



Deutscher Akademischer Austauschdienst
German Academic Exchange Service

BOOK OF ABSTRACTS

**DAAD ALUMNI EVENT - FIRST CONFERENCE
ON MINERAL MINING IN GHANA AND
PHYTOREMEDIATION**

JUNE 15 – 18, 2025

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ADJEI BOAKYE



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SUB-THEME 1: POTENTIALLY TOXIC ELEMENTS IN MINE SOILS AND HUMAN HEALTH/ENVIRONMENTAL RISK ASSESSMENT/BIOAVAILABILITY OF HEAVY METALS IN SOILS

I. Tackling Complexity: Integrating Social-Ecological Sustainability in Ghana's E-waste Management Landscape

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Abstract

This chapter examines the relationship between interventions and social-ecological sustainability in Ghana's ewaste sector. We analyse how intervention frameworks influence e-waste practices within the context of socioecological sustainability. Our objectives include clarifying the effects of these frameworks on the socio-ecological aspects of e-waste management, evaluating their effectiveness in encouraging sustainable practices, and identifying gaps and challenges in integration. We used a qualitative research approach to conduct in-depth interviews with 21 key industry leaders. The findings suggest that thorough regulatory frameworks are present, including the Hazardous and Electronic Waste Control and Management Act of 2016 (Act 917) and a technical guideline - legislative instrument (LI2250). However, effective enforcement and institutional diligence are crucial for their success. Collaborative initiatives among government agencies, international partners, NGOs, and the private sector are essential for sustainable e-waste management programs, including Integrated Public-Private Partnerships (PPPs) to formalise e-waste activities and improve recycling efforts. Policy integration, stakeholder involvement, and bilateral collaborations shape agenda-setting processes, showcasing a multifaceted strategy towards e-waste management. Despite significant progress, we face ongoing challenges such as the absence of a comprehensive policy framework, limited stakeholder participation, fragmented networks, high capital demands, unfair market conditions, foreign competition, and inadequate funding for e-waste management infrastructure. To tackle these issues, this chapter proposes future intervention strategies for sustainable e-waste management, highlighting the importance of responsible production, consumption, and recycling, collaborative stakeholder efforts, integration of the e-waste value chain, and the promotion of circular economy principles. These strategies provide a pathway for improving e-waste management practices in Ghana, contributing to a cleaner, more sustainable environment in the future.

Keywords: Circular economy, E-waste management, Intervention strategies, Regulatory frameworks, Sustainability, Ghana

2. From Rice Fields to Gold Pits: A Shift from Agrarian Livelihoods to Galamsey in the Nobewam Farming Community of Ghana

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Extended Abstract

I. Introduction

The farming industry continues to be the pillar of Ghana's socio-economic development, being one of the main livelihood sources for rural people and an essential supplement to the provision of national food security. Rice production has emerged as an increasingly strategic crop in the provision of increasing demand for food throughout the nation and the reduction of reliance on imports. In the last two decades, state-run projects such as the Rice Sector Support Project (RSSP), the Planting for Food and Jobs (PFJ), and the Ghana National Rice Development Strategy (GNRDS) have sought to enhance local rice production and farmer rehabilitation (MOFA, 2009; FAO, 2023). But the increased incidence of illegal artisanal and small-scale gold mining (ASGM), otherwise known as galamsey, is undermining these achievements.

Though ASGM has brought instant prosperity to economically disadvantaged rural groups, its artisanal status has resulted in extensive environmental degradation, land-use conflict, and elimination of sustainable agricultural systems (Kazapoe et al., 2023). Nobewam, a peri-urban agricultural settlement within the Ashanti Region, is a case in point. Now a region formerly a model of agrarian prosperity, with irrigated rice farming and the adoption of innovations like the System of Rice Intensification (SRI), Nobewam must now deal with large-scale invasion by illicit mining.

The shift from agriculture to mining in Nobewam is a symptom of a greater development paradox. Although mining has its short-term economic benefits in the areas of poverty and unemployment, it reaps long-term socioecological vulnerabilities like deforestation and land degradation, water contamination, and involuntary displacement of agricultural workers (Assan et al., 2018; Ofori et al., 2020). More specifically alarming is the toxic heavy metal, mercury, and arsenic contaminants in the Nobewam River that have been proven to both

undermine human health as well as agricultural productivity (Mishra et al., 2019). This change has triggered critical livelihood disruptions.

Many young people and adult farmers are exiting agriculture, not only due to the gold lure but also due to declining productivity on rice farming amid a decline in the quality of land, polluted water sources, and uncertain tenure rights (Bissah et al., 2022). These processes have entrenched food insecurity and strained community cohesion and public health systems. The impacts extend beyond the regional frontiers. Ghana's rice import bill of over \$ 450 million annually captures the country's price of idle domestic capacity (Angelucci et al., 2013). Moreover, the Nobewam case encounters direct threats to the achievement of Sustainable Development Goals (SDGs), namely SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 15 (Life on Land). It violates the vision of the African Union's Comprehensive Africa Agriculture Development Programme (CAADP) 2026–2035 Action Plan (CAADP Strategy and Action Plan, 2025). This essay examines the scale-up and implications of the transition from rice farming to illicit mining in Nobewam. Using a mixed-method study design, it investigates land degradation, farmer displacement, environmental contamination, and food system push factors of this transition. By adopting policy institutions' local contexts, stakeholders, and narratives, the study aims to contribute to sustainable land use, rural development, and food system resilience among agricultural communities impacted by mining.

2. Materials and Methods

2.1 Study Area

The study was conducted in Nobewam, a peri-urban farming community located in Ejisu Municipality, Ashanti Region, Ghana. Nobewam's geographic location is at 6.6502° N latitude and -1.4423° W longitude. The area falls within the semi-deciduous forest agroecological zone, characterised by moderate rainfall, fertile soils, and a formerly congenial environment for rice production, particularly under both irrigated and rainfed systems. Nobewam has been incentivized for the use of sustainable agricultural practices, including the System of Rice Intensification (SRI), encouraged by public-private research activities. Farm surveys were conducted in April 2025, during the primary rice cropping season when land preparation was underway. This enabled scientists to determine the extent of land degradation and the status of farm activities before sowing.

2.2 Research Design

The study relied on a mixed-methods approach, utilizing both quantitative and qualitative approaches in analyzing the socio-ecological impacts of illegal artisanal and small-scale gold mining (ASGM) on rice cultivation. a. Field Mapping and Observations

Field observation was conducted to identify and record signs of mining encroachment, such as open pits, soil erosion, tailings, and vegetation loss. A Global Positioning System (GPS) receiver was used to map the perimeter of agricultural land affected by mining. Spatial coordinates were processed and mapped using QGIS software to infer land use patterns and trends over time.

b. Participatory Rural Appraisal (PRA)

Participatory methods, including community mapping, timeline analysis, and problem ranking, were employed with opinion leaders and local farmers. Three PRA sessions involving 15–20 participants were conducted. These sessions established a historical background on land conversion and the community's perceptions of the effects of mining.

c. Household Surveys and Key Informant Interviews

Systematically constructed questionnaires were administered to a sample of 120 rice farmers in Nobewam, these included 70 currently farming rice and 50 displaced or affected by mining. Additional key informant interviews were conducted with traditional leaders, agricultural extension staff, and district-level policymakers to triangulate the evidence.

2.3 Data Analysis

Quantitative data were analyzed using descriptive statistics in Microsoft Excel and SPSS. Variables assessed included land area (in hectares), the number of affected and active farmers, and land-use changes resulting from mining activities. Field data on total agricultural Land, Land degraded or occupied by mining, active rice production land, total rice farmers in the community, farmers affected or displaced by mining, and farmers still active in rice production were collected with the help of an Unmanned Area Vehicle mounted with an RGB camera and on the ground measurements and interviews. These data were visualized through bar charts, as presented in Figures 1 and 2 (see Results section). Qualitative data were transcribed and coded thematically using NVivo software. Emerging themes included: “loss of land rights,” “youth migration,” “ecological risk,” and “institutional neglect.”

3. Results

Out of 140 hectares (350 acres) of total farmland, 80 hectares (200 acres) have been destroyed by illegal gold mining, and only 60 hectares (150 acres) remain under active rice production. This is a 57.1% loss of productive land (Figure 1A). The community previously had 120 registered rice farmers, but currently only 70 are active, while 50 have been displaced (Figure 1B).

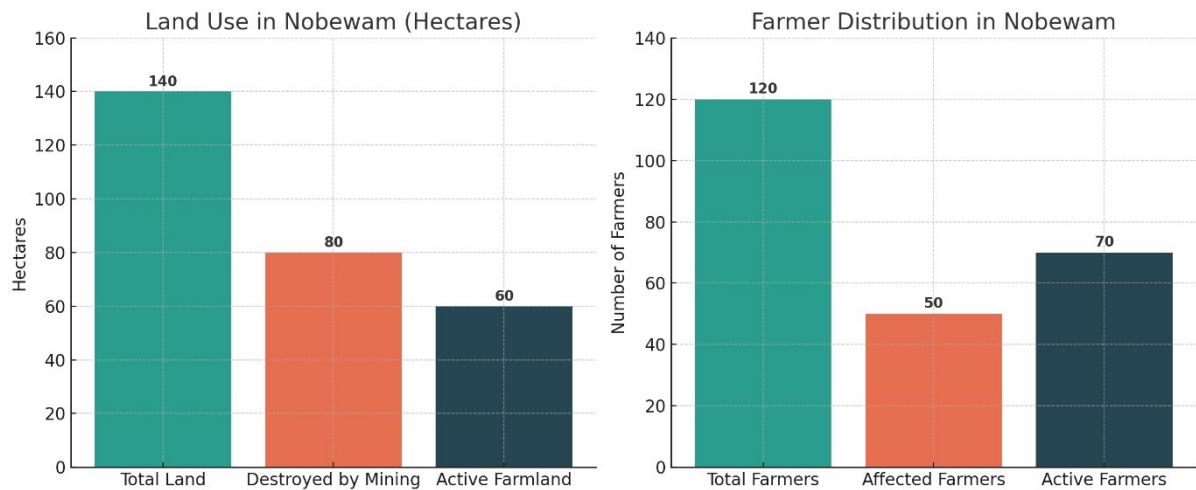


Figure 1 shows the distribution of land use among productive, degraded, and total Land. (Hectares, A) Moreover, the depiction of the categorization of farmers based on displacement and continued activity (B).

Each chart reflects the proportional shifts in land use and labour allocation, indicating that 57.1% of arable land has been lost to illegal mining and 41.7% of the farming population has been directly affected. These statistics support the narrative of agricultural decline and rural transformation in Nobewam.



Figure 2: On-the-ground photos near the Nobewam River where rice used to be and has now turned into a Galamsey site.

Figure 2 shows the destruction of land at Nobewam River and its environs. The river, which had previously served as a drinking water source, appears milky, indicating high turbidity and chemical residue contamination resulting from mining activities in the area.

4. Discussion

The findings in Nobewam provide a clear microcosm of the broader challenge between agriculture and informal extractive economies in sub-Saharan Africa. The extensive conversion of productive rice land to mining zones was proven to be over 57% in this study. This shows a rise in land-use crisis driven by the overexploitation of illegal artisanal and small-scale gold mining (ASGM). This transformation is not only spatial, but also structural, representing a profound reorganization of rural economies and socio-ecological systems.

4.1 Land Alienation and Agrarian Crisis

The loss of land is a central part of the agrarian distress in Nobewam. The use of 80 hectares of productive land for mining results in the physical displacement of farmers and a decline in agricultural productivity, ultimately leading to increased food insecurity. This corroborates the findings of Tschakert (2009) and Banchirigah (2008), who show how ASGM in Ghana displaces traditional land users and undermines food production systems. In Nobewam, displaced farmers have no recourse to the law because customary tenure systems are not favourable to protecting agricultural fields from mining encroachments, especially if state governments do not offer protection (Issahaka Fuseini, 2016).

4.2 Environmental and Health Externalities

The destruction of the Nobewam River indicates the heavy environmental cost of unscrupulous mining. Aquatic pollution by mercury and arsenic threatens aquatic life, reduces irrigation potential, and directly jeopardizes human health. Donkor et al. (2006) and Obiri et al. (2010) have reported similar pollution patterns in other mined communities in Ghana, as the bioaccumulation of heavy metals compromises water and soil quality. The routes of exposure through drinking water, crops, and fish are well-established and result in long-term health conditions, such as neurological diseases, kidney injuries, and reproductive challenges (UNEP, 2019).

4.3 Socioeconomic Disruption and Youth Migration

The most significant socioeconomic impact is the diversion of labour away from farming to mining, largely impacting the youth. This labour diversion is attributed to the realized immediacy and profitability of gold mining even though it is conducted in exploitative and precarious terms (Maconachie & Binns, 2007). In Nobewam, this innovation breaks generational farming continuity, depletes long-term farming skill, and increases household dependence on informal economies. The decline of farming cooperatives and innovation platforms, such as the promotion of the System of Rice Intensification (SRI), contributes to rural vulnerability.

4.4 Food Insecurity and Policy Contradictions

The displacement of rice farmers and destruction of irrigation facilities pose a challenge to local food production, leading to a decline in rural food security. This conflicts with Ghana's stated goal for self-sufficiency in rice, as outlined in the National Rice Development Strategy (MOFA, 2020). It also suggests an incongruence between extractive governance and agricultural development. While policies such as the Minerals and Mining Act (2006) provide regulatory frameworks, enforcement remains weak, and rural voices are often overlooked in decisionmaking processes (Yaro et al., 2016). The net effect is a policy incoherence favouring short-term mineral extraction over long-term agrarian sustainability.

4.5 Implications for Sustainable Development

The challenges observed in Nobewam illustrate critical reverses that threaten Ghana's progress towards achieving some of the Sustainable Development Goals (SDGs), with implications that extend beyond the local population. Specifically, degradation of lands that can be utilized for food production through unregulated mining poses SDG 2 (Zero Hunger) directly, as food security and agricultural yields are both imperiled. Mercury exposure and water pollution are unhealthy, hindering progress towards SDG 3 (Good Health and Well-being). Furthermore, extensive deforestation and the loss of natural habitats through open-pit mining threaten SDG 15 (Life on Land), which aims to conserve, restore, and sustainably use terrestrial ecosystems. Scholars such as Veit and Maingi (2017) emphasize that for such resource-rich countries as Ghana to attain sustainable development, there must be a concerted effort in integrated land-use planning, protection of community rights, and establishment of effective institutional mechanisms for environmental accountability and equitable governance of resources.

Conclusion

Nobewam's transformation from rice fields to gold pits highlights a clash between short-term extractive gains and long-term agrarian sustainability. The unchecked expansion of illegal mining has displaced farmers, degraded ecosystems, and weakened food security and public health.

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3. Impact of Biochar, Compost, and NPK on Metal Uptake, Soil Quality, and Lettuce Biomass in Mine Tailings

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1.0 Introduction

The gold industry is among the most essential sectors worldwide. In Ghana, it employs a lot of people, particularly the youth, and acts as a significant source of livelihood for multiple communities. Nonetheless, gold mining activities produce substantial waste, including mine tailings, which are sometimes poorly managed. Gold mine tailings are waste materials generated after ore processing, often characterized by poor soil fertility, low organic matter, and elevated concentrations of potentially toxic elements (PTEs) such as arsenic, cadmium, and titanium (Edraki et al., 2014; Wang et al., 2018; Mensah et al., 2020). After mining operations, these sites are left abandoned. These abandoned sites pose significant environmental and health risks due to PTE mobility and contamination of nearby ecosystems (Mensah et al., 2021). Due to land scarcity in these areas, local communities convert such degraded lands into farmlands (Armah et al., 2014).

Establishing crops on mine tailings is challenging due to harsh soil conditions (Fellet et al., 2011), yet agriculture remains a key post-mining land use option (Mborah et al., 2016). Previous studies have shown that soil amendments such as biochar, compost, and inorganic fertilisers can improve soil quality and reduce contaminant uptake in crops (Mensah et al., 2022b; Alhar et al., 2021). However, using abandoned mine sites for lettuce production and their food chain contamination is debatable in the context of food safety, and that the soil chemical processes influencing soil-plant metal uptake remain unexplored.

This study evaluates the potential of rice husk biochar, poultry litter, and NPK fertiliser, applied alone or in combination, to enhance soil quality, improve lettuce yield, and limit PTE uptake in gold mine tailings from southwestern Ghana. The findings aim to guide safe food production and sustainable land reclamation in mining-impacted areas.

2.0 Materials and methods

2.1 Study area, site characterization and sample preparation

The gold mine tailing samples were collected from Akaporiso-Obuasi in the Ashanti Region of Ghana (6°11'10.29" N, 1°37'13.13" W), an area abandoned for the past 20–30 years. The region has a bimodal rainfall pattern, with annual rainfall between 1250 mm and 1750 mm. Relative humidity ranges from 75% to 85% during the rainy season. The site covers approximately 38 acres and is surrounded by farming communities, where many local farmers, small-scale miners grow vegetables such as carrots, cabbage, lettuce, tomatoes, and okra, along with staple crops like cassava and plantain. Tailing samples were collected randomly from the top 20 cm using a stainless-steel scoop, following the method of Samsuri et al. (2021). Composite samples were formed, air-dried,

homogenised, ground, and passed through a 2 mm sieve. The prepared samples were then stored in plastic bags for laboratory analysis.

2.2 Soil amendments characterization

Three soil amendments were used in this study: rice husk biochar (BC), poultry litter compost (C), and NPK fertiliser (90:80:80). The biochar was produced from rice husks sourced from a local rice mill in Ghana and pyrolysed at 550 °C for one hour using a muffle furnace. After air-drying for 48 hours, it was crushed, homogenised, and sieved through a 2 mm mesh. Their pH, organic carbon, total nitrogen, phosphorus, potassium, calcium, and magnesium contents were analysed. Additionally, PTEs' content in the selected amendments was determined.

2.3 Experimental design, treatments, and pot experiment

A greenhouse pot experiment was conducted to evaluate the effects of organic and inorganic amendments on the suitability of gold mine tailings for lettuce production. The experiment used a completely randomised design (CRD) with eight treatments and three replicates (ie. 7Tx3Rx 1 plant per pot). The treatments were as follows:

i) Unaltered dry tailings = control (ii) 5 t ha⁻¹ biochar = BC (iii) 90 kg N-80 kg P₂O₅-80 kg K₂O = NPK (iv) 2.5 t ha⁻¹ biochar + 45 kg N-40 kg P₂O₅-40 kg K₂O = BNPK (v) 5 t ha⁻¹ compost = C (vi) 2.5 t ha⁻¹ compost + 45 kg N-40 kg P₂O₅-40 kg K₂O = CNPK (vii) 2.5 t ha⁻¹ biochar + 2.5 t ha⁻¹ compost = BC (viii) 2.5 t ha⁻¹ biochar + 2.5 t ha⁻¹ compost + 45 kg N-40 kg P₂O₅-40 kg K₂O = BCCNPK.

2.4 Chemical Analyses and Extraction of Nutrients and Potentially Toxic Elements

Soil pH and EC were measured using a glass electrode pH meter (1:2.5 soil-water) and a Thermo Scientific EC electrode, respectively. Organic carbon was determined using the modified Walkley-Black method; total nitrogen by the Kjeldahl method; and available phosphorus using Bray-I extraction. Exchangeable bases (Ca, Mg, K, Na) were extracted with 1.0 M NH₄OAc. Particle size distribution was analyzed using the hydrometer method. Selected trace metals (As, Cd, Cr, Hg, Pb) in soil were measured by AAS after ammonium acetate + EDTA extraction. For plant analysis, harvested lettuce biomass was washed, oven-dried at 70 °C, ground, and sieved. A 0.5 g subsample was dry-ashed at 500 °C, digested in H₂O:HNO₃ (2:1), and analyzed for trace metals using Atomic Absorption Spectrometry (Agilent 200 Series A.A.).

2.5 Determination of lettuce biomass yield, metal, and nutrient uptake

After 42 days, the harvested plants were weighed to determine their fresh weight, then oven-dried at 70 °C for 48 hours to achieve a constant weight. Total dry matter was obtained by the difference between the fresh weight and oven-dry weight in grams per pot. The total nutrient uptake in the dry matter of lettuce was obtained by

multiplying the dry matter yields (kilograms) by the plant concentration (in mg kg⁻¹) of N, P, K, Ca, and Mg, as well as those for the PTEs (As, Cd, Pb, Cr, and Hg) as used by others (Antoniadis 2017, 2021; Mensah et al., 2022c). For metal uptake in mg element kg⁻¹ soil, we divided total metal plant uptake (in mg kg⁻¹) by the total soil weight (kg) in the pot.

2.6 Quality control and statistical analyses

All data were checked for normality and homogeneity. Quality control of PTE was ensured using certified reference soils (BRM No. 13 and BRM No. 10a) from the German BAM Institute, with recovery rates: As= 81%, Cd=112%, Cr=97%, Pb=97%, Hg=88%. Analyses included blanks, triplicates, and standard solutions. Detection limits were; As= 0.03 g L⁻¹, Cd=0.002 g L⁻¹, Cr= 0.006 g L⁻¹, Pb= Hg= 0.01 g L⁻¹. Treatment means were compared using ANOVA and Tukey's test ($p < 0.05$) in OriginPro 2021b. Pearson correlations were also performed to explore relationships between soil properties, plant uptake, and soil quality.

3.0 Results and Discussion

3.1 Soil physicochemical properties and amendments characterization

The soil was predominantly sandy (75.8% sand, 15.5% silt, 8.8% clay. It was slightly alkaline (pH 7.2) with moderate EC (372.5 $\mu\text{S cm}^{-1}$), low organic matter (1.4%), total nitrogen (0.1%), and available phosphorus (15.5 mg kg⁻¹). Exchangeable K, Mg, and Ca were 0.07, 2.5, and 4.8 mg kg⁻¹, respectively. Heavy metals included Cu (19.4 mg kg⁻¹), Fe (811 mg kg⁻¹), and Mn (194 mg kg⁻¹), with PTEs (As, Cd, Pb, Cr, Hg) below critical thresholds. Biochar and compost were both alkaline (pH 8.9 and 9.1, respectively). Compost had higher organic carbon (14.4%) and total N (1.0%) than biochar (8.0% C, 0.6% N). K content was 0.21% in biochar and 0.8% in compost. All PTE levels were below thresholds except Cd (3.7 mg kg⁻¹ in biochar, 3.5 mg kg⁻¹ in compost). The NPK fertilizer contained 15% each of N, P, and K, with pH 7.5–8 and no detectable heavy metals.

3.2 Impacts of biochar, compost and NPK fertilizer on the soil quality

3.2.1 pH and electrical conductivity

The incorporation of biochar and compost significantly increased soil pH in comparison to the control (Fig. 1). After 42 days, the pH varied from 6.8 (control) to 7.8 (BCC), indicating a 14% rise in BCC compared to the control. Treatments involving BC, NPK, BCNPK, C, CNPK, and BCCNPK significantly ($P < 0.05$) elevated soil pH. This increase is attributed to the alkaline properties and liming impact of biochar and compost, which can ameliorate soil acidity by substituting acidic cations (H^+ , Al^{3+}). Electrical conductivity (EC) varied between 291.1 and 458.1 $\mu\text{S cm}^{-1}$. Electrical conductivity (EC) considerably improved ($p < 0.05$) in C, BCNPK, and CNPK

treatments, to a maximum of $458.1 \mu\text{S cm}^{-1}$. Treatments with NPK, BCCNPK, BCC, and BC decreased EC, with the minimum value ($291.07 \mu\text{S cm}^{-1}$) observed in BC. These alterations in EC may affect nutrient availability and the movement of potentially toxic elements as elaborated in Sections 3.5.

3.2.2 Organic matter, nitrogen, and available P

After 42 days, the highest organic matter (OM) content (1.39%) was observed in PLC, a 27% increase over the control (1.09%). This was followed by RPNPK (1.37%), RPLC (1.35%), PNPk (1.34%), RNPK (1.31%), and NPK100 (1.30%). RHB5 had 1.2%. The increase in OM is attributed to the high organic carbon content of compost (14.4%) and biochar (8.0%) used. Mine tailings typically have low OM due to limited microbial activity and vegetation (Mensah, 2015), but additions of compost and biochar can enhance OM, support revegetation, and improve soil quality. NPK significantly increased total nitrogen by 14.3% compared to the control ($p < 0.05$), likely due to its high N content. This highlights the potential of mineral fertilizers in improving N-deficient mine tailings, aligning with findings from Sheoran et al. (2010). Alternatively, nitrogen-fixing plants could also help restore N levels (Zhang et al., 2001). Available P increased significantly across all treatments, with BCCNPK showing the highest value (27.0 mg kg^{-1}) compared to 11.4 mg kg^{-1} in the control. This may result from P sorption or co-precipitation on amendment surfaces rich in Ca^{2+} , K^+ , Mg^{2+} , and Na^+ , becoming available at higher pH or with increased OM. Correlation analysis revealed strong positive relationships between pH and P ($r = +0.92$, $p < 0.05$, Fig. 4), and OM and P ($r = +0.8$, $p < 0.01$, Fig. 4), suggesting that pH and OM shifts enhance P availability via desorption, deprotonation, or microbial activity (Mensah et al., 2022c).

3.3 Impacts of biochar, compost and NPK fertilizer on the soil potentially toxic elements contents (As, Cd, Cr, Hg, Pb) in the abandoned mine tailings

Amendments had a significant impact on the concentrations of potentially toxic elements (PTEs) in the mine tailings Fig. 2. Arsenic (As) concentrations varied between 0.07 and 0.24 mg kg^{-1} , with the highest levels observed in the RPNPK treatment. All As values were significantly lower than the global threshold of 6.83 mg kg^{-1} for uncontaminated soils (Kabata-Pendias, 2011), suggesting a minimal environmental risk. Lead (Pb) concentrations were elevated in all treatments relative to the control, with RPLC exhibiting the highest concentration at 7.37 mg kg^{-1} , representing a 63% increase compared to the control. All values, however, remained below the safety threshold of 67 mg kg^{-1} . Mercury (Hg) concentrations varied between 1.3 and 1.8 mg kg^{-1} , with the maximum observed in RNPK, indicating a 35% increase compared to the control group. Although there was a decrease in mercury levels from the original tailings (3.5 mg kg^{-1}), the concentrations remained above the global soil average of 0.5 mg kg^{-1} (Kabata-Pendias, 2011), indicating persistent contamination likely attributable to historical artisanal gold mining activities.

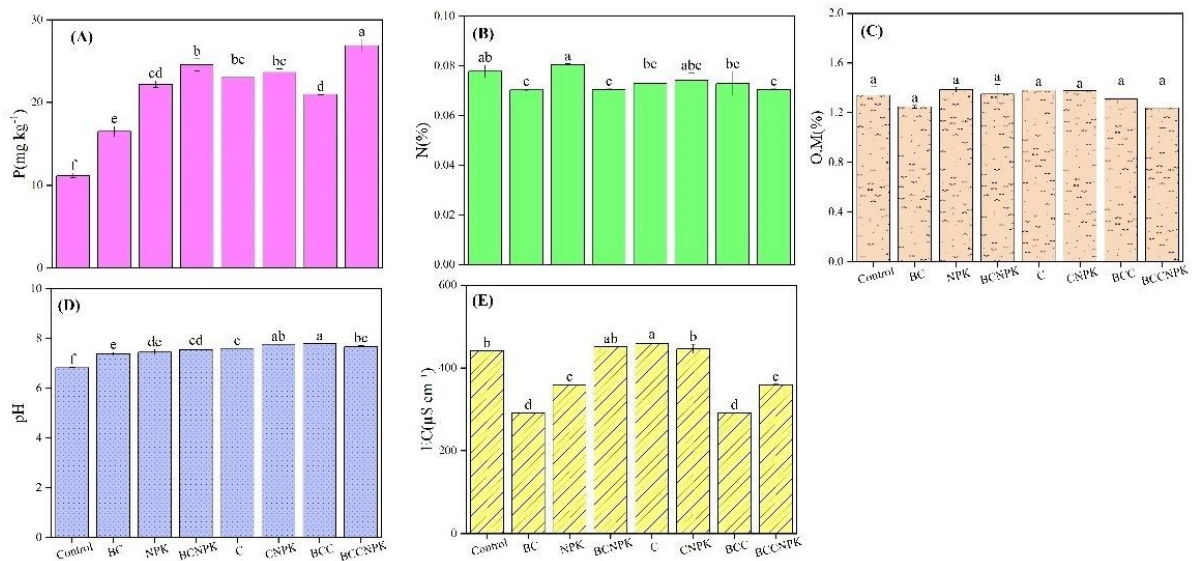


Fig. 1: Impact of soil amendments on the changes in pH, EC, %O.M, nitrogen, and phosphorus in gold mine tailings compared to the control. Changes in pH, EC, % O.M, nitrogen, and phosphorus in abandoned gold mine tailings after a 42-day trial period following treatments with rice husk biochar, poultry litter compost and chemical fertilizer. Control =un-amended; BC= biochar; NPK = NPK fertilizer; BCNPK: 1/2 biochar + 1/2 NPK; C= compost; CNPK= 1/2 compost + 1/2 NP K; BCC= 1/2 biochar + 1/2 compost, BCCNPK: 1/2 biochar + 1/2 compost + 1/2 NPK. Charts represent means of three replicates and error bars represent their standard deviations. Means with different letters differ significantly among treatments at $P < 0.05$ and the same letters indicate no significant differences among means according to Tukey's Honestly Significant Different test.

Following the application of amendments, Hg levels decreased; however, the treatments involving biochar and compost, particularly BCNPK, likely affected Hg retention through their liming effects and enhanced cation exchange capacity (CEC), notably attributed to increased Ca and Mg concentrations. A notable positive correlation exists between CEC and Hg ($r = +0.6$; $P < 0.01$, Fig. 4), which substantiates this inference. The findings are consistent with prior research (e.g., Kelly et al., 2014; Beesley et al., 2011), suggesting that amendments enhance soil fertility but may influence PTE dynamics variably based on their composition and interactions with soil properties.

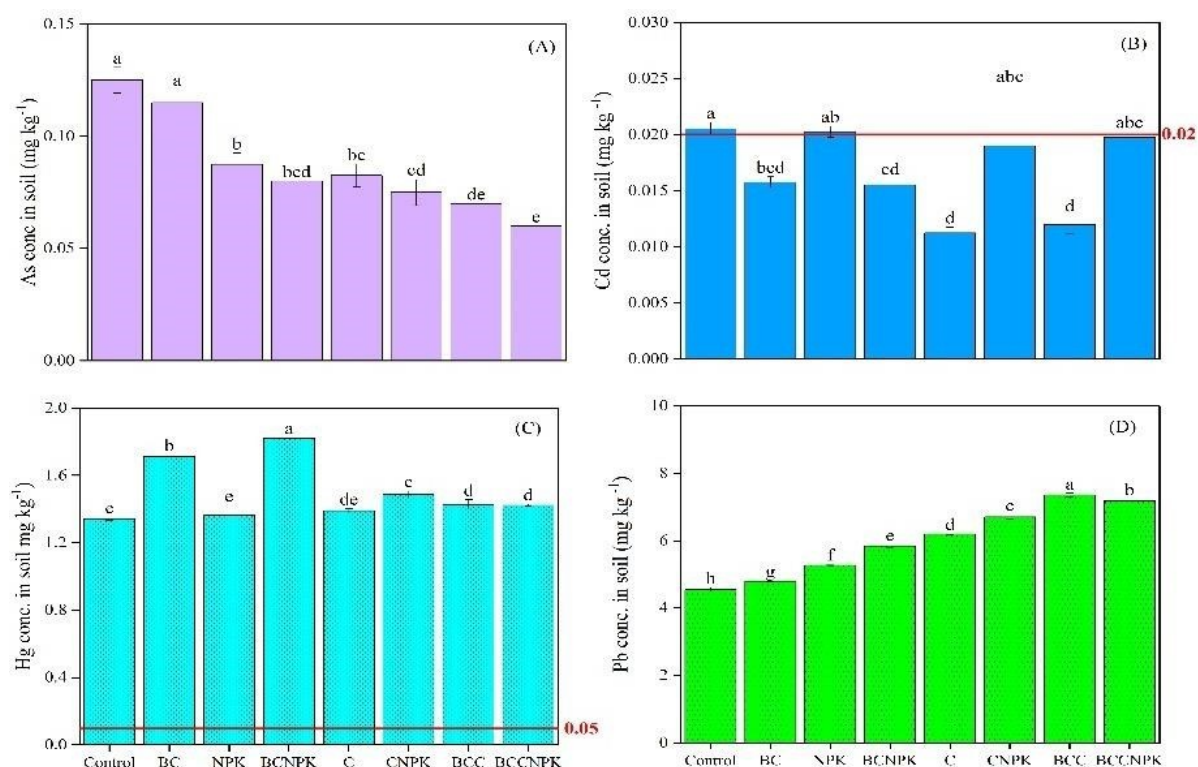


Fig. 2: Impacts of soil amendments on selected potentially toxic elements concentration in the tailings after harvest. Control =un-amended; BC= biochar; NPK = NPK fertilizer; BNPK: 1/2 biochar + 1/2 NPK; C= compost; CNPK= ½ compost + 1/2 NP K; BCC= 1/2 biochar + 1/2 compost BCCNPK: 1/2 biochar + 1/2 compost + 1/2 NPK. Charts represent means of three replicates and error bars represent their standard deviations. Means with different letters differ significantly among treatments at $P < 0.05$ and the same letters indicate no significant differences among means according to Tukey's Honestly Significant Different test.

3.4 Impacts of biochar, compost and NPK fertilizer on dry matter of lettuce

The highest dry matter (5.0 g) was found in RNPK amended mine tailing, and it was followed by the PNPK (4.8 g). The lowest total dry matter (3.0 g) was observed in the control (Fig. 3). The RNPK increased the growth of dry biomass by six-folds. Conductive and buffered pH of the amended mine tailing, its high CEC, its increased capacity to store nutrients from the soil amendments, and from the inorganic chemical NPK fertilizer, and improved soil physico-chemical properties due to modifications from the addition of the rice husk biochar and poultry litter may be additional responsible for the greater dry biomass in the BCNPK and CNPK treated mine tailings (Shaheen et al., 2017). For example, results from the correlation matrices (Fig. 4) indicated a significant positive relationship between pH and dry matter biomass ($r = +0.7$; $p < 0.01$); thus, increased pH may lead to modification in the soil chemical properties such as the exchangeable cations, and consequently make nutrients available for the plant use.

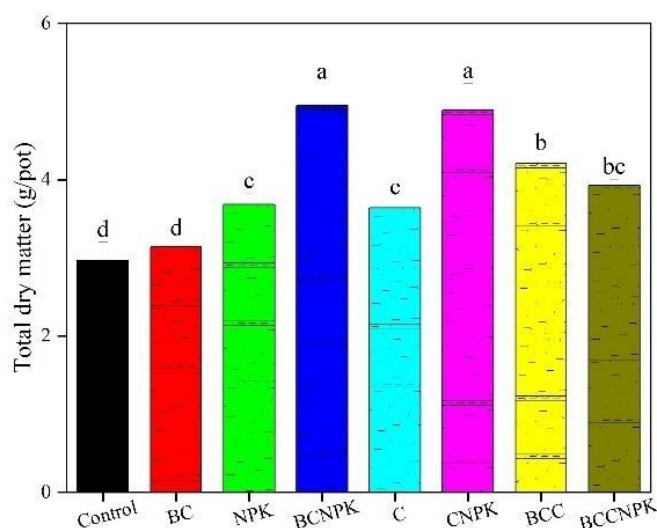


Fig.3: Impact of soil amendments on total dry matter biomass of *Lactuca sativa* L. Control =un-amended; BC= biochar; NPK = NPK fertilizer; BCNPK: 1/2 biochar + 1/2 NPK; C= compost; CNPK= 1/2 compost + 1/2 NPK; BCC= 1/2 biochar + 1/2 compost, BCCNPK: 1/2 biochar + 1/2 compost + 1/2 NPK. Charts represent means of three replicates and error bars represent their standard deviations. Means with different letters differ significantly among treatments at $p < 0.05$ and the same letters indicate no significant differences among means according to Tukey's Honestly Significant Different test.

3.5 Impacts of biochar, compost and NPK fertilizer on the uptake of Hg, Pb, As, Cd and Cr in lettuce

The application of biochar, compost, and NPK fertilizer significantly influenced the uptake of potentially toxic elements (PTEs) such as Hg, Pb, As, Cd, and Cr in lettuce grown on mine tailings Table I. Arsenic (As) uptake ranged from 0.08 to 0.21 mg As kg⁻¹ soil in pot. The BCNPK treatment had the highest As uptake, with a 40% increase over the control, followed by BCCNPK (0.17 mg kg⁻¹). The least As concentration was observed in the BC treatment (0.08 mg kg⁻¹). All As concentrations were below the 5 mg kg⁻¹ threshold suggested for food crops grown on uncontaminated soils (Antoniadis et al., 2021). This suggests that while some treatments increased As uptake, the levels remained within acceptable limits. Cd uptake ranged from 0.37 to 0.78 mg Cd kg⁻¹ soil in pot, with the highest concentration recorded in the BCC treatment, representing a 110% increase over the control. Although all treatments increased Cd uptake compared to the control, concentrations remained below the 5–10 mg kg⁻¹ threshold recommended for sensitive plants (Kabata-Pendias, 2011). The observed increases in Cd uptake correlated negatively with soil electrical conductivity (EC), ECEC, and exchangeable Mg and Ca (Fig. 4). Low EC conditions may reduce Cd sorption, increasing its mobility and plant availability. Additionally, decreased ECEC, often associated with soil acidification, enhances Cd solubility and uptake. Hg concentration ranged from 0.09 to 0.24 mg kg⁻¹, with the control treatment exhibiting the highest concentration. The BCCNPK amendment showed the greatest reduction in Hg uptake, decreasing concentrations by 62.5% compared to the control. Treatments like BC, CNPK, C, and NPK also reduced Hg uptake by 25%, 29%, 33%, and 37.5%, respectively. These reductions were attributed to increased soil pH, exchangeable potassium (K), and available phosphorus (P), which

exhibited significant negative correlations with Hg uptake (Fig. 4). Bradl (2004) explains that higher pH conditions can facilitate the formation of metal-hydroxo complexes, enhancing Hg adsorption onto soil particles and reducing bioavailability. Although all treatments reduced Hg uptake compared to the control, the levels in all lettuce samples still exceeded the 0.02 mg kg^{-1} limit recommended by UNEP (2002) and the 0.10 mg kg^{-1} threshold set by the European Commission (KEG, 2006), indicating potential health risks. Pb uptake in lettuce varied significantly across treatments, ranging from 0.41 to $1.01 \text{ mg Pb kg}^{-1}$ soil in pot. The lowest Pb concentration was observed in the BC treatment, while CNPK recorded the highest. Control and NPK treatments registered 0.68 and $0.66 \text{ mg Pb kg}^{-1}$, respectively. Although these concentrations were lower than the European Commission's maximum permissible threshold of 0.3 mg kg^{-1} (fresh weight) for plants, the variations were influenced by soil exchangeable calcium (Ca), magnesium (Mg), and effective cation exchange capacity (ECEC). Exchangeable Ca was positively correlated with Pb uptake, whereas Mg and ECEC showed negative correlations. According to Sparks (2003), acidic soil conditions, characterized by elevated H^+ and Al^{3+} concentrations, can increase Pb mobility by reducing its adsorption, thus enhancing plant uptake. Conversely, the reduction in Pb uptake in the BC treatment was likely due to biochar's sorption capacity and its ability to co-precipitate Pb, thereby lowering its availability in the soil.

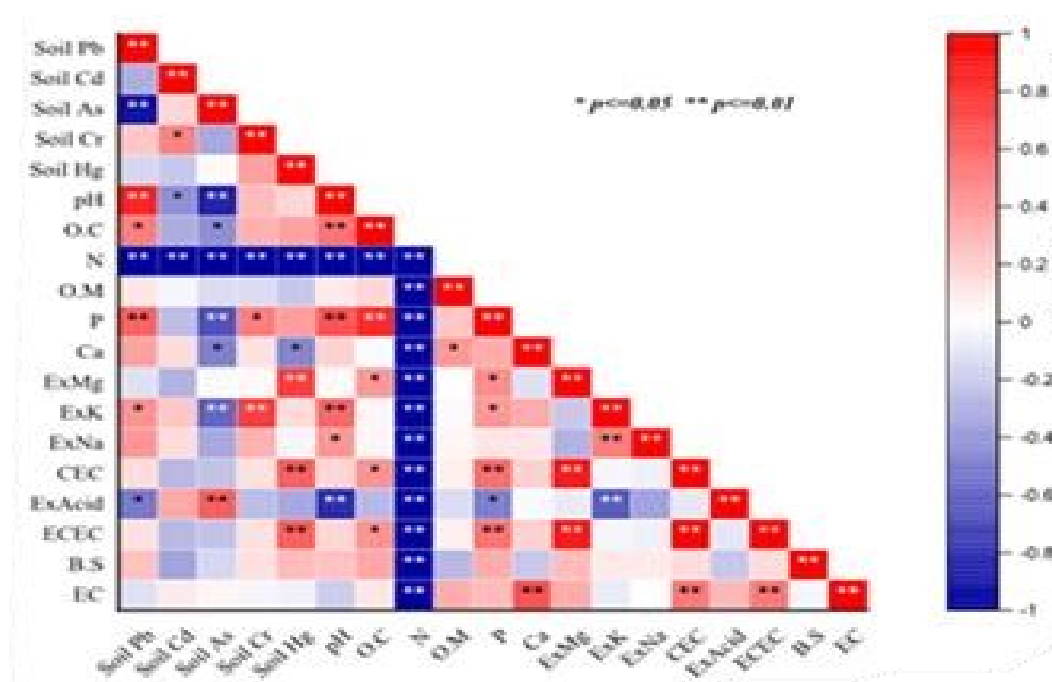


Fig. 4: Pearson correlation matrix between soil chemical properties and selected potentially toxic elements at the end of the trial. * indicates significant relationships at $p < 0.05$; ** indicates significant relationships at $p < 0.01$; OC = organic carbon; O.M = organic matter; N = nitrogen, P = phosphorus; Ca = calcium; EC = electrical conductivity; BS = base saturation; ExCa = exchangeable calcium; ExK = exchangeable potassium; ExMg = exchangeable magnesium; ExNa = exchangeable sodium; CEC = cation exchange capacity; ECEC = effective cation exchange capacity; ExAcid = exchangeable acidity; Soil Pb = Soil lead; Soil Cr = Soil chromium; Soil As = Soil Arsenic; Soil Cd = Soil Cadmium. Image Source (Addai et al. 2023)

Table 1: Total mean values and their associated percentage changes (%) (Inc/dec) in the contents of potentially toxic elements (Pb, Cd, As, Hg,) in lettuce at the end of the 42-day experimental period

PTE concentration in the lettuce (mg kg ⁻¹)								
Treatment	Pb	Inc/dec	Cd	Inc/dec	As	Inc/dec	Hg	Inc/dec
Control	0.23	-	0.12	-	0.05	-	0.24	-
BCC	0.13	-43.48	0.17	39.39	0.03	-46.67	0.18	-26.52
NPK	0.18	-21.74	0.11	-5.25	0.03	-33.33	0.15	-38.43
BNPK	0.13	-43.48	0.09	-24.24	0.04	-13.33	0.13	-45.08
C	0.16	-30.43	0.15	24.42	0.04	-26.67	0.16	-31.34
CNPK	0.21	-8.70	0.13	4.17	0.03	-33.33	0.17	-30.38
BCC	0.20	-13.04	0.18	52.78	0.03	-33.33	0.13	-46.91
BCCNPK	0.21	-8.70	0.14	19.44	0.04	-13.33	0.09	-62.08

Values represent mean of three replicates. Control =un-amended; BC= biochar; NPK = NPK fertilizer; BNPK: 1/2 biochar + 1/2 NPK; C= compost; CNPK= ½ compost + 1/2 NP K; BCC= 1/2 biochar + 1/2 Compost; BCCNPK: 1/2 biochar + 1/2 compost + 1/2 NPK. mg = milligram, kg = kilogram, % Inc/dec = percentage

increase/decrease. $\% \text{increase or decrease} = \frac{\text{Concentration in the treatment} - \text{concentration the control}}{\text{in the control}} \times 100$

4.0 Conclusion

This study revealed that applying biochar, compost, and NPK fertiliser either alone or in combination can improve the soil quality of abandoned gold mine tailings, enhance lettuce biomass, and influence uptake of PTEs. While soil Hg concentrations exceeded recommended thresholds, As, Cd, Cr, and Pb remained below critical limits. Soil amendments, particularly those involving biochar (e.g., BC, BCCNPK), significantly reduced the uptake of Hg, Pb, As, Cd, and Ni. These effects were mainly due to increased soil pH, nutrient availability (especially K and P),

organic matter, and improved cation exchange capacity (CEC). These factors promoted immobilisation or adsorption of PTEs, thereby reducing their bioavailability to plants. However, Hg concentrations in lettuce biomass (0.09–0.24 mg kg⁻¹) exceeded food safety limits, raising public health concerns. Pb uptake also surpassed the European Commission's threshold of 0.3 mg kg⁻¹, especially with CNPK treatments. Overall, combining rice husk biochar with NPK fertiliser appears most effective in reducing Hg uptake, supporting its potential for safer lettuce cultivation on mine-affected soils.

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4. Assessment of Soil System Changes Using Climate Smart Agricultural Practices on A Degraded Tropical Ultisol in Imo State, Southeastern Nigeria

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Abstract

Degradation of soils due to inappropriate agricultural practices is a significant issue, especially in the tropics. Climate smart agriculture approaches have the potential to reverse this degradation and promote sustainable agriculture. This study therefore assessed the effects of climate smart agriculture (CSA) practices on soil properties on a degraded ultisol in Owerri, Imo State, Southeastern Nigeria. The research was carried out in the teaching and research farm of Federal University of Technology Owerri. The experiment was laid out in a Randomized complete block design with different CSA management practices. The treatments were; A with no soil water conservation measure, 'B' with application of crop residue and farm yard manure and 'C' with application of crop residues, farm yard manure and intercropping with groundnut which is a legume. This was replicated four times. Soil samples from the study area were analyzed and post planting soil sampling was also done by collecting surface soil samples at a depth of 0 – 20cm. The samples were subjected to laboratory analyses to determine the soil physical and chemical properties and the data generated were analyzed statistically using ANOVA and significant means separated using Fischer's least significant difference. Soil system changes were rated using the rating scheme of Eze et al. (2022) as 1, 2 or 3 which represent increase, no change or decrease respectively. The results of the soil physiochemical properties showed that the soils were predominantly sandy in texture with moderate acid reactions. Sand particles occurred in high amounts with the range of 931g/kg - 956.8g/kg. There was no significant change in all the soil physical properties studied with the exception of moisture content. There was an increase in soil moisture content. The figures were 15.92 %, 18.59 % and 19.40 % for Treatments A, B and C respectively. There was a reduction in soil bulk density with figures of 1.46g/cm³, 1.44 g/cm³ and 1.43 g/cm³ and an increase in total porosity with figures of 44.82 %, 45.76 % and 46.14 % for Treatments A, B and C respectively. The results of the soil chemical properties revealed that there were significant increases in potassium, calcium, percentage base saturation and total nitrogen with the highest figures recorded from treatment C with figures of 0.84 Cmol/kg, 2.09 Cmol/kg, 94.33 % and 2.35 g/kg respectively. There was also increase in organic carbon and soil pH which were not significantly different at (P=0.05). The study revealed that there were significant changes in soil properties with climate smart agricultural practices. It is therefore recommended that climate smart agriculture practices such as intercropping, crop rotation, crop residue and manure application/mulching, conservation tillage etc. be used to improve soil health which will ultimately lead to agricultural sustainability and food security.

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5. A Review on Forest and Farmland Management in the Wake of Illegal Mining Activities in the Western Region of Ghana

Abraham Magsiah Adongo and Patrick Ateah Yeboah

Extended Abstract

Illegal small-scale gold mining, known locally as *galamsey*, has intensified in Ghana's Western Region, severely impacting forests, farmlands, and rural livelihoods. This review examines the environmental, socio-economic, and

institutional consequences of galamsey, with a focus on cocoa-producing and forest-rich zones. Through a mixedmethods approach—combining policy analysis, geospatial mapping, field surveys, and environmental sampling—the study shall evaluate land use changes, degradation patterns, and community responses. Expected outcomes of this paper shall focus on: a policy review report identifying strengths and weaknesses in the current regulatory framework, evaluating environmental impact on forest and farmland loss and a socio-economic analysis documenting community experience and identifying viable alternative livelihood strategies. The paper would eventually propose sustainable alternatives and policy recommendations to guide rehabilitation efforts and promote resilient livelihoods in mining-affected areas.

I. Introduction

Illegal small-scale gold mining, commonly referred to as galamsey, has escalated dramatically in Ghana, especially in the Western Region, where it poses significant threats to forest ecosystems and farmlands. This region plays a crucial role in Ghana's economy, being one of the country's main zones for cocoa cultivation and timber production (ISSER, 2022). The incursion of illegal mining into these landscapes endangers biodiversity, agricultural productivity, water resources, and ultimately, the livelihoods of rural communities. According to the Ghana Forestry Commission, over 4,700 hectares of forest have been destroyed by galamsey activities, while tens of thousands of acres of cocoa farms have either been degraded or completely destroyed (African Agribusiness Magazine, 2023).

The environmental degradation from mining includes deforestation, water pollution, and soil erosion. Contaminants like mercury and cyanide leach into water bodies, affecting both aquatic life and human health (Annan, 2024). These dynamics highlight an urgent need for research focusing on how best to manage forests and farmlands sustainably amidst the ongoing illegal mining pressure. Although numerous studies have addressed the environmental impacts of galamsey, few have provided a comprehensive review of the integrated management of forest and agricultural resources in affected regions. This paper aims to bridge that gap by synthesizing current knowledge on policy, environmental, land use, and livelihood issues related to illegal mining in the Western Region of Ghana.

2. Problem Statement

The unregulated expansion of illegal small-scale mining in Ghana's Western Region has resulted in severe degradation of natural resources. Forest reserves and productive farmlands, especially cocoa farms, are increasingly being converted into mining sites. The aftermath includes gaping pits, infertile soils, polluted water bodies, and disrupted ecosystems (Caldwell et al., 2021). Farmers often report abandoning their land due to pollution or direct takeovers by miners (African Agribusiness Magazine, 2023).

Despite enforcement efforts by state agencies and the military, illegal mining continues unabated. There is an evident lack of coordination among institutions like the Forestry Commission, Environmental Protection Agency (EPA), and Ghana Cocoa Board, resulting in ineffective monitoring and enforcement (ISSER, 2022). Moreover, economic dependencies on both farming and mining have created land-use conflicts. Many community members are torn between the quick financial gains of mining and the long-term sustainability of agriculture.

While some literature documents the impacts of galamsey, few studies have analyzed the policies and practical interventions that could enable co-management or rehabilitation of forests and farmlands. Without a systematic review of this kind, developing sustainable land use policies remains a challenge. This paper addresses this gap by evaluating the environmental, economic, and social dimensions of illegal mining and offering integrated forest and farmland management strategies.

3. Justification for Research

Ghana is the world's second-largest producer of cocoa, and the Western Region contributes significantly to this output. The forests in this region are biodiversity hotspots and play a critical role in carbon sequestration and watershed protection. However, these resources are under threat. Between 2015 and 2022, cocoa production in key areas of the Western Region fell by nearly 50%, largely due to galamsey encroachment (African Agribusiness Magazine, 2023).

Although the government has launched initiatives such as Operation Vanguard and community mining schemes, their effectiveness remains limited. Observers note that these efforts are often reactive and suffer from poor coordination and political interference (Ministry of Lands and Natural Resources [MLNR], 2025). This research provides timely evidence that can inform ongoing policy reforms and guide stakeholders in designing more sustainable interventions. Specifically, it will contribute to national efforts aligned with the Sustainable Development Goals (SDGs), particularly SDG 15 (Life on Land) and SDG 13 (Climate Action).

4. Objectives

The overarching aim of this study is to evaluate forest and farmland management strategies in the context of illegal mining activities in Ghana's Western Region. The specific objectives are:

1. To examine existing laws, regulations, and institutional frameworks governing mining, forestry, and agriculture, and identify gaps in the Western Region.
2. To analyze the environmental impacts of galamsey on forest cover, soil quality, water resources, and biodiversity.

3. To quantify and characterize land-use changes resulting from illegal mining, especially the conversion of cocoa farms and forest reserves.
4. To assess the impact of illegal mining on community livelihoods, food security, and propose sustainable alternatives.

5.0 Literature Review

5.1 Policy Frameworks

Ghana's legal framework for small-scale mining is anchored in the Minerals and Mining Act, 2006 (Act 703) and the 1989 Small-Scale Gold Mining Law. These laws attempt to regulate and formalize artisanal mining by limiting operations to Ghanaian nationals and requiring licenses. In recent years, enforcement mechanisms have been strengthened through initiatives such as task forces and inter-ministerial committees. (MLNR, 2025).

Despite these efforts, enforcement is often inconsistent. Annan (2024) critiques the top-down approach that excludes local communities from decision-making processes. The lack of synchronized action among regulatory bodies further complicates enforcement. For instance, the Forestry Commission, EPA, and the Ghana Cocoa Board often operate in silos, undermining land-use planning and enforcement.

5.2 Environmental Impacts

Illegal mining has profound environmental consequences. It involves the removal of vegetation and topsoil, leading to irreversible soil degradation (Annan, 2024). Mercury and other heavy metals used in ore processing contaminate water sources, posing serious health risks (ISSER, 2022). Data from the Forestry Commission indicates that 34 out of 288 forest reserves have been affected by galamsey (ISSER, 2022).

Moreover, the disruption of hydrological systems through open pits and tailings affects water retention and increases the risk of flooding. As documented by Caldwell et al. (2021), stagnant water in abandoned mining sites often becomes breeding grounds for mosquitoes, contributing to higher incidences of malaria in surrounding communities. These environmental issues underscore the urgent need for targeted reclamation efforts and land rehabilitation strategies.

5.3 Land Use Change

Illegal mining competes directly with agriculture for land. In many instances, cocoa farms are either sold under duress or abandoned due to mining pollution. According to the Ghana Cocoa Board, up to 74% of cocoa farms in the Western Region have experienced some form of encroachment by illegal mining (African Agribusiness Magazine, 2023).

Remote sensing studies reveal a fragmentation of the landscape, with former agricultural zones now pockmarked by mining pits. These changes undermine sustainable agricultural practices and reduce the resilience of farming systems to climate shocks. Without an effective land-use plan that balances mining, agriculture, and conservation, land conflicts will persist.

5.4 Community Livelihoods

The socio-economic effects of *galamsey* are multifaceted. While mining offers short-term income, it undermines long-term livelihood sustainability. Cocoa yields have dropped significantly, and food insecurity is on the rise in affected communities (ISSER, 2022).

Health risks associated with contaminated water sources include skin diseases and kidney problems. NGOs and civil society organizations have called for urgent government intervention. Annan (2024) advocates for promoting alternative livelihoods such as agroforestry, aquaculture, and artisanal food processing. These interventions can help absorb the labor displaced from illegal mining and revitalize local economies.

6. Methodology

This research employs a mixed-methods approach that integrates policy analysis, remote sensing, field surveys, and environmental sampling. The study will be conducted in selected districts of the Western Region, including Wassa Amenfi East and Prestea Huni-Valley.

6.1 Policy and Document Review

A systematic review will be conducted of national policies such as the Minerals and Mining Act, Forestry Commission Act, Land Use and Spatial Planning Act, and Ghana Cocoa Board regulations. Reports from government agencies and NGOs will also be analyzed to identify policy gaps and implementation challenges.

6.2 Geospatial Analysis

Remote Sensing will be used to analyse Satellite imagery from Sentinel 2 and Landsat 5, 7 and 8. The Analysis will also rely on data from Global Forest Watch, Hansen Global Forest Change and other forest dataset using the cloud computing platform Google Earth Engine. This will help track changes in land use land cover and deforestation over the past decade. GIS tools such as QGIS will be used to visualize deforestation trends viz-a-viz land use land cover changes and the effects on mining activities into forest and agricultural zones.

6.3 Field Surveys and Interviews

Structured questionnaires will be administered to farmers and community members to assess the impact of mining on crop yields, income, and food security. Key informant interviews with forestry officers, local government

officials, traditional leaders, and miners will provide qualitative insights. Focus group discussions will explore community attitudes towards alternative livelihoods.

6.4 Environmental Sampling

Soil and water samples will be collected from affected and unaffected sites to test for heavy metals and sedimentation. Laboratory analyses will help establish the environmental footprint of illegal mining.

6.5 Data Analysis

Quantitative data will be analysed using statistical software to determine correlations between proximity to mining sites and indicators such as crop yield or household income. Qualitative data will be thematically coded. Spatial data will be used to produce maps showing land-use changes.

Spatial software such as QGIS and Google Earth Engine will be used to analyse trends and changes in land use land cover while analysing the deforestation extent and mining activities/sites and its proximity to farmlands.

This analysis will then be visualised using maps and charts.

7. Expected Outcomes

1. A policy review report identifying strengths and weaknesses in the current regulatory framework, with recommendations for integrated land-use governance.
2. Environmental impact maps and quantitative data on forest and farmland loss, providing a baseline for future monitoring and intervention.
3. A socio-economic analysis documenting community experiences and identifying viable alternative livelihood strategies.
4. Guidelines for reclamation and sustainable land management, incorporating best practices from other mining-affected areas.
5. Dissemination of findings through academic publications, policy briefs, and stakeholder workshops.

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6. How the Ghanaian Media Covers Mining – An Analysis of Some News Reports

Emmanuel K Dogbevi

Extended Abstract

Introduction

This paper will attempt to look at how the Ghanaian media has been covering the mining sector in the last ten years, from 2015 to 2025. It will examine the nuances and how the media frames the narratives and what the focus is. It will also look at how much attention the media pays to soil pollution and remediation.

Mining in Ghana predates colonial times and has been going on for centuries. According to Hilson¹, gold mining in Ghana has a long history of over 1000 years from the Ancient Kingdom of Ghana, the former Gold Coast and present-day Ghana.

Ghana for many years has been a major exporter of gold in the world with the country's economy substantially contributed to by gold exports.

Hilson further notes that gold mining companies in the region started operations not long after the British had established the Gold Coast Colony in 1874, and, following two successive gold rushes in the early-1900. Gold prospecting and mining were common in Obuasi, Tarkwa and Prestea.

One area of contention in Ghana is land ownership and development, and the mining sector has always been a major area of conflict related to land. Schueler² et al, discuss the impact of surface mining. Using Landsat satellite images from 1986–2002 they mapped land cover change and did field interviews with farmers to understand the livelihood implications of mining-related land cover change. According to the authors, their results showed that 58% of deforestation resulted from surface mining, 45% loss of farmland occurred within mining concessions, and they also found widespread spill-over effects as relocated farmers expand farmland into forests.

While the coverage of illegal mining, has been going on in traditional media for many years, the role of digital media as discussed by Ayelazuno & Aziabah² has brought to the fore the scandals of illegal mining closer to the people and more forcefully, eliciting wider conversion and in some cases action. But even that the focus is on the generality of environmental pollution, deforestation and land degradation.

Methods

Due to time limitations, this presentation will not be able to follow the strict requirements for this conference and for the fact that it is not a scientific paper. It will however provide some evidence from some randomly selected news publications in Ghana with the objective of showing how the news media covers the general subject of mining and its impacts on the environment.

¹ <https://www.sciencedirect.com/science/article/abs/pii/S0301420703000023>

² <https://pmc.ncbi.nlm.nih.gov/articles/PMC3357810/>

² <https://www.sciencedirect.com/science/article/abs/pii/S2214790X23001557>

Discussion

Five local news sources were looked at in the determining how the Ghanaian media covered mining in the country in general and how they reported soil pollution. These are Myjoyonline, Citinews, 3News, Graphiconline and GhanaWeb.

Largely these news outlets cover regulatory and policy frameworks, the economics of mining and earnings from precious metal. They cover mining companies, sometimes in what can be described as promotional pieces and the public's reaction to mining especially with regards annexing of land for mining and local community responses to mining activities.

The cover water pollution, destruction of farmlands and generally about environmental degradation and pollution. None of the reports focused on the specifics of soil pollution and remediation.

Graphiconline³ a digital platform of the state-owned newspaper Daily Graphic covers the overall mining sector with a focus on the institutional and legal framework, and in recent times, the framing of the news on mining has been around illegal mining also known as *galamsey* with emphasis on land degradation, water pollution and destruction of farmlands. The publication also mentions the use of chemicals like cyanide and mercury in mining and how they affect soil and plant life.

Citinewsroom⁴ is the digital publication of the radio station CitiFM. Not significantly different from the Graphiconline, citinewsroom sometimes focuses on communities and the impact of mining on livelihoods with emphasis on the destruction of farmlands. The radio station also frequently invites experts and political actors to discuss the subject of mining and its impact on the environment and human life.

The coverage by myjoyonline⁵, which is also the digital news platform of a radio station, JoyFM features links to the media outlets YouTube channel that broadcasts investigative reports that uncover extensive illegal mining activities. The news portal reports about soil pollution and environmental cost of mining and the consequences on

human health. The portal also focuses specifically on soil contamination that results in soil infertility and the overall impact on farming communities and food security.

The coverage by 3News⁶, a digital news portal belonging to Media General, owners of TV3 focuses on the subject of soil pollution as part of the broader reportage on mining, especially illegal mining. 3News interviews technocrats and government officials and captures their views on mining, the problems posed by illegal mining and what

³ <https://www.graphic.com.gh/>

⁴ <https://citinewsroom.com/>

⁵ <https://www.myjoyonline.com/>

⁶ <https://3news.com/>

remediation efforts the government has been implementing, paying attention to the dangers of soil and waterbodies contamination.

The oldest of the online news portals ghanaweb⁷, an aggregator of news from other portals also does some coverage of news with a focus on mining. It's coverage is also not substantially different from the other portals, considering the fact that ghanaweb aggregates most of its news from the other portals. Like the other portals it covers the wider subject of mining, mining companies, the political actors in mining, as well as the overall impact of mining activities on the environment, soil and waterbodies.

Conclusion

From the analysis, none of the news sources specializes in any one area of mining, and therefore, there is no express evidence of specialization on soil pollution and remediation. The reportage focuses on the general trend of mining, covering of mining companies, interviewing of technocrats, civils society actors, government officials and communities affected by mining activities.

While these news outlet do not have specializations, their coverage of the mining sector gives a good idea of the sector and the challenges of illegal mining, which to a large extent also impacts the environment. The reportage also only focus on the subject of general pollution and contamination of soil, waterbodies and farmlands with extended effects on human health.

Recommendation and contribution to science, society and policy

Considered the Fourth Estate of the realm, news outlets have the duty of serving the wider public interest, and the stories they report on, while they may not have a direct influence on scientific policy and direction, they do sometimes draw the attention of the science community, policymakers and society to what the issues are and what ought to be done. The reports of news outlets have led to the promulgation of legislation and review of laws, new policies as well as review of policies. Their work also serves as a mirror to the scientific community and as a window to new ideas for further investigation.

7. One Health Approach: From Hazardous Mining to Sustainable Mining

Evelyn Addai Acheampong

Abstract

⁷ <https://www.ghanaweb.com/>

The One Health approach offers a holistic framework for addressing the health and environmental impacts of hazardous mining. By recognizing the interdependence of human, animal, and ecosystem health, this approach fosters interdisciplinary collaboration to restore mine-contaminated landscapes sustainably. This presentation examines how One Health can guide risk assessment, community engagement, and land rehabilitation practices. Case studies and international examples illustrate its application in zoonotic disease control, food safety, and environmental conservation. Despite challenges—such as limited resources and institutional fragmentation—the One Health model emerges as a promising solution for mitigating the effects of artisanal and industrial mining. The presentation advocates for policy reform, coordinated action, and long-term investment in One Health strategies to transform degraded mining areas into safe, productive, and ecologically resilient spaces.

8. Impact of illegal mining activities on Cocoa pollinator abundance in Ghana In Shifting Frontiers of Theobroma cacao - Opportunities and Challenges for Production

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Introduction

In recent years, the environmental impact of illegal small-scale gold mining, commonly known as "galamsey," has become a growing concern worldwide. Galamsey activities involve the extraction of gold from deposits using rudimentary methods that often result in significant ecological degradation and the release of toxic substances into the environment. Across the globe, numerous countries face comparable challenges associated with unregulated artisanal and small-scale mining operations. For instance, countries such as Brazil (Bruno et al., 2020; Lobo et al., 2016), Colombia, Indonesia (Bruno et al., 2020), and the Democratic Republic of Congo (Geenen, 2012; Hayes & Perks, 2012; Otamanga & Poté, 2020) have grappled with the adverse environmental consequences of informal mining activities. Pollination services are an essential element to maximize production in sustainable agriculture (Knapp, 2017). They are critical to food production and human livelihood, directly connecting wild ecosystems to agricultural production systems (Lázaro & Alomar, 2019). Wild pollinators are important in both agricultural and natural ecosystems and are threatened by landuse change (Guzman et al., 2019), intensive agricultural management and pesticide use (Gaffney et al., 2019), pathogens (Graystock et al., 2016) and climate change. The most important cocoa pollinators are midges. In cocoa, pollination occurs almost exclusively by ceratopogonid midges (order Diptera) of the genus *Forcipomyia* (Winder, 1977). The midges species that pollinate cocoa belong to the genus *Forcipomyia*. Most researchers studying cocoa pollination assume that *Forcipomyia*, which is common in cocoa plantations in Ghana, is *Forcipomyia squamipennis* I. In West Africa, it is predicted that 89.5% of current cocoa growing areas will experience a decline in cocoa suitability by 2050 (Läderach et al., 2013). Businesses and governments are advocating sustainable cocoa initiatives to prevent deforestation and promote ecosystem services, biodiversity and sustainable livelihoods (IDH, 2018). The cocoa industry generates about US\$2 billion in foreign exchange annually and plays an important role in the national economy. The sector employs around 800,000 farming families in six of the country's sixteen regions (McDermott, 2019). Ghana is the second highest cocoa producing country in the world after Ivory Coast, with the sector producing approximately 970,000 tonnes of cocoa in 2017 (COCOBOD, 2018). A recent USAID study found that despite the massive expansion of cocoa production in the country, cocoa production may now be of secondary economic importance to gold due to its increased environmental impact and economic importance, even if mining is not practiced by all (McDermott, 2019). While Ghana has developed action plans to end deforestation in the cocoa sector and restore forest lands, actions to address the rapid expansion of artisanal and small-scale gold mining have so far been quite limited, jeopardizing potential gains in reducing deforestation in the cocoa sector.

Global cocoa production and economic value

Cocoa is a cash crop for many West African smallholder farmers. Although global annual cocoa production quantities are below those of other tropical crops such as sugar cane, rice, soybeans, oil palm, cassava or bananas, it is a unique crop as more than 90% of its production comes from smallholder farmers (ICCO, 2017). Cocoa production is estimated to be around 10 million hectares, which accounts for only 0.7% of the total global arable land but 7% of the global permanent land (Anafo, 2017). Therefore, cocoa cultivation and especially cocoa agroforestry systems play an important role in carbon sequestration and therefore have a significant mitigation potential (Silatsa, 2017). Climate change, deforestation, diseases and low world market prices threaten global cocoa production. Global annual cocoa production has doubled in recent decades, reaching 3.6 million tonnes in 2009–2010, increasingly being concentrated in a handful of countries. Africa has established itself as a leading cocoa supplier over the past 10 years. According to the International Cocoa Organization, Africa's production has increased at an average annual rate of 2.7% since 2000. Farmers throughout the cocoa belt of West and Central Africa account for more than two-thirds of the world's cocoa production. World annual production reached 4.5 million tons in 2013 and growth came mainly from West Africa (ICCO, 2017).

The cocoa sector in Ghana

Cacao is an important source of income for the provision of various public infrastructures and a profession mostly loved by farmers in Ghana and other countries. Cocoa dominates the agricultural sector and is an important source of income for approximately 800,000 farmers and many others involved in the trade, transport and processing of cocoa (COCOBOD, 2018). Ghana's cocoa sector has seen an impressive recovery in recent years. Ghana can boast of over 1,000,000 tons of cocoa in the 2010/2011 harvest year. Ghana is the second largest cocoa producer in the world (Boateng, 2014). Together with Ivory Coast, it produced almost 52% of the world's total cocoa production in 2016. About 800,000 cocoa households produce 75 percent of all cocoa in Ghana (Maguire Rajpaul, 2020). The Ghanaian government generates most of its income from the export of cocoa (Silatsa, 2017). Cocoa provides resources for poverty alleviation as well as food, money, employment and industrial raw materials (Peprah, 2015). The small size of farms in Ghana may be due to cocoa farm agreements where the farm is sometimes shared between the landowner and the caretaker (Barrientos, 2012). The inheritance system in Ghana often leads to fragmentation of farmland when a farmer shares his farm to several sons. Smaller farms result in decreased yields as small farms are a disincentive to invest, leading to reduced use of fertilizers and fungicides/pesticides (Steijn, 2016). The average cocoa acreage fell from 9.6 to 7.5 ha between 2008 and 2014 (Silatsa, 2017).

Cocoa pollination

The intensity of pollination and fruit set largely determine the cocoa yield (Young, 1986). However, very little attention has been paid to pollination management as a factor of production, as pollination is often not considered an important process for crop yield. Even when pollination is acknowledged, its management is often not considered. This is because most people believe that there are enough pollinators in the wild to carry out pollination without active human intervention. Cocoa flowers are hermaphrodite (male and female parts). Group of flowers (inflorescence) and pods are produced by the mature tree on the main stem and branches. This type of flowering is called cauliflory. The flowers are produced at the same defined areas on the tree and these swell with time to form flower cushions. Every cushion bears up to 50 flowers per flowering season. There are two flowering seasons per year, which thus yields 100 flowers per year. The pentamerous flower is about 15 mm in diameter. Flowers that are well pollinated develop to form fruits called pods. The main pod development stage is the cherelle or immature pod. A mature cocoa tree can produce over 10,000 flowers every year of which 1–50% are pollinated with 10–50 pods reaching maturity. It takes 5–6 months for pollinated flowers to become ripe pods. Different sizes or growth stages of flowers and pods can be found on the tree at any given time. Mature pods grow up to 30 cm long and 10 cm wide, and contain 20–60 beans (seeds) (Addae, 2014). The cocoa fruit is an indehiscent drupe. During the first 40 days after fertilization, pod growth is slow. Afterward, growth accelerates. The first division of the zygote only takes place between day 40 and 50. Pod and ovule growth decrease from day 85 onwards, when embryos start to develop. On day 140, the embryo has completed its development and pod ripening starts (Bos, 2007).

Biology and phenology of *Forcipomyia* spp.

Adult midges can be found between the buttresses of large shade trees, in cracks of decayed old tree trunks, in hollow tree stumps and in piles of cocoa husks. Swarming occurs at any time of the day or in the late afternoon. Midges are present on cocoa plantations year-round, but the largest population occurs during the rainy season. Adult females lay eggs in batches of 40 to 90 on damp, rotting wood, cocoa husk, and other plant debris. The larvae hatch in 2–3 days and pupate after four molts when they are about 12 days old. The pupal stage lasts 2–3 days. Adult females require liquid plant food for survival and oviposition, although ovum maturation occurs independently of adult feeding or mating. Unfertilized eggs do not develop. The maximum life expectancy for either sex in captivity is eight days. *Forcipomyia* goes through at least 12 generations per year. Due to its abundance and continuous reproduction on cocoa plantations, *Forcipomyia* is probably the most important ceratopogonid cocoa pollinator in Ghana. According to (Kaufmann, 1975), midges are attracted by the vertically aligned staminodes and use them to land. The fact that style pollination generally leads to greater fruit set than stigma pollination makes the ceratopogonid midges efficient pollination candidates (Posnette, 1958). Distance traveled during one foraging event, and consequently during which pollination is performed, can reach up to 50 m. It has been shown that there are 5–7 times more *Forcipomyia* species above the cocoa canopy than below the canopy (Anaifo, 2017). Since wind speed above the canopy is

higher than below, it can be expected that wind could play an important role in horizontal cocoa pollinator distribution over the cocoa field. Ceratopogonid pollinator populations can be abundant and exceed one million individuals per ha (Addae, 2014). Moist environments favor ceratopogonid midge abundance. In fact, there is a positive correlation between soil moisture and ceratopogonid population levels (Addae, 2014). Stable moist conditions are indispensable for successful development of eggs and larvae (Soria, 1975). Pollinator populations thus increase with each rainy period, and decrease with the onset of a drier period (Wood, 1985).

Methods

Extensive research was conducted to gather relevant publications and articles on the ecology of species, pollinator abundance and ecosystem health implications of galamsey activities in Ghana. The search was carried out between 2000 and 2023 and several electronic databases were selected to cover a wide range of disciplines and research areas, including PubMed, Scopus, Web of Science, and Google Scholar. These databases were chosen for their extensive coverage of scientific literature in the fields of environmental science, public health, toxicology, mining, and related disciplines. A combination of keywords and controlled vocabulary was used to construct search queries. The keywords and phrases encompassed various aspects of the topic, including "galamsey," "illegal mining," "Ghana," "ecological impact," pollinator, habitat fragmentation and cocoa. The search queries were adapted to the specific syntax and requirements of each database. Truncation and Boolean operators (e.g., and, or) were utilized to expand or narrow down the search results, as appropriate. Inclusion criteria were established to ensure the selection of articles and studies that directly addressed the ecological impact of galamsey activities in Ghana and their Phytoremediation. Relevant criteria included studies published in peer-reviewed journals, research articles, review articles, and reports from reputable organizations. Articles and studies that focused on other forms of mining activities or were not specific to the Ghanaian context were excluded from consideration. Similarly, studies that did not investigate the ecology of species, pollinator abundance and ecosystem health implications of galamsey activities in Ghana were excluded. The literature selection prioritized studies with methodologies, including field surveys, laboratory analysis, and empirical data collection. Duplicate records were removed using reference management software, and the remaining records were screened based on titles and abstracts. The selected articles proceeded to the full-text review stage. The full-text review involved a careful assessment of the selected articles to determine their relevance to the research objectives. Articles that met the inclusion criteria were retained for data extraction and synthesis. The final selection of literature was made based on consensus between the researchers after discussing any discrepancies or disagreements during the review process. To ensure completeness, a supplementary search was conducted by reviewing the reference lists of the selected articles and performing a citation search on key papers. This process aimed to identify additional relevant studies that may have been missed in the initial search. The supplementary search helped uncover older or

seminal studies that might have been missed in the initial search, ensuring the inclusion of comprehensive and foundational literature on the topic. A total of 85 studies were found and 10 met the inclusion criteria and were selected for data extraction and synthesis. These papers encompassed a range of study designs, including empirical research, case studies, and review articles. The review encompasses studies conducted across multiple regions of Ghana to capture the health impact of galamsey operations across the country. Specifically, studies from various regions, including but not limited to Ashanti, Eastern, Western, Central, Ahafo, Bono, Northern and upper East Region were included in the analysis. The selection aimed to provide a comprehensive understanding of the health impacts associated with galamsey operations in different regions of Ghana.

Results and Discussion

Impact of illegal mining on pollinator abundance

The Ghanaian government generates most of its income from the export of cocoa (World Bank, 2018). Threats considered that lead to low cocoa yields include old aged trees (cocoa plantations over 30 years old), predominance of low-yielding traditional cultivars, smaller farm sizes due to fragmentation of land tenure agreements, illegal mining activities, and non-compliance with good agricultural practices (Cobbina, 2014). Artisanal and small-scale mining is understood to mean mining operations by individuals, groups, families or cooperatives with minimal or no mechanization, often carried out in the informal sector. The Ghanaian government recognized the potential of the sector for job creation and legalized artisanal mining in 1989 [66]. The Minerals and Mining Act 2006 (Act 703) further defines artisanal and small-scale mining as mining operations in an area corresponding to the prescribed number of blocks. In addition, small-scale mining was legalized as the exclusive domain of Ghanaians (Duodu, 2017). However, foreigners with sophisticated machinery found their way into the sector, accelerating the rate of extraction in the mining communities (Duodu, 2017). As a result, illegal small-scale mining activities increased after legalization aimed at regulating mining activities to protect the environment. Small-scale illegal gold mining is referred to as Galamsey, which derives from the jumbling Ghanaian local jargon “gather-am-and-sell” (Cobbina, 2014). Although illegal small-scale mining has drawn criticism from several quarters, the Ghana Cocoa Board takes a closer look at its impact on cocoa productivity and trusts farmers are destroying their farmland for illegal gold mining activities (COCOBOD, 2017). In fact, the Ghana Cocoa Board has been one of the major complainers about the Galamsey threat (Burrows, 2017), as Galamsey creates factors that discourage or adversely affect cocoa cultivation. First, Galamsey presents pull factors as a more attractive investment. Some people are drawn to informal mining because they believe mining offers them a get-rich-quick opportunity (Hilson, 2012). The farmers who have their cocoa farms close to the mining areas observe early dropping of immature pods, wilting and yellowing of leaves because the galamsey activities deplete the topsoil which supports the healthy growth of plants (Aneani, 2017). The damaging environmental impacts associated with the unregulated mining activities include effluent dumping, unrehabilitated excavations, improperly stored waste, dust emissions,

deforestation, acid mine, river siltation and the release of chemicals such as cyanide and mercury (Boafo, 2019) asserted that between 1 and 20 hectares of cocoa lands are been taken over by galamsey activities in numerous Ghanaian cocoa-producing districts annually. According to GSS (Ghana Statistical Service) (2018), the GDP contribution of cocoa decreased from 3.6% in 2011 to 1.8% in 2017. The rife mining activities in the nation have been partly blamed for the reduction in cocoa production and economic contribution.

Landscape degradation

Habitat destruction from land-use changes such as habitat loss, fragmentation, deforestation and conversion of natural habitats to cropland is the most important driver of biodiversity loss in terrestrial ecosystems (Snapir, 2017). From an ecological perspective, changes in land cover involve shifts in land cover composition and variations in their spatial arrangement (Fahrig, 2003), which directly affect the composition of biological communities and pollinator-flowering plant relationships (Vanbergen et al., 2014). Species that survive in such environments need to adapt to changing habitats and periodic disturbances. The integration of shade trees into cocoa agroforests can bring numerous economic and environmental benefits (Blaser et al., 2018), such as Increased Diptera visitation rates with increased canopy closure found in Indonesia (ToledoHernández et al., 2021). Therefore, the long-term conversion of forests to mining sites in Ghana could result in agroecological disadvantages such as forest degradation, biodiversity loss, soil quality disruption associated with low yields and food insecurity (Toledo-Hernández et al., 2021). A recent report estimates that the annual cost to the global economy of habitat loss will reach \$10 trillion by 2050, making ongoing biodiversity loss as much an economic crisis as an environmental crisis. For more sustainable agriculture, three complementary strategies are envisaged that address several key drivers of pollinator decline: ecological intensification, strengthening existing diverse farming systems, and investing in ecological infrastructure (Vanbergen et al., 2014). These three strategies simultaneously address several key drivers of pollinator decline by mitigating the impacts of land-use change from illegal mining, pesticide use and climate change. Protecting large areas of semi-natural or natural habitat (tens of hectares or more) helps conserve pollinator habitats at a regional or national scale (Toledo-Hernández et al., 2021).

Habitat fragmentation

Habitat destruction, fragmentation and degradation, combined with conventional intensive farming practices, often reduce or alter pollinator food and nesting resources. It is well known that habitat destruction can reduce the population size, composition and species richness of pollinator communities (Bommarco et al., 2012), and thereby affecting evolutionary processes at the species level. Significant declines have already been observed for some pollinator groups (e.g. Hymenoptera, Lepidoptera), which may be due in part to a history of habitat conversion (Hadley & Betts, 2012) as well as the loss of certain habitat elements such as nesting or foraging sites (Kennedy et al., 2013). Differences in ecological and morphological traits (feeding adaptation, mobility,

body size, behavior) can affect the response of pollinator species to changing environments and their ability to survive in poor quality environments (Hadley & Betts, 2012). Pollinator species that are more specialized for habitat or food requirements tend to be more vulnerable to land cover changes that alter the availability of food or nesting resources (Bommarco et al., 2012), leading to homogenization of pollinator communities dominated by common generalist species (Fischer, 2007). Gene flow has a major impact on genetic variation within populations, as it offsets the detrimental effects of genetic drift, determines effective population size, and has important implications for the management and conservation of genetic resources (Kennedy et al., 2013). Since pollen movement is a key component of gene flow, density effects can be expected to alter genetic structure and, especially in small populations, increase the likelihood of extinction (Hadley & Betts, 2012). Therefore, given that tropical forests experience high rates of deforestation (Potts, 2010), knowledge of gene flow is fundamental to understanding reproductive success and management of tropical tree species.

Deforestation

Crop loss occurs when the Galamsey operations are done directly on the farm. Cocoa crops are being destroyed by large machines such as bulldozers used to clear land on Galamsey farms. Loss of crop yield and income usually occurs when the Galamsey operators forcibly take part of the farmland from the farmers. This has several negative impacts on the environment, including water and air pollution, deforestation and land degradation. Tropical forests are the most biodiverse ecosystems and species-rich habitats in the world, but are significantly threatened by widespread ongoing deforestation (Bommarco et al., 2012). Primary forests are of vital importance for the conservation of biological diversity due to their unprecedented diversity of species and habitats (Gyasi, 2006). Deforestation of primary and secondary forests can result in biodiversity loss and forest fragmentation, reducing previously uninterrupted habitat to smaller fragments (Potts, 2010). This can result in forest-dependent species being isolated in small patches of forest that are not large enough to support a healthy population. However, secondary forests play a key role in providing habitat for a wide variety of species and in establishing connections between primary forest areas. Protection and restoration of primary and secondary forests are critical to improving tropical forest health (IPBES, 2019). Beyond habitat loss, land use change can lead to deterioration in habitat quality, known as habitat degradation. In these cases, the species are able to survive, but their populations may decline (Fischer, 2007). For example, a recent study suggested that agricultural expansion has reduced the richness and composition of pollinators of bees and wasps in the UK (Jezeer et al., 2017).

Conclusions

Since cocoa production is largely dependent on pollination by insects, any threat to pollinators will negatively impact cocoa production. There is evidence that cocoa pollination is currently below optimal levels in Ghana

and that increasing pollinator populations in cocoa fields could increase cocoa production (Winfree et al., 2011). This was demonstrated by the Cocoa Research Institute of Ghana (CRIG) in Tafo using additional (artificial) hand pollination to increase yield and also to breed new cocoa varieties (COCOBOD, 2018). It is noted that illegal small scale mining (Galamsey) has actually been the major factor affecting cocoa production due to land degradation, water and air pollution, diversion of water bodies, damage to farms and farmhouses, etc. The findings from this suggest that Ceratopogonidae midges alone were probably too rare to act as the main or even sole pollinator of cocoa in Ghana, since the relative abundance observed on cocoa flowers in Ghana are low due to the operations of illegal mining activities done right in the cocoa farms (ToledoHernández et al., 2021). The study identified the need for protection of extensive natural forest areas to protect the genetic identity of wild cacao pollinators in Ghana and, in addition, to promote genetic exchange between wild populations to maintain genetic variability of viable populations (Boateng, 2014). Evidence has shown that areas of secondary forest surrounding cocoa farms may provide pollinator resources similar to natural forests, and that deforestation and habitat fragmentation reduce the population size, composition and species richness of pollinator communities in cocoa farms to increase production (IPBES, 2019). Different pollinator species respond differently to changing environmental conditions caused by illegal small-scale mining due to their physiological, behavioral or other mechanisms (Winfree et al., 2011).

Recommendation

Ecological intensification Management of nature's ecological functions is needed to improve cocoa production and livelihoods while minimizing environmental damage. Strengthening existing diverse farming systems This includes the management of systems such as forest gardens and agroforestry to promote pollinators through scientifically and local knowledge validated practices, for example, Crop rotation, cultivation of sunflowers and edge crops to provide alternative food resources to increase pollinator abundance and diversity necessary for cocoa production in Ghana. Policies and laws concerning Galamsey Existing legislation should be strengthened by involving farmers in stakeholder decision-making on Galamsey, so that offenders are punished and others are deterred. To achieve this, the government should provide COCOBOD with structures that enable it to effectively and efficiently impose sanctions against illegal small-scale mining. Strategies to conserve pollinators and biodiversity Mining activities should be structured to strike a balance between economically driven extraction of mineral resources and the strategies needed to conserve natural resources and maintain ecosystem integrity and species viability.

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9. Arsenic Pollution of Arable lands: Spatial distribution, Ecological and potential Health Risks

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Abstract

Arsenic continues to be one of the environmental stress factors of global health concern because it has the potential to accumulate in the soil-water-plant-consumer system to cause serious health infractions. Up to 30000ppm has been found in the environment in recent years often discovered around artisanal small-scale gold mining (ASGM). A previous research conducted at the study area and published during the Covid-19 pandemic found heavy metal levels in increasing order from $Cd < Hg < Pb < As$. It signalled potential As stressed soils and impact on agricultural produce. This current study aims to identify the sources of As in arable lands from thirteen (13) farming communities of Twifu Ati Mokwaa district in the Central Region of Ghana. Soil samples collected to a depth of 20cm were acid digested (HNO_3 , HCl , H_2O_2) and the extracts analysed by GF-AAS. We determined the total element contents and calculated their pollution indices using the soil contamination factor (CF), enrichment factor (EF), the geo-accumulation index (Igeo), ecological risk (Er) and as well estimated potential health risk (PHR) from Hazard Quotients. Geospatial maps generated showed patches of hotspots close to mined areas spreading into farmlands. Pollution status estimated from CF fell within moderate contamination (0.4 – 2.6) and that based on Igeo indicated that some soils were within the unpolluted to moderately polluted domain (-2.5 – 0.7). Ten arable lands in communities including Otumpan, Konyarko, Moseaso, Sebenso, Mokwaa, Ntafrewaso, Mampong and Nuamakrom (representing 50%) recorded CF values greater than the threshold of 1. The EF values ranged from 0.2 – 1.6 suggesting low enrichment. These indicators point to anthropogenic activities such as use of agrochemicals, human settlement and mining increasingly becoming prevalent in the study area although there is a potential geomorphology underpinning the dominance of soil As. Data for Er (4.1 – 20.0) were below the 40 threshold indicating no potential ecological risk. On the other hand, PHR data for long term cancer risk (0.3 – 1.9) suggested that all exposed age groups would be at risk through soil ingestion.

Keywords: arsenic, geogenic, arable land, artisanal gold mining, spatial distribution, local geochemical background, pollution indices

SUB-THEME 2: PHYTOREMEDIATION SOLUTIONS AND RESTORATION OF MINING SITES

I. Cost of repair: Rehabilitation of Degraded/Galamsey Mining Sites via Revegetation

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Abstract

In Ghana, galamsey is an informal mining operation that utilises a rudimentary, artisanal, and uncontrolled approach for gold extraction. It originates from the expression 'gather them and sell.' Galamsey serves as a significant source of income for millions in gold mining communities. This type of mining is unlicensed, unregulated, and consequently, they deteriorate the ecology and induce significant alterations to formerly stable

lands. Additionally, galamsey activities critically jeopardise environmental sustainability, and create degraded lands and water without any reclamation or restoration initiatives. Post-reclamation monitoring and management are crucial for ensuring the long-term efficacy of restoration projects. Phytoremediation, a plant-based technology that can offer a cost-effective and environmentally sustainable approach to alleviate, detoxify, and rehabilitate contaminated and degraded mining sites. This study and public lecture seek to propose and examine the possibilities of employing revegetation through phytoremediation to rehabilitate derelict lands affected by galamsey in Ghana. The public lecture outlines a framework for effective reclamation and restoration of abandoned mine lands destroyed via galamsey mining. The importance of site characterisation and risk assessment, selection of appropriate plant species, appraisal and monitoring of reclaimed mining sites, and the advancement of strategies for the maintenance of restored mining sites are underscored. In conclusion, I argue for comprehensive policy and financial investments and commitments to encourage the broader use of phytoremediation in Ghana, aiming to restore degraded areas for agricultural and ecological purposes.

2. Soil Remediation Practices Among Home Gardeners

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Abstract

Home and urban gardening has several advantages, ranging from nutrition and food security to social and environmental well-being. These gardens, however, are frequently susceptible to contamination by potentially toxic elements (PTEs), especially heavy metals, which could pose major hazards to both ecological and human health. This study evaluated gardeners' knowledge of soil contamination, their competency with remediation methods, and the variables affecting their propensity to use soil remediation approaches. A structured questionnaire was given out. A total of 86 respondents responded which include experts in the field in various locations of Europe and Ghana, including the Ashanti, Accra, and Bono regions. 96.5% of respondents had never tested their soil for heavy metals, despite 63.5% of them being aware of the possible health concerns associated with such contamination. Also, just a small percentage of participants had put mitigation plans into practice, and 86.05% were not aware with soil remediation approaches. The most well-known technique among people with some level of knowledge in soil remediation practices was phytoremediation. Knowledge was found to be the most evident driver influencing gardeners' decisions by decision tree analysis, with time availability, cost, and worries about food safety serving as important moderating factors. There were no discernible correlations between gardeners' demographic traits (age, gender, or geography) and their interest in or adoption of remediation techniques, according to inferential statistics like chi-square tests. The results point to important limitations in institutional support, training, and understanding that prevent soil remediation approaches from being widely used. Promoting safer urban agriculture and safeguarding public health require filling these gaps with focused education and easily available tools.

Keywords: Garden, urban garden, gardener, health, heavy metal, soil remediation, knowledge

3. Biochar and Compost: Effective Soil Ameliorants for Remediating Cd, As, Hg and Pb In Flooded-Sites Contaminated By Artisanal Gold Mining.

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Abstract

This study aims at evaluating the total concentrations of dissolved potential toxic elements (PTEs) in flooded soils contaminated by artisanal gold mining in Ghana. Flooding-induced changes in the soil properties of the mine soil that control PTE mobilization, contents of soil nitrate, ammonium and mineral or available nitrogen, soil basic cations, mobilization of PTEs in the mine tailings influenced by iron to element molar ratio and mobilization of the major PTEs based on multiple regression models were assessed. Samples were collected from five (5) different abandoned gold-mining sites in Nsiana located near Antoakrom in the Amensie West district of the Ashanti region from 0–20 cm horizon at five (5) randomly selected abandoned gold mining sites. Cd, As, Pb, Hg and Ni were determined by an Agilent 200 Atomic Absorption Spectrometer. From the results of the study, Cadmium, lead and mercury were identified as problematic as their levels surpassed their corresponding global soil averages whilst pseudo-contents of As in our samples fell below the recommended limits for industrial sites in Italy (i.e., 50 mg kg⁻¹), Germany (i.e., 140 mg kg⁻¹), and in South Africa (i.e., 580 mg kg⁻¹); and they also fall below those limits indicated for agricultural land use in Australia (i.e., 20 mg kg⁻¹). The highest pH (7.69) and redox potential (eh=400 mV) were recorded by manure and CCB respectively. The highest level of NO₃-N (113.48 mg L⁻¹) and AN, and NH₄-N (144.93 mg L⁻¹) were recorded by treatment M, and Com respectively. The utilization of biochar, compost and manure enhanced the basic cation content and overall cation exchange capacity of the soil evidenced in the elevated K⁺ levels present in CCB, Com and manure. From the results obtained Com recorded significantly lower Cd level lower than the global soil average of 0.02 mg/kg whilst Cd levels of Manure, CCB and C treatments surpassed the 0.03 mg/kg threshold set by FAO/WHO soil environmental quality guideline. Consequently, the significant decreased in Cd levels by Com is ascribed to the elevated levels of Fe and Mn in the compost compared to the control. Furthermore, a notable and substantial concentration of dissolved As was detected under CCB and RB compared to the control and other treatments attributable to the elevated levels of EC, pH, salinity and increased contents of Fe/Mn. Results in the soil PTEs and their relationships with the relevant governing parameters showed soil pH exhibiting a significant positive correlation with the concentrations of dissolved As and Hg, with $r = +0.5$ and $p < 0.05$ indicating that soil pH increases the levels of dissolved As and Hg in the flooded mine tailings. The addition of CCB and compost led to a significant increase in the Fe/Cd ratio making them ideal for mitigating migration and transportation of Cd by runoff water and flooding into groundwater. The addition of RB, CCB, and M led to a notable reduction in Fe/As in contrast to the higher values in the compost and the control. Multiple stepwise regression showed that As mobilization due to flooding were governed by changes in pH and eh with Mn exhibiting characteristics that can restrict the availability of Cd in the inundated ecosystem via precipitation or complexation. Results from NIR spectroscopy analysis showed a good model calibration for Hg (83.7% performance) with low prediction. Therefore, in remediating Cd contamination in flooded sites caused by artisanal mining, biochar and compost are promising whilst the use of manure solely for similar purpose should be done with caution since manure possess the potential to migrate Cd into the ecosystem and groundwater.

4. Evaluating the Potential of Rice Cultivation As a Post-Mining Land Use Option

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Extended Abstract

I. Introduction

The increasing spate of land degradation caused by artisanal and small-scale mining (ASM) threatens global food security. In Ghana, activities from the ASM sector are largely informal and thus cause damage and devastation to the soil and water resources. The devastating nature of the ASM activities and poor management of mine tailings render the natural resources contaminated with potentially toxic elements (PTEs) such as cadmium (Cd), Arsenic (As), Chromium (Cr), lead (Pb), mercury (Hg), copper (Cu), etc., and thus make such lands not safe for food production.

In the face of increasing population with the concomitant competition for land for multiple purposes, including crop production, it is crucial to investigate and invest in strategies which can possibly return those degraded lands to beneficial uses. Incorporating organic soil amendments such as biochar, poultry manure, cow dung, compost, etc., into PTEs-contaminated soils has been widely applied globally, either solely or in combination for remediation before revegetation or crop production (Kobina et al., 2025; Navarro-Ramos et al., 2022). Those abandoned sites are mostly located in inland valleys and waterlogged environments that could support rice growth. Thus, there is the need to explore proven technologies that could remediate such contaminated and abandoned sites to a state that could be useful again. Considering this context, this study sought to evaluate the practicality of growing rice on PTEs-contaminated ASM gold mine tailings and the potential use of organic soil amendments to facilitate this process.

The specific objectives of the study include the following:

- i. To investigate the availability and dynamics of PTEs mobilisation and immobilisation during rice growth under continuous flooding and as amended with rice husk biochar, corncob biochar, poultry manure and compost.
- ii. To quantify the effect of the application of the soil amendments on the growth of rice cultivated in a contaminated mining site
- iii. To quantify the effect of the application of soil amendments on the yield parameters of rice grown in the ASM-contaminated mining site
- iv. To assess the bioavailability and uptake of PTEs in rice cultivated on ASM-contaminated sites.

2. Materials and methods

2.1 Study area characteristics

A study involved a pot experiment carried out in a greenhouse located at the CSIR-Soil Research Institute in Kumasi in the Ashanti region of Ghana. The samples of mine tailings investigated were collected from five (5) different abandoned gold-mining sites in Nsiana located near Antoakrom in the Amensie West district of the Ashanti region.

The district falls within the semi-deciduous forest agroecological zone, characterised by a bimodal rainfall pattern with the major rainy season spanning March–July, while the minor rainy season occurs within September–November, as reported by Sekyi-Annan et al. (2021).

Sandy soil is the dominant soil type in the study area, which is an endemic small-scale mining and crop production enclave (Wongnaa et al., 2024), where degraded lands abandoned after mining operations with several heaped tailings prone to soil erosion are ubiquitous.

2.2 Characterization of soil amendments and mine tailings

Soil pH, organic carbon, total nitrogen, exchangeable bases, and cation exchange capacity in the organic amendments as well as existing potentially toxic elements (i.e., Zn, Cu, Mn, Fe, Cd, Pd, As, and Hg), were determined using standard analytical methods.

2.3 Incubation experiments, treatments and experimental design

Five treatments were tested, including sieved tailing samples and four organic soil amendments: rice husk biochar, corncob biochar, poultry manure, and compost. The tailing samples were mixed with the amendments, resulting in a total weight of 6.3 kg for each treatment in a pot experiment. The treatment pots were arranged in RCBD in a greenhouse. The treatments were then ponded to a water depth of ≥ 2 cm above the surface for 28 days.

2.4 Nursery establishment and transplanting of rice

Certified AGRA rice seeds were nursed in uncontaminated soil for 21 days. Each treatment pot with a diameter of 20 cm and depth of 18 cm, measuring 0.0314 m² in surface area, was cultivated with one (1) seedling.

2.5 Fertilizer and irrigation water application

Basal application of NPK 15:20:20 at a rate of 90:60:60 kg ha⁻¹ was applied at transplanting. Top dressing with ammonium sulphate was applied 25 days after transplanting. Irrigation water was applied at a regular interval to maintain water depth at ≥ 2 cm (Figure 1).



Figure 1. Application of irrigation water to a treatment pot

2.6 Agronomic data collection

In all the treatment pots, crop growth parameters, including plant height, number of tillers, number of panicles, and days to panicle initiation, were measured at two-week intervals. At physiological maturity (i.e., approximately three and a half months after transplanting), all rice plants were manually harvested from the pots using a sickle and yield components including grain yield, total aboveground biomass and weight of 1000 grains were determined.

From all pots, rice biomass samples separated into three (3) parts, including roots, shoots and panicles, were oven dried at 65 °C for 48 hours to have the dry aboveground biomass per pot area, which will be extrapolated to dry aboveground biomass per hectare. Harvested panicles were carefully threshed and winnowed.

Rice grains were then weighed using an electronic balance and paddy rice yield per pot area was calculated and subsequently extrapolated on a per-hectare basis. The weight of 1000 grains was determined for each treatment pot by counting filled grains, weighing and extrapolating to 1000 grains in cases where the number of grains was not up to 1000.



Figure 2. Rice biomass separated into roots, shoots and panicles

2.7 Monitoring of soil chemical properties and potentially toxic elements during crop growth

A handheld meter was used to measure soil chemical properties, including pH, electrical conductivity (EC), redox potential, salt content, salinity, soil temperature, fertility and resistance. Additional soil slurry samples were collected for the analysis of PTEs (As, Cd, Pb, Hg, Cu, Zn, Cr, Ni) via aqua regia digestion (Figure 3).



Figure 3: Collected soil slurry for laboratory analyses

2.8 Determination of uptake potentials of the plants (Soil-to-plant element mobility indices using translocation factor (TF))

TF quantifies and estimates the mobility of the elements from the roots (below-ground biomass) into other aerial parts (above-ground biomass, e.g., stem, shoot) of the plant. A TF of 1 is used to assess or estimate food chain contamination and uptake potential of the PTE. A $TF < 1$ indicates metal uptake and food chain contamination and vice versa.

$$TF = C_{shoot} / C_{root}$$

Where TF = Translocation factor; C_{shoot} = contents of As in the plant shoot in mg/kg; C_{root} = contents of As in the plant root in $mg\ kg^{-1}$.

3.0 Analyses using NIRS

3.1 Soil samples

The soil samples originated from pot experiments done by researchers at the Soil Research Institute, Kwadaso, Kumasi, Ghana. A total of 15 wet soil samples from five main groups, i.e., control or untreated, poultry manure, compost, corn cob biochar, and rice husk biochar-treated soils, were collected in triplicate into ziplock transparent bags and prepared for NIR analysis.

3.2 NIR measurement

Under room temperature (25 °C), a handheld NIR device (NIR-S-GI, InnoSpectra Co., Hsinchu, Taiwan) with a wavelength range of 900-1700 nm and 10 nm resolution was used to collect the transmittance spectra of the 15

wet soil samples placed in transparent ziplock bags. To obtain the representative spectra of all the soils, ten successive scans at different contact points were recorded for each soil sample, resulting in a total of 150 spectra.

3.3 Multivariate Data Analysis

The Unscrambler 11.0 (CAMO Analytics AS, Oslo, Norway) was used for the multivariate data analysis. A moving average smoothing of 5 points was applied to the raw spectra data before the second-order Norris derivative with a 5-point gap (Norris, 2001) was calculated to decrease the additive and multiplicative influence of light scatter for all spectra.

Qualitatively, principal component analysis (PCA) (Cowe & McNicol, 1985) was used to describe the basic multidimensional characteristics of the NIR data matrix and to visualise the differences between the sample groups.

Starter calibrations for the microelements (As and Pb) were conducted using partial least squares (PLS) regression (Fearn, 2011). The models were validated with the leave-one-out cross-validation, where, iteratively, the spectrum of each sample was omitted from the calibration set, and the model was tested on the samples left out (Næs et al., 2017).

The robustness of each model was determined by evaluating the determination coefficients (R^2 , R^2_{cv}) and the root mean square error (RMSEC, RMSECV) of calibration and cross-validation, respectively (Næs et al., 2017).

3.4 Data analysis

Laboratory analysis of the slurry, soil and plant samples, data processing and statistical analysis are ongoing. ANOVA and Pearson correlation analyses are being done using OriginPro to identify treatment effects and relationships among variables.

4.0 Results and discussion

4.1 Findings from the NIR Spectroscopy analyses

From the PCA score plot, along PC1, the soils treated with rice and corn cob biochar separated from the rest of the soil samples, including the control or untreated soil, with a variance of 98% of the total variation of 99%. This separation was influenced by two important absorptions, i.e., 1375nm (C-H combination and SiOH absorption, representing soil hydrocarbon or aliphatic and silica compounds) and 1445nm (N-H, 1st overtone, representing N-H aromatic compounds such as soil aromatic primary amines) (Williams & Antoniszyn, 2019).

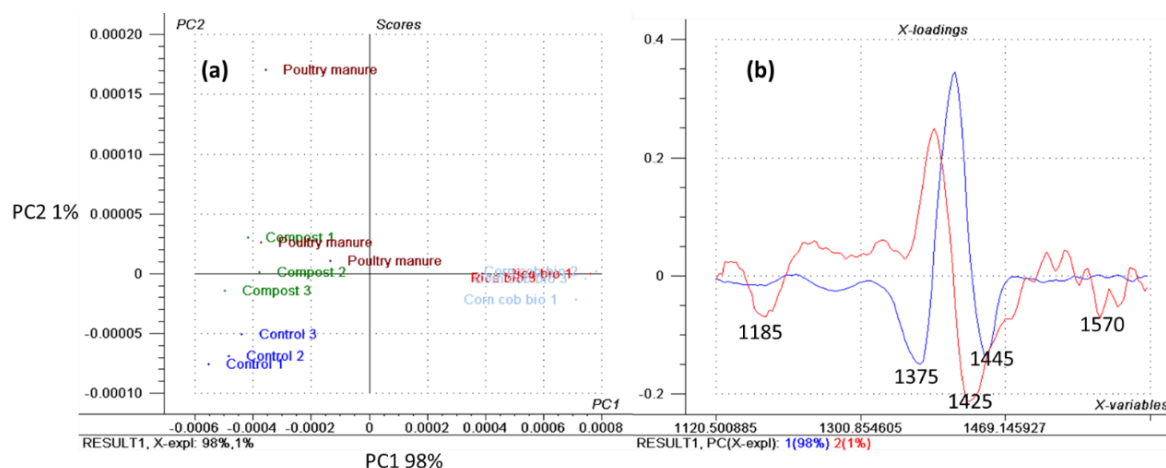


Figure 1. PCA score plot (a) calculated from second derivative (gap 5; smoothing 5) NIR spectra (1120-1600 nm) showing the treated soils (poultry manure, compost, corn cob biochar and rice husk biochar) and control soil with PC1 and 2 loading vectors defining the plane of the score plot and absorbances (nm) that contributed to the scores.

Along PC2, however, a small variation of 1% was observed between the control, compost and poultry manure treated soils. This was influenced by 1185nm (C-H, 2nd overtone), 1425nm (O-H 1st overtone) and 1570nm (N-H 1st overtone) (Williams & Antoniszyn, 2019), representing hydrocarbon, hydroxyl, and amide-containing compounds in the soil.

Redox potential dynamics and implications for PTE mobility

Redox potential (Eh) varied significantly across treatments, indicating differences in soil redox status (Fig. 3). The control (C) showed a steady rise in Eh values from about 250 mV at week 2 to over 500 mV by week 5, indicating increasingly oxidising conditions. These conditions usually hinder the mobility of many PTEs, as oxidised environments encourage the precipitation or adsorption of metals such as Pb, Cu, and Cr onto mineral surfaces or oxides.

The M treatment consistently maintained reducing conditions during the incubation, with Eh values remaining below -200 mV. This reduced environment promotes the dissolution of Fe/Mn oxides, increasing the solubility and mobility of associated PTEs like As (Mensah et al., 2022). These findings support earlier reports that organic-rich amendments can enhance microbial activity and cause oxygen depletion, resulting in reductive dissolution processes (Yang et al., 2021). Compost (Com) and CCB amendments kept Eh values between 200 and 400 mV. Moderately oxidising conditions help stabilise metals via adsorption or co-precipitation. The RHB treatment followed a similar trend until week 4 but saw a significant drop in Eh by week 5, likely due to anaerobic decomposition and oxygen depletion. This shift may briefly enhance the mobility of redox-sensitive elements. The redox behaviour of each treatment shows its ability to affect PTE dynamics. Manure may worsen metal

mobilisation in prolonged reducing conditions, while Com and CCB seem more effective in maintaining redox conditions that restrict PTE release, suggesting potential for soil remediation strategies.

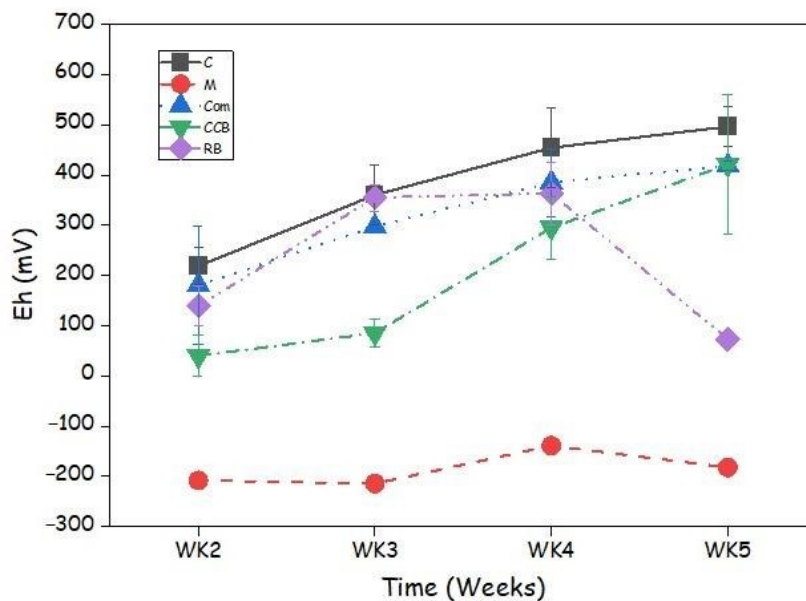


Fig. 3: changes in the soil redox potential during the pot experimental period

4.2 Effects of treatments on plant height

Plant height varied significantly across treatments over five weeks. The control group achieved the highest growth at about 75 cm, indicating optimal conditions. The M treatment showed the poorest growth, peaking at 30 cm before declining, likely due to PTEs becoming more available under reducing conditions. In contrast, com, CCB, and RB treatments resulted in intermediate growth, reaching 65-70 cm by week 5, suggesting they improved soil conditions and reduced toxicity, making them viable for remediation strategies.

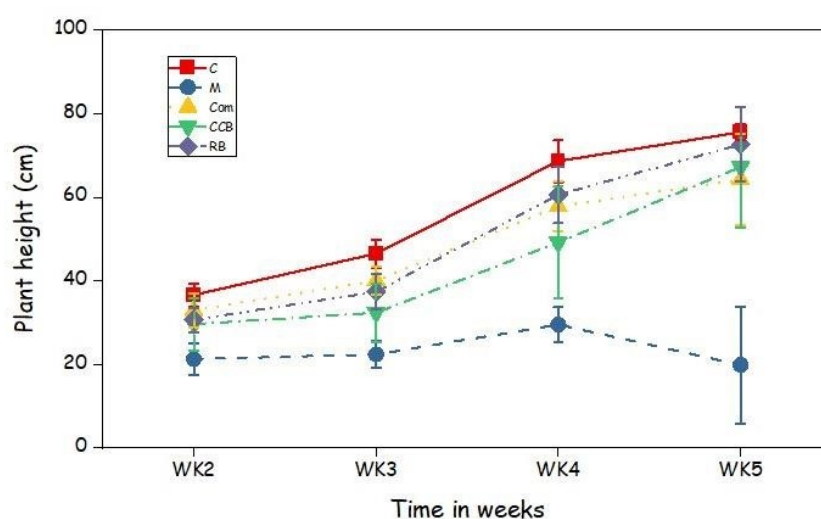


Fig. 4: changes in the plant height of the samples during the pot experimental period

Table 1. Arsenic (As mg/L) and Mercury (Hg mg/L) levels in treated soils used in calibration and cross-validation.

Heavy metals in treated soils	Min value	Max value	Mean	SD	N
Arsenic (As mg/L)	0.62	18.15	5.42	5.95	15
Mercury (Hg mg/L)	0.23	1.5	0.69	0.3	15

Table 2. Starter calibration and cross-validation results for the As and Hg (N = 15) with second derivative (smoothing 5, gap 5) pre-treatment

Heavy metals in treated soils	LV	R ²	RMSEC	R ² CV	RMSECV
Arsenic (As mg/L)	3	0.929	1.634	0.802	2.943
Mercury (Hg mg/L)	3	0.837	0.001	0.525	0.002

R²: coefficient of determination for calibration calculated in percentage; R² Cv: coefficient of determination for cross-validation calculated in percentage; RMSEC: root mean squared error of calibration; RMSECV: root mean squared error of cross-validation; SD: standard deviation; N: number of samples.

Arsenic (As) starter calibration model: from Table 2, the coefficient of determination for calibration R² and root mean square error of calibration show a very good fit (92.9% performance) to the training data, with moderate error. In cross-validation, the model still has a good performance, but since the number of samples (N=15) for the starter calibration was small, the possibility of overfitting may be possible.

Mercury (Hg): The model for Hg in calibration is good (83.7% performance) with low predicting errors, but not as that of As. In cross-validation, the performance decreased (52.5%) and may therefore not be good for the generalised overall predicting performance in new

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5. Concurrent Revegetation and Rehabilitation of Degraded Lands: An Integrated Approach to Environmental Restoration

John Peter Okoro

Extended Abstract

I. Introduction

Land degradation can be referred as the reduction or loss of the biological or economic productivity of land, often caused by a combination of human-induced and natural factors, including deforestation, mining, overgrazing, agricultural intensification, and climate change (UNCCD, 2022). Globally, a report shows that land degradation directly affects over 3.2 billion people and jeopardizes the livelihoods, food security, water supply, and health of entire populations, particularly those living in dryland and sub-Saharan African regions (UNEP, 2021; IPBES,

2018). This multidimensional challenge has galvanized global attention, especially within the context of the UN Decade on Ecosystem Restoration (2021–2030), which calls for large-scale efforts to restore degraded ecosystems. Restoration efforts are essential not only to reclaim productivity and ecological integrity but also to contribute to global climate mitigation and biodiversity conservation goals (Aronson et al., 2020; FAO & UNEP, 2021). In this regard, the tools of revegetation and rehabilitation have become increasingly pivotal.

Revegetation is typically seen as the re-establishment of vegetation cover on barren or eroded land. It may involve the planting of grasses, shrubs, and trees, both through natural regeneration or assisted techniques, to stabilize the soil, restore biodiversity, and enhance microclimates (Tighe & Brown, 2000). On the other hand, rehabilitation encompasses broader ecological and structural interventions to restore the ecosystem's capacity to deliver essential functions and services. This includes soil conditioning, hydrological management, re-contouring of landscapes, and contaminant removal (Bradshaw, 1997; Mendez & Maier, 2008). However, these approaches have often been treated as sequential or isolated strategies, which can reduce their long-term effectiveness and ecological coherence. For instance, revegetation alone may produce transient aesthetic improvements without restoring the underlying soil fertility or hydrology. Conversely, structural rehabilitation without vegetation fails to re-establish critical ecological processes such as photosynthesis, organic matter cycling, and habitat creation (Parrotta et al., 1997). Thus, a concurrent approach, where revegetation and rehabilitation activities are designed and implemented together, has gained traction as a more holistic and efficient pathway to land restoration. This integrated method acknowledges the interconnectedness of biotic and abiotic elements within ecosystems and leverages their mutual reinforcement to achieve sustainable recovery (D'Odorico et al., 2013; Chazdon & Guariguata, 2016).

In regions impacted by extractive industries, such as gold mining in some West African countries, the urgency for concurrent revegetation and rehabilitation cannot be overstated. Open-pit mining leaves behind massive land scars, topsoil loss, toxic residues, and disrupted hydrological regimes, posing severe environmental and public health risks (Asante et al., 2021; Obiri et al., 2020). Evidence from Ghana and the Democratic Republic of Congo suggests that restoration initiatives that simultaneously address soil remediation, pollutant removal, and the establishment of resilient vegetation are more likely to succeed (Aigbedion & Iyayi, 2007; Nwachukwu & Mmom, 2011). In areas affected by gold mining, especially artisanal and small-scale gold mining (ASGM), soils and water bodies are often contaminated with heavy metals like mercury (Hg), arsenic (As), lead (Pb), and cyanide residues. Phytoremediation offers a sustainable approach to restoring these sites.

Furthermore, successful concurrent approaches are increasingly being aligned with ecosystem-based adaptation and climate-smart land use strategies. They enhance carbon sequestration, improve rainfall infiltration, mitigate dust and erosion, and restore livelihoods through agroforestry or multipurpose land-use systems (FAO & UNEP, 2021). Technological innovations, such as remote sensing, geographic information systems (GIS), and phytotechnologies are also facilitating better assessment, monitoring, and targeting of concurrent restoration interventions (Panagos et al., 2018; Xu et al., 2006). Despite the promise, integrating revegetation and rehabilitation remains constrained

by technical, financial, and governance barriers. Limited capacity in local institutions, inadequate enforcement of environmental restoration regulations, and short-term profit motives of industries often lead to fragmented or superficial restoration efforts. Additionally, there is a need to better incorporate local knowledge systems, customary land-use practices, and the participation of indigenous and rural communities in restoration design and implementation (IUCN, 2011; UNEP, 2021).

This article explores the principles, methodologies, challenges, and benefits of concurrently applying revegetation and rehabilitation strategies to degraded landscapes. Emphasis is placed on lessons drawn from mining-affected areas in Ghana and Congo, where the integration of ecological, technological, and sociocultural dimensions is essential to achieving long-term land restoration and sustainable development. By adopting a systemic, contextsensitive approach to land recovery, concurrent revegetation and rehabilitation not only enhance ecological resilience but also strengthen climate adaptation, food security, and community well-being in the vulnerable regions.

2. Literature Insight

2.1 Revegetation, Restoration, Rehabilitation, and Reallocation

Technically, four terms usually come to mind whenever refurbishment of degraded ecosystem is mentioned. These include revegetation, restoration, rehabilitation, and reallocation. Revegetation refers to the process of reintroducing plant life to an area where vegetation has been lost or severely diminished. This process aims to stabilize soil, reduce erosion, improve water retention, and create habitats for wildlife. Revegetation can be natural (passive) or assisted (active), involving planting native or non-native species depending on the restoration goals (Tighe & Brown, 2000).

Restoration aims at complete return of a site to a pre-existing state from a taxonomic point of view – reestablishment of all indigenous species and the extirpation of all exotics.

Rehabilitation focuses on restoring the functional aspects of degraded ecosystems to support sustainable land use and ecological processes. It involves soil amendment, water management, erosion control, and re-establishment of vegetation and fauna. Rehabilitation may not necessarily aim to return the land to its original state but to a condition that supports ecological stability and human use. Rehabilitation concentrates on repairing damaged or blocked ecosystem functions, with the primary goal of raising ecosystem productivity quickly yet sustainably. It implies a higher level of ongoing site management than does restoration, wherein it is hoped that innate ecosystem processes will eventually take over. Reallocation, unlike restoration and rehabilitation, disregards the indigenous ecosystem while imposing new uses on the site (FAO, 2015).

2.2 Phytoremediation is an environmentally friendly and cost-effective method that uses plants to clean up soil, water, and air contaminated with hazardous contaminants. It harnesses the natural abilities of certain plants to

absorb, accumulate, degrade, or stabilize pollutants such as heavy metals, pesticides, solvents, crude oil, and other environmental toxins. For example, Sunflowers have been used to remove radioactive contaminants from soil in areas affected by nuclear disasters like Chernobyl.

Key Types of Phytoremediation:

1. Phytoextraction (Phytoaccumulation) – Plants absorb contaminants (especially heavy metals) through their roots and store them in above-ground parts, which are later, harvested and disposed of.
2. Phytostabilization – Plants immobilize contaminants in the soil, preventing them from leaching into groundwater or spreading.
3. Phytodegradation (Phytotransformation) – Plants break down organic pollutants into less harmful substances through metabolic processes.
4. Phytovolatilization – Plants absorb contaminants and release them into the air in a less toxic form through transpiration.
5. Rhizofiltration – Plant roots absorb or adsorb pollutants, particularly from water or wastewater.

2.3. The Need for Concurrent Approaches

Revegetation without rehabilitation can be short-lived if underlying soil or hydrological issues are not addressed. Conversely, rehabilitation without revegetation may stabilize land but fail to re-establish critical ecological interactions. A concurrent approach recognizes the interdependence of biotic and abiotic factors in ecosystem recovery.

2.4. Drivers of Land Degradation

Several factors contribute to land degradation, necessitating comprehensive restoration efforts:

1. Mining and industrial activities: Strip vegetation, pollute soil and water, and disrupt topography.
2. Deforestation: Reduces biodiversity, disrupts water cycles, and leads to soil erosion.
3. Overgrazing and unsustainable agriculture: Lead to soil compaction, nutrient depletion, and erosion.
4. Urbanization: Causes land sealing, fragmentation, and habitat loss.
5. Climate change: Exacerbates drought, erosion, and land-use pressures.

3. Methodologies for Concurrent Revegetation and Rehabilitation

3.1. Site Assessment and Planning

Effective concurrent restoration begins with a thorough assessment of:

- Soil type and quality
- Hydrology and drainage patterns
- Existing vegetation and fauna
- Land use history
- Pollution levels

3.2. Soil Preparation and Amendment

Degraded soils often lack essential nutrients and structure. Steps include:

- Removing contaminants (e.g., heavy metals, hydrocarbons)
- Amending soil with organic matter, compost, or biochar
- Enhancing microbial activity through inoculation with mycorrhizae

3.3. Plant Selection and Establishment

Plant species should be selected based on:

- Native status and ecological suitability
- Ability to improve soil and support wildlife
- Tolerance to site-specific stresses (e.g., salinity, heavy metals)

Thus, revegetation methods include direct seeding, seedling transplantation, hydroseeding, and use of seed balls.

3.4. Erosion Control and Water Management

Structural and vegetative measures are used to stabilize the land:

- Contour bunding and terracing

- Check dams and silt traps
- Mulching and cover crops
- Constructed wetlands for water filtration

3.5. Monitoring and Adaptive Management

Post-restoration monitoring ensures long-term success:

- Assess vegetation cover, species diversity, and soil quality
- Adjust management practices based on feedback
- Engage local communities in participatory monitoring

4. Case Studies of Successful Concurrent Restoration

4.1. Gold Mining Sites in Ghana

In Ghana, artisanal and small-scale gold mining has caused extensive degradation. Integrated restoration using vetiver grass for erosion control, Indian mustard for phytoextraction, and composted waste for soil improvement has shown promising results in restoring land functionality and vegetation (Yeleele et al., 2018).

4.2. Australia's Mining Rehabilitation Framework

Australia mandates concurrent rehabilitation during mining operations. Companies must progressively restore land by re-contouring terrain, replacing topsoil, and replanting native vegetation, reducing the total area of disturbed land over time (World Bank, 2020).

4.3. China's Loess Plateau Restoration

One of the most ambitious land restoration efforts globally, the project used terraces, vegetation cover, and soil amendments to rehabilitate over 35,000 km² of severely degraded land, improving agriculture, biodiversity, and carbon sequestration (Xu et al., 2006).

5. Challenges in Implementing Concurrent Revegetation and Rehabilitation

5.1. Technical Challenges

- Selecting appropriate species for stressed environments

- Managing invasive species
- Ensuring seedling survival in harsh conditions

5.2. Socioeconomic Constraints

- High initial investment and maintenance costs
- Land tenure issues affecting long-term stewardship
- Lack of technical capacity in local communities

5.3. Policy and Institutional Barriers

- Weak enforcement of environmental regulations
- Poor coordination among stakeholders
- Inadequate integration into land use planning

6. The Role of Stakeholders in Restoration Efforts

6.1. Government Agencies Governments play a crucial role in policy formulation, funding, and enforcement. Integrated land restoration programs must be embedded in national development strategies (UNEP, 2021).

6.2. Local Communities Community involvement ensures sustainability and relevance. Participatory approaches enhance local ownership and build capacity for long-term management (IUCN, 2011).

6.3. Private Sector and NGOs Mining companies, agricultural businesses, and NGOs contribute expertise, resources, and innovation. Public-private partnerships can scale up restoration efforts (Parrotta et al., 1997).

7. Ecosystem Services and Benefits of Concurrent Restoration

Concurrent revegetation and rehabilitation yield multiple ecosystem services:

- Provisioning: Improved soil fertility and productivity
- Regulating: Carbon sequestration, flood mitigation
- Supporting: Soil formation, nutrient cycling
- Cultural: Aesthetic, spiritual, and educational values (UNEP, 2021; FAO, 2015)

8. Future Directions and Innovations

8.1. Use of Remote Sensing and GIS These tools help in site assessment, monitoring vegetation cover, and detecting degradation trends (IUCN, 2011).

8.3. Assisted Natural Regeneration (ANR) This low-cost method protects and nurtures natural regrowth, particularly effective in tropical regions (FAO, 2015).

8.4. Integrating Indigenous Knowledge Traditional land management practices often align with ecological principles and can inform adaptive restoration approaches (UNEP, 2021).

8.2. Phytotechnology Combining phytoremediation with revegetation enhances the removal of pollutants and improves plant growth (Mendez & Maier, 2008). Phytoremediation can contribute to both revegetation and rehabilitation processes, but its effectiveness and scope depend on how it is applied and the specific goals of the restoration project. Revegetation can improve fertility of degraded mined lands although it requires longer period to restore the fertility close to the original level (Mensah, 2015). Some of the promising tree species that can be used for revegetation are Acacia, Leucaena and other legume trees that are acid-tolerant and can add substantial amount of organic matter to the soil (Mensah, 2015). A study has shown that introduction of specific vegetation in a heavy metals/metalloid-polluted area can help prevent erosion or contaminant leaching (Opoku, et al., 2020). Through phytoremediation, plants can extract, stabilize, or degrade contaminants in soil, water, or air. As such, it inherently involves the reintroduction and growth of vegetation on degraded lands, contributing directly to revegetation. These processes contribute to re-establishing plant cover, stabilising soil, and enhancing biodiversity all goals of revegetation.

Indigenous and Adapted Phytoremediation Plants

	Name	Role	Application	Source
I	Acacia spp.	Nitrogen-fixing trees that improve soil fertility and structure.	Commonly used in revegetation efforts to stabilize soils and enhance nutrient content.	Mensah, 2015
	Leucaena leucocephala	Fast-growing leguminous tree that enriches soil nitrogen levels.	Effective in rehabilitating degraded lands and preventing erosion	Mensah, 2015
	Paspalum vaginatum	Salt-tolerant grass species suitable for areas with saline conditions	Used in the rehabilitation of saltaffected lands and restoration of degraded sites	Opoku et al, 2020

	<i>Fimbristylis</i> spp.	Grass-like plants capable of accumulating heavy metals	Utilized in the phytoremediation of soils contaminated with hydrocarbons and heavy metals	Phytoremediation potential of indigenous Ghanaian grass and grass-like species
	<i>Sporobolus pyramidalis</i> (Giant Rats-tail Grass)	Grass species known for its ability to thrive in degraded soils	Assessed for phytoremediation potential in mining impacted areas	Assessing phytoremediation potentials of selected plant species in Ghana
	<i>Melinis repens</i> (Natal Grass)	: Fast-growing grass that establishes quickly on disturbed soils	Evaluated for its effectiveness in stabilizing soils and aiding in phytoremediation	Assessing phytoremediation potentials of selected plant species in Ghana
	<i>Lantana camara</i>	Shrub known for its hardiness and ability to grow in poor soils	Studied for its potential in phytoremediation of contaminated sites	Assessing phytoremediation potentials of selected plant species in Ghana
	<i>Crotalaria juncea</i> (Sunn Hemp)	Leguminous plant that improves soil fertility and structure	Used in phytoremediation to extract heavy metals and enhance soil quality	Crotalaria juncea
	<i>Eichhornia crassipes</i> (Water Hyacinth)	Aquatic plant effective in removing heavy metals from water bodies	Employed in the phytoremediation of water bodies contaminated by mining activities	Pontederia crassipes

9. Conclusion

Phytoremediation is a sustainable and cost-effective method for restoring degraded mining lands, and several plant species native or adapted to Ghana have demonstrated significant potential in this regard. These plants not only aid in the removal or stabilization of heavy metals and other pollutants but also contribute to soil stabilization and biodiversity enhancement, addressing both revegetation and rehabilitation needs. Phytoremediation does not only solve revegetation; when used strategically, it supports both revegetation and rehabilitation simultaneously. Therefore, in integrated restoration approaches like the one your document promotes, phytoremediation serves as a dual-purpose tool that can effectively contribute to the success of concurrent revegetation and rehabilitation. Phytoremediation can contribute to both revegetation and rehabilitation processes, but its effectiveness and scope depend on how it is applied and the specific goals of the restoration project. Concurrent revegetation and

rehabilitation represent a holistic, synergistic approach to restoring degraded lands. By addressing both biotic and abiotic factors simultaneously, this strategy enhances ecological resilience, promotes sustainable land use, and contributes to global environmental goals such as the UN Decade on Ecosystem Restoration. Success requires collaboration across sectors, investment in research and innovation, and the empowerment of local communities as stewards of restored landscapes.

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6. The Role of Biotechnology in Phytoremediation

Benjamin Aboagye Danso and Nana Ama Appiagyei Okyere

Abstract

The rapid expansion of illegal gold mining activities in Ghana has precipitated a severe environmental crisis, with approximately 60% of the nation's freshwater sources contaminated by persistent heavy metals such as arsenic, cadmium, lead, and mercury. These toxic elements, which are non-biodegradable and bioaccumulative, pose profound threats to human health, agricultural productivity, and ecosystem stability. Conventional remediation techniques, including soil excavation and chemical treatments, are often prohibitively expensive, technologically complex, and environmentally disruptive, particularly in resource-limited settings. In this context, phytoremediation—a plant-based, eco-friendly remediation strategy—has emerged

as a promising alternative. By harnessing the natural ability of certain plant species to uptake, stabilize, or metabolize pollutants, phytoremediation offers a cost-effective and sustainable solution for rehabilitating contaminated soils and water bodies.

However, the efficacy of phytoremediation is constrained by inherent biological limitations, such as the slow growth rates and low biomass production of many metal-hyperaccumulating plants, as well as their restricted capacity to tolerate and accumulate diverse pollutants. Recent advances in biotechnology present transformative opportunities to overcome these challenges. Genetic engineering techniques enable the transfer of hyperaccumulator traits—such as enhanced metal uptake, translocation, and sequestration—into fast-growing, high-biomass plant species. For instance, the introduction of genes encoding metalbinding proteins, transporters, or detoxification enzymes can significantly augment a plant's phytoremediation potential. Additionally, biotechnological interventions can optimize root exudate profiles to stimulate microbial communities in the rhizosphere, thereby accelerating the degradation of organic pollutants.

This review synthesizes current research on the integration of biotechnology with phytoremediation, emphasizing its application in addressing heavy metal contamination in Ghana's mining-impacted regions. We evaluate case studies of genetically modified plants and their performance in field trials, highlighting successes such as the use of transgenic *Brassica* species for cadmium and zinc removal. Furthermore, we discuss the ecological and socioeconomic benefits of biotech-driven phytoremediation, including its potential to restore arable land, safeguard water quality, and provide economic opportunities through the cultivation of non-food biomass for bioenergy or industrial uses. Despite these advantages, we also address regulatory, ethical, and public acceptance challenges associated with genetically modified organisms (GMOs) in environmental remediation.

By bridging the gap between laboratory research and real-world implementation, biotechnology holds the key to unlocking the full potential of phytoremediation. Strategic collaborations among scientists, policymakers, and local communities will be essential to deploy these innovations effectively, ensuring sustainable environmental restoration and long-term resilience against pollution. This review paper underscores the urgent need for interdisciplinary approaches to combat environmental degradation, positioning biotech-enhanced phytoremediation as a cornerstone of ecological conservation in Ghana and other mining-affected regions globally.

Keywords: Phytoremediation, Biotechnology, Heavy Metal Contamination, Genetic Engineering, Environmental Sustainability, Mining Pollution, Ghana.

7. The environmental and social consequences of illegal and unregulated mineral mining in Ghana

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Abstract:

The environmental and social consequences of illegal and unregulated mineral mining in Ghana continue to threaten ecological stability and community health. In response, Quick Impact Agency (QIA), a German Ghanaian ecological NGO, is piloting a scalable community-driven model that integrates phytoremediation, agroforestry, and environmental education to restore degraded mining landscapes. Currently reclaiming 92 acres

of severely damaged land in Ghana's Western North Region, QIA's strategy combines fast-growing phytoremediation tree species with native crops to simultaneously detoxify soil, restore biodiversity, and reintroduce sustainable land use. This interdisciplinary effort is powered by a participatory governance model that engages youth, local farmers, and indigenous experts to co-create solutions and cultivate stewardship. Preliminary soil assessments pre- and post-intervention show promising reductions in heavy metal concentrations and improvement in soil quality parameters. Moreover, the initiative incorporates biochar application and companion planting to enhance metal immobilization and soil fertility. This presentation will explore: (1) The phytoremediation protocol used by QIA, (2) Challenges and successes of working with mine-contaminated soil, (3) The role of agroforestry in long-term ecological and economic recovery, and (4) Pathways to replicate this model in other parts of Africa. QIA seeks to share our findings, learn from other researchers and practitioners, and form strategic collaborations aimed at reclaiming degraded lands across the Global South through sciencebased, community-led solutions.

8. Impact of Mining Activities on Soil Quality and its Remediation Measures

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Introduction

Mining of minerals, most especially gold, has been on the major activities in recent years in Ghana. Mining for gold has been an activity that has impacted negatively on the environment. There have been several attempts to address the problem but with no avail. The unregulated artisanal and small-scale gold mining known as *galamsey* in Ghana has become a significant concern in countries with gold deposits. These operations often involve numerous unlicensed and untrained individuals working across multiple sites using various equipment to excavate soil in search of gold. The methods of gold extraction do not only lead to the random destruction of land and vegetation but also releases hazardous substances like mercury and cyanide into the soil. Soil serves as a reservoir

for many contaminants, including heavy metals like mercury (Hg) and lead (Pb). Numerous studies (Amuah et al., 2022; Mantey et al., 2020; Opoku et al., 2022) have linked soil contamination to mining activities. These activities significantly impact the environment, particularly soil quality, by degrading surface morphology and soil structure, resulting in detrimental effects on the land (Hu et al., 2020). Soil contamination from mineral exploration can have severe consequences for the health of the surrounding communities and their livelihoods, making the evaluation of soil quality essential for understanding the environmental impact of mining (Leuenberger et al., 2021). Understanding these environmental impacts is essential for developing effective strategies to mitigate the adverse effects of illegal mining. This research aims to evaluate the impact of mineral extraction activities on soil quality in Ahafo Kenyasi and how the contaminants could be remediated.

Materials and Methods (or Methods)

The study adopted an integrated approach, incorporating laboratory scrutiny of soil samples, and the acquisition of data through questionnaires. This diversified design was crafted to offer a comprehensive insight into the consequences of illegal mining on soil characteristics within Ahafo Kenyasi. The sampling procedure aimed to assess the impacts of illegal mining on soil quality in Ahafo Kenyasi. Four illegal mining sites—Site 1, Site 2, Site 4 and Site 4 were selected, along with a control site (Control 1) without no mining activities. This control site served as a benchmark to compare the four selected sites. Soils samples were taken from each site using auger and homogenized to create a composite sample to reflect the overall soil characteristics of each site (Wang et al., 2002). The samples were preserved in cool, dry conditions as per Sekely & McClain (2008), transported to the lab within 48 hours for analysis of pH, organic carbon, organic matter, nutrients (Ca, Cu, Mg, K, P, N, Na), and heavy metals (Cd, Pb, As, Ni, Mn, Hg, Zn, Fe). The data obtained was analyzed using IBM SPSS 27.0 and Microsoft Excel 2016. 5)

5) Results

The heavy metal concentrations in soil samples collected from various locations, including Bogyampa Nkwantah (control site) and four other mining-impacted areas (Bepow So, Old Site, Kenyasi Number 1, and Akentenso), reveal concerning levels of pollutants, particularly in the mining zones.

Table 8: Summary of Heavy Metal concentration by Sampling Locations

Sample Location	Zn	Fe	Mn	Cu	Hg	Cd
Bogyampa Nkwantah (Control)	25.85±2.05	278.83±55.29	27.92±14.82	29.96±4.56	1.57±0.25	4.44±0.52
Bepow So	243.17±9.77	558.70±91.39	56.52±6.60	77.89±42.87	34.52±10.82	30.13±6.78
Old Site	201.68±13.04	780.82±57.55	100.39±35.72	87.82±25.12	62.91±6.12	44.31±26.77
Kenyasi Number 1	95.14±2.94	623.11±28.46	49.42±47.37	126.44±22.83	80.29±12.90	28.67±2.66
Akentenso	168.67±28.91	1424.50±340.23	82.58±8.91	126.79±4.52	65.18±8.75	26.03±4.23
WHO Standard(mg/L)	3.0	0.3	0.4	2.0	0.006	0.003

Sample Location	As	Pb	Ni
Bogyampa Nkwantah (Control)	1.44±0.81	0.74±0.18	0.82±0.10
Bepow So	23.04±5.02	9.44±13.80	1.56±0.46
Old Site	24.31±3.52	21.66±1.55	3.89±1.49
Kenyasi Number	17.92±1.67	21.90±5.55	4.18±0.944
Akentenso	24.94±5.20	24.60±7.88	4.97±0.60
WHO Standard (mg/L)	0.01	0.01	0.02

Table 4. 1 Correlation Coefficients of heavy metals in soil

Parameters	Zn	Fe	Mn	Cu	Hg	Cd	As	Pb	Ni
Zn	1								
Fe	0.416	1							
Mn	0.689	0.697	1						
Cu	0.352	0.740	0.510	1					
Hg	0.355	0.610	0.611	0.944*	1				
Cd	0.779	0.395	0.844	0.567	0.728	1			
As	0.877	0.699	0.822	0.743	0.741	0.873	1		
Pb	0.398	0.783	0.757	0.925*	0.959**	0.723	0.785	1	
Ni	0.251	0.822	0.693	0.911*	0.918*	0.586	0.679	0.982**	1

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Discussion

The heavy metal concentrations in soil samples collected from various locations, including Bogyampa Nkwantah (control site) and four other mining-impacted areas (Bepow So, Old Site, Kenyasi Number I, and Akentenso), reveal concerning levels of pollutants, particularly in the mining zones. For instance, Zinc (Zn) levels in Bepow So (243.17 mg/kg) and Old Site (201.68 mg/kg) significantly exceeded the WHO standard of 100 mg/kg for agricultural soil (Wyszkowska et al., 2016). Similarly, Iron (Fe) concentrations were alarmingly high in Akentenso (1424.50 mg/kg) and Old Site (780.82 mg/kg), far above the WHO guideline of 300 mg/kg, indicating possible soil contamination from mining activities (Rashid et al., 2023). Copper (Cu) levels were also elevated, particularly in Kenyasi Number I (126.44 mg/kg) and Bepow So (77.89 mg/kg), which exceeded the WHO standard of 50 mg/kg, suggesting significant pollution. The presence of Mercury (Hg) and Cadmium (Cd) is particularly troubling, with values at the Old Site (62.91 mg/kg for Hg) and Bepow So (30.13 mg/kg for Cd) well above the WHO guideline of 1 mg/kg for Hg and 3 mg/kg for Cd, indicating severe environmental and health risks associated with illegal mining operations (Zhou et al., 2020). For Arsenic (As), levels at Bepow So (23.04 mg/kg)

and Old Site (24.31 mg/kg) far exceed the World Health Organization (WHO) guideline of 0.01 mg/kg for arsenic in agricultural soil, indicating a severe contamination issue that poses serious health risks, including skin lesions, respiratory problems, and increased cancer risk (WHO, 2019). Lead (Pb) concentrations were alarmingly high in Akentenso (24.60 mg/kg) and Old Site (21.66 mg/kg), surpassing the WHO limit of 300 mg/kg for agricultural soils, which indicates potential health hazards, particularly neurological impairments in children (Zhang et al., 2020). The high variability in Pb levels, especially at Bepow So (9.44 mg/kg), also reflects the widespread environmental impacts of mining activities. For Nickel (Ni), levels in Akentenso (4.97 mg/kg) and Kenyasi Number 1 (4.18 mg/kg) are concerning but below the WHO guideline of 50 mg/kg for agricultural soils. However, continuous exposure and accumulation in the food chain can lead to toxicity (Baker et al., 2021). Overall, these findings highlight the urgent need for stringent environmental monitoring and remediation strategies to mitigate the adverse effects of illegal mining, as the levels of these heavy metals present significant risks to human health and the surrounding ecosystem.

Correlation analysis of heavy metals

Zinc (Zn) exhibited a strong positive correlation with arsenic (As) ($r = 0.877$) and cadmium (Cd) ($r = 0.779$), reflecting findings from Adesuyi et al. (2020), who reported similar patterns in soils near mining areas, where Zn often co-occurs with other heavy metals due to anthropogenic activities. Iron (Fe) showed a moderate correlation with lead (Pb) ($r = 0.783$), indicating that Fe may play a crucial role in the retention and mobility of Pb in contaminated soils. This is consistent with the work of Hartley & Lepp, (2008) who highlighted the importance of iron oxides in mitigating the bioavailability of heavy metals. The correlation between mercury (Hg) and copper (Cu) ($r = 0.944$) underscores the potential for simultaneous contamination, aligning with the observations by Chen et al., (2021) who noted that urban runoff can mobilize multiple heavy metals, posing health risks. Additionally, the strong relationship between nickel (Ni) and Pb ($r = 0.982$) suggests a shared anthropogenic source, particularly from industrial activities, as evidenced by studies like that of Bolea-Fernandez et al. (2018), which linked heavy metal pollution to specific industrial processes. Furthermore, the positive correlation between manganese (Mn) and cadmium (Cd) ($r = 0.844$) indicates potential interactions that could affect soil quality and plant uptake, a phenomenon discussed by Wang et al., (2019) who examined the competitive dynamics of heavy metals in agricultural soils.

Conclusion

The study on soil quality and heavy metal contamination in Kenyasi Ahafo reveals significant environmental impacts primarily associated with illegal mining activities. Key findings show strong positive correlations between soil moisture and essential nutrients (phosphorus, potassium, calcium, and magnesium), suggesting that improving moisture levels and pH could enhance nutrient availability for crops. In contrast, aluminum toxicity poses a substantial challenge, as indicated by negative correlations with nitrogen, magnesium, organic carbon, and organic matter, which impede nutrient uptake in acidic conditions. Analysis across locations identified Bogyampa

Nkwantah (Control) as having the most favorable soil conditions, characterized by higher moisture content, neutral pH, and elevated nutrient levels, whereas Bepow So exhibited significant soil degradation, pointing to substantial mining impact. Heavy metal analysis found alarming concentrations of zinc, arsenic, cadmium, lead, and other metals, particularly at the Old Site, raising concerns about the associated environmental and health risks. These levels exceed World Health Organization (WHO) safety standards, highlighting the need for immediate action to mitigate contamination. The community survey results also indicate widespread awareness of soil degradation, with many residents expressing concern over the environmental effects of illegal mining. These findings highlight the urgent need for soil remediation efforts, stricter enforcement of mining regulations, and sustainable land management practices to restore soil health and safeguard public well-being.

Recommendation and Contribution to Science, Policy and Society Soil Remediation Strategies:

Implement effective soil remediation techniques, such as phytoremediation and bioremediation, in areas heavily impacted by heavy metal contamination. Engaging local communities in these efforts can enhance soil quality and reduce the bioavailability of harmful metals. Sustainable Agricultural Practices: Promote sustainable farming practices, including organic fertilization, crop rotation, and cover cropping, to enhance soil health and mitigate aluminum toxicity. Educating farmers on these methods can improve agricultural productivity and environmental sustainability. Establish Monitoring Programs: Develop and maintain comprehensive soil and water quality monitoring programs to regularly assess heavy metal levels and soil nutrient status. This will facilitate timely interventions and help track the effectiveness of remediation efforts. Community Education and Engagement: Launch community education initiatives to raise awareness about the risks of heavy metal contamination and the importance of soil health. Engaging local residents in sustainable land management practices will foster a sense of ownership and responsibility for environmental stewardship. Strengthen Environmental Regulations: Advocate for stricter enforcement of environmental regulations concerning mining activities, particularly illegal operations that contribute to soil degradation and contamination. Collaborating with local authorities to implement these regulations is crucial for protecting public health. Support Collaborative Research: Encourage collaborative research between universities, governmental bodies, and NGOs to study the long-term impacts of heavy metal contamination on health and the environment. This research can inform policy decisions and guide effective management strategies. Integrated Land Management Plans: Formulate integrated land management plans that balance economic development with environmental conservation. Involving stakeholders, including local communities, government agencies, and the private sector, is essential for successful implementation. References

Yet to be sorted

9. Crop Recommendation System using Tiny Machine Learning in Reclamation of Mining Sites in Ghana

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Abstract

Optimizing crop selection based on environmental conditions and soil health in mining communities in Ghana is crucial for enhancing productivity and sustainability. This project presents a Crop Recommendation System utilizing Tiny Machine Learning (Crop-TinyML) to assist farmers in making informed decisions about which crops to cultivate during reclamation of mining sites for farming. The system is designed to recommend the top four crops suitable for cultivation based on input parameters such as nutrient levels (NPK values), temperature, humidity, and soil pH. The model was built using a neural network architecture, incorporating techniques like batch normalization and dropout to prevent overfitting and enhance generalization. After training, the model achieved high accuracy in predicting crop suitability, making it a reliable tool for agricultural decision-making. By integrating machine learning into a compact, low-power device, this system addresses the need for scalable, easy-to-use technologies that can improve crop management and contribute to global food security in mining communities in Ghana.