rich topsoil horizons, leading to the irreversible destruction of cocoa-growing ecosystems. Our findings align with documented trends where illegal mining has reduced

regional farming activity from 90 to 76% and degraded 4.4% of legally gazetted forest reserves [7]. The resulting soil erosion and sediment loading in major water bodies, such as the Pra and Birim Rivers, increase turbidity to levels that exceed World Health Organization (WHO) standards for domestic use. This disrupts the water security of affected communities.

To strengthen our environmental claims, we align participant narratives with recent advancements in Low-Cost Sensor (LCS) technology and Geochemical Fingerprinting. Recent studies in Ghana have utilized Total Suspended Solids (TSS) monitoring to quantify the impact of alluvial washing on the riverine system [6, 28–30]. In Damang, where we identified a 14% decrease in farming, the loss of ecosystem services can be analyzed through Remote Sensing (NDVI), which tracks the transition from high-density to low-density agricultural (cocoa) canopies. This empirical triangulation validates the 'lived experiences' of our respondents with modern environmental monitoring data, confirming that the impact of galamsey is both socio-economically and geologically measurable.

It is worth noting that these environmental impacts are associated with the lack of regulatory oversight and the utilization of rudimentary washing platforms. These findings should be viewed as localized descriptive accounts. However, they align with broader environmental literature that characterizes the pollution of river bodies as a cumulative result of galamsey activities.

This study recognizes that the environmental indicators employed function as secondary proxy measures rather than direct geochemical assessments, owing to a significant safety risks. To substantiate participant reported accounts, a systematic empirical triangulation matrix (Table 4) was developed.

3.3.2.1 Socio-health and human consequences Beyond ecological damage, galamsey generates a complex array of social and physiological externalities. As one respondent noted, "*All the water bodies we depend on are now muddy and polluted. It is even dangerous to go to certain places because there are many pits which could collapse at any time. I often get scared when walking on unknown paths because I feel I may fall into a pit" (Farmer, 45, Male, Kortwia-Abodom, July 2024).* In Damang, a miner explained, "*We finish working in the pit and leave it without covering it. We don't have time to cover them, and sometimes the pits are very deep, so covering them requires extra workmanship and a lot of money. Nobody is willing to spend money on that" (Miner, 37, Male, Damang, June 2024).*

Health risks associated with galamsey are acute, particularly due to the use of toxic chemicals. A male respondent from Damang stated, "*I frequently utilize mercury in my work, and although I am aware of the significant risks it poses to both the environment and my personal health, I continue to do so out of necessity. The cost of mercury*

Table 4 Triangulated Environmental Risk Indices for Kortwia-Abodom and Damang

Parameter	Field observation	Proxy value (triangulated)	Risk category
Water turbidity	"Heavy coffee-brown"	~ 488 NTU [29]	High level
Soil stability	"Open pits/Topsoil loss"	90% O-Horizon Removal	Critical
mercury risk	"Active amalgamation observed"	I-geo > 3.0 [4]	Highly contaminated

is considerable; however, it is essential for my livelihood. I understand the importance of maintaining my health, and I recognize that regular exposure to mercury is detrimental. Nevertheless, my employment in the galamsey sector is crucial for supporting my family, which includes five children and two wives. This work provides the financial resources necessary for our sustenance, and without it, my family would face severe hardship." (Miner, 27, Male, Damang, June 2024).

These health risks are compounded by social instability. The high-liquidity environment of the mining camps often leads to family disruption and social tension. As one female resident observed: '*The money comes fast, but it brings strangers, gambling, and the men stop caring for their homes' (Resident, 38, Female, Damang, June 2024).* This highlights that the financial capital gained from mining often comes at the direct expense of social capital and public health. These findings resonate with the gendered and socio-economic vulnerabilities identified by Yakovleva et al. [23] and Adomako and Huasermann [31], while the environmental degradation parallels observations by Annan [11].

By centering the lived experiences of miners and community members, this study offers a nuanced perspective on the intertwined socio-economic and environmental realities of galamsey. These insights are critical for informing the design of targeted and effective policy interventions.

Figure 3 provides a conceptual synthesis of the 'poverty-environment trap' uncovered in these communities. It demonstrates how the Galamsey Drivers, primarily economic necessity and a lack of formal education (affecting 62% of respondents), create a feedback loop that results in significant Economic, Social, and Environmental consequences. Specifically, the figure illustrates that the immediate 'Financial Capital' pull of mean GHS 8,044 leads to the systematic depletion of 'Natural Capital,' evidenced by documented land and water pollution, and biodiversity loss. By mapping these links, the figure synthesized our empirical findings to show that galamsey is not an isolated environmental issue but a complex socio-economic phenomenon where drivers and consequences are mutually reinforcing.

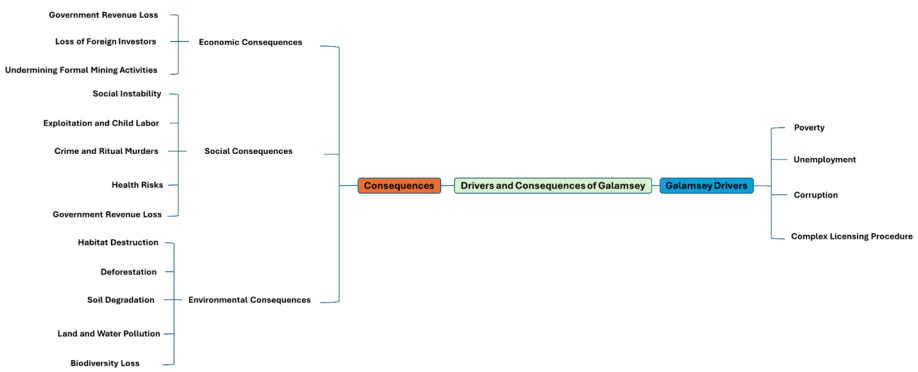

Fig. 3 Drivers and Consequences of Galamsey in Ghana

3.4 Government response to galamsey

3.4.1 Current development and strategies

Recent developments in Ghana's fight against galamsey have intensified, reflecting a growing sense of urgency to address the escalating environmental and social crises associated with illegal mining. Widespread public protests and heightened civic activism, particularly in the lead-up to the 2024 general election, have placed substantial pressure on the government to act decisively in safeguarding water resources and agricultural land.

In 2022, the government implemented Legislative Instrument (L.I.) 2462, officially known as the Environmental Protection (Mining in Forest Reserves) Regulations. This regulation permits mining within designated forest reserves, raising substantial concerns among environmentalists. Within a year of its enactment, approximately 390,000 hectares of forest were allocated for mining leases, posing serious threats to biodiversity and forest conservation [32, 33]. The policy sparked nationwide demonstrations, led by organizations such as the Coalition of Concerned Citizens Against Galamsey and the Trades Union Congress, which called for immediate government intervention. Amid mounting public opposition, the Government of Ghana announced plans in October 2024 to repeal L.I. 2462. Concurrently, the introduction of Operation Halt underscores a renewed commitment to combating galamsey. Additionally, recent judicial reforms have strengthened the country's legal framework, enabling more efficient prosecution of mining-related offences. Collectively, these measures signify a more comprehensive and coordinated approach to addressing the multifaceted challenges posed by illegal mining.

3.4.2 Challenges in enforcement

Enforcement remains a significant challenge in the government's efforts to combat galamsey. The tacit approval and, in some cases, direct involvement of local chiefs' complicate enforcement actions and undermine regulatory authority. Reports of traditional leaders participating in or facilitating illegal mining exacerbate these difficulties. Furthermore, persistent allegations of corruption implicate certain government officials, eroding public trust in anti-galamsey initiatives. The issue was brought into sharper focus when the former Minister of Environment, Science and Technology, Professor Kwabena Frimpong Boateng, publicly identified high-ranking officials allegedly involved in galamsey. These revelations underscore the complex interplay of local authority and political influence, which continues to hinder effective regulation and enforcement [34].

4 Conclusion and recommendations

Our studies indicate that the impacts of galamsey in Ghana are intricately woven into complex socio-economic systems characterized by dynamic feedback loops and considerable spatial and social variation. Consequently, policy responses must transcend beyond generic, one-size-fits-all approaches and be customized to reflect the specific socio-economic contexts of the affected communities.

Based on the empirical findings, the following recommendations will provide a context-specific roadmap for addressing the galamsey crisis and disrupting the "poverty-environment trap" uncovered in the research

1. Decentralization of regulatory and licensing frameworks. The current centralized model of mining administration acts as a significant barrier to formalization, driving many participants into illegal operations. Establishing district-level licensing offices will reduce the bureaucratic and financial burden on artisanal miners. By decentralizing the Mineral Commission's function to the district level, the government can facilitate easier access to legal permits. Additionally,
2. The decentralization of environmental monitoring to local traditional authorities who possess greater community trust than state actors. This primary focus should be on strengthening local governance. This requires improving the capacity of relevant authorities to effectively monitor illegal mining, enforce environmental regulations, and promote inclusive decision-making that actively involves community members.
3. The establishment of district-level ecological restoration. The study identified extensive land degradation and abandoned mining pits that pose a direct threat to community safety and agricultural productivity. Instead of imposing prison sentences on offenders, the community should create a reclamation initiative that allows these individuals to participate in the restoration process as a form of restitution for their actions.
4. Targeted alternative livelihood diversification must be socially acceptable and economically competitive with the high returns of mining. Value addition agriculture that focuses on subsidized inputs for high-value agribusiness and local processing centres must be prioritized. This increases the financial capital available to farming, enabling it to compete with mining. Given the low formal literacy rates in these mining communities, e.g. 28% in Kortwia-Abodom (based on this study), technical and vocational training that allows youth to transition into formal technical roles within the wider mining sector is recommended.
5. Incentivized education programs, including scholarship programs specifically for children in mining enclaves, would reduce the economic pressure on families that leads to school dropouts.
6. Finally, establishing platforms for knowledge exchange across policymakers, researchers, and local stakeholders can facilitate adaptive management by continuously integrating new evidence and community feedback into policy adjustments.

This multi-tiered, context-sensitive approach holds promise for disrupting the reinforcing cycles of degradation and socio-economic vulnerability uncovered in our study, promoting pathways toward more sustainable and resilient governance of galamsey in Ghana.

While transitioning to decentralized licensing and community reclamation offers a sustainable regulatory path, implementing these strategies involves complex structural challenges. First, institutional resistance from centralized state bodies may slow down the transfer of licensing authority to the district level. Second, community-led restorations are highly vulnerable to elite capture, where local traditional leaders or

influential opinion leaders might misappropriate funds or equipment meant for ecological restoration. Finally, underfunding local assemblies face severe capacity shortages that hinder continuous environmental monitoring. Overcoming these barriers requires strict oversight mechanisms, transparent local audits, and legally binding revenue-sharing frameworks that incentivize local compliance while minimizing institutional corruption.

5 Limitations and directions for future research

While this study advances understanding of the socio-economic and environmental dynamics of galamsey in Ghana, several limitations warrant consideration. The key informant interviews offer valuable insights, yet the illicit nature of galamsey may introduce social desirability and reporting biases, potentially affecting data reliability. Future research should prioritize the development of longitudinal socio-ecological monitoring frameworks to systematically capture both immediate and long-term impacts of galamsey. Integrating participatory mapping and ethnographic methods would yield richer qualitative insights into local perceptions, cultural influences, and informal governance mechanisms shaping mining activities.

Evaluative studies examining the implementation and efficacy of policy interventions are essential for identifying best practices and refining strategies across diverse contexts. Comparative research in other West African countries confronting similar illegal mining challenges would enable assessment of the robustness and applicability of the socio-ecological resilience framework proposed here. Such cross-national studies would strengthen regional knowledge and facilitate more collaborative governance approaches to address illegal mining.

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Author contributions
M.A.B., J.A.A. conceptualized this study, designed and led the overall methodology. J.A.A and D.K.A. were responsible for material preparation, field data collection, drafting the initial manuscript and editing. I.O., K.K., and O.B analyzed the data and interpreted the results. M.A.B., supervised the research. All authors contributed to the reviewing, editing, and improving the final version of the manuscript.

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Data availability
All data analyzed during this research are available upon request.

Declarations

Ethics approval and consent to participate
The protocol was approved by the Ethics Committee of Institut Pertanian Bogor, (IPB University), Indonesia (Ref. 13481/IT3/RT.01.01/M/B/2024), in accordance with institutional guidelines and the principles of the Declaration of Helsinki. All participants, including key informants, supervisors, enumerators and survey households provided informed consent before participating in the questionnaire and the interviews. They were briefed on the study objectives, joined voluntarily, and were assured that their identities and responses would be kept confidential and anonymous.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interest.

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