Artisanal and Small-Scale Gold Mining Impact on Soil and Agriculture: Evidence from Upper Denkyira East Municipality, Ghana

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ABSTRACT

The gold mining industry in Ghana has made a substantial contribution to the country's economic growth by generating diverse employment opportunities, both directly and indirectly, in mining communities. This has the potential to mitigate poverty and improve the quality of life for individuals and households in rural areas, where climate change is having a disproportionate impact on small-scale farmers. Nevertheless, it is crucial to recognize that this sector has also resulted in detrimental environmental impacts. A total of 150 key informants in Upper Denkyira East Municipality, comprising representatives from the Environmental Protection Agency, the Forestry Commission, the Mineral Commission, and other stakeholders, were interviewed using standardized questionnaires to ascertain the impact of mining on the soil, agriculture, and the environment. The study also employed inductively coupled plasma to assess the concentration of heavy metals in soils at a small-scale mining site. The soil analyses indicated high concentrations of heavy metals, such as mercury, arsenic, nickel, zinc, and iron. The Weighted Average Index, which was used to assess the impact of mining, revealed that communities face challenges such as deforestation, low crop yields, water pollution, land tenure issues, and a high cost of living. The study's analyses of measures to address small-scale mining challenges revealed that alternative livelihood, law enforcement, training and support, and access to mining concessions were perceived as suitable for addressing artisanal and small-scale mining. The study concluded that stricter mining regulations, promoting sustainable mining practices, and providing comprehensive training to miners on environmental protection and land reclamation can help mitigate the negative impacts of artisanal and small-scale mining. Additionally, supporting alternative means of livelihood for mining communities, such as agriculture or eco-tourism, can reduce reliance on mining and promote sustainable development.

Keywords: Agriculture, Mining, Small scale, Soil.

1. Introduction

Small-scale gold mining has served as a substantial means of subsistence for rural communities worldwide [1]. Research indicates that around 15 million people have engaged in gold mining as a result of the widespread desire to become wealthy quickly [2], [3]. Artisanal gold extraction has played a substantial role in the economies of many developing countries [4], [5]. According to [2], artisanal gold mining is primarily driven by poverty and is widespread in the remote rural areas of Africa and Asia. Artisanal gold mining in South Africa and Ghana, two major global gold producers, has resulted in a substantial rise in the earnings of rural communities [6], [7]. Reference [8] suggest that small-scale gold mining in Tanzania is often seen as a way to improve one's socioeconomic status. Reference [9] states that artisanal gold mining is used as a strategy to expand sources of income in developing nations.
Nevertheless, it is crucial to acknowledge that artisanal gold mining has been linked to substantial environmental issues [10]. According to [11], the perilous nature of environmental issues associated with artisanal gold mining in Sub-Saharan Africa has increased. The environmental impact of small-scale gold mining in Ghana, Tanzania, and Mozambique has been extensively documented in academic literature [3]–[4]. Reference [12] discovered that farming communities experience environmental stresses, specifically an increase in sheet, rill, and gully erosion. The erosion formations in Zimbabwe and Tanzania have increased as a result of the lack of technical interventions and land restoration at abandoned gold mining sites [13]–[15]. Scientific research has shown that artisanal gold mining has negative impacts on essential soil properties, which in turn poses a threat to the already depleted vegetation resources in tropical countries [16], [17]. Extensive deforestation in Ghana’s mining communities has led to a decline in biodiversity and genetic resources, as documented by [18]. Similarly, [19] found that a higher proportion of the plant life surrounding mining areas in South Africa experienced a decrease in biodiversity traits. Further research indicates that the existence of small-scale and illegal mining activities in the buffer zone of the Tambopata National Reserve in Peru has negatively affected the decline of vocalizing bird and frog populations [17]. In a study conducted by [20], the researchers investigated the effects of deforestation caused by artisanal gold mining on the spatial distribution of biodiversity in mining areas in Jordan.

Reference [21] found that artisanal gold mining activities have a significant impact on the hydrology of African mining regions. Reference [22] conducted a study which found that artisanal mining activities in Ghana have caused the depletion of 40 percent of the nation’s groundwater resources. Reference [9] found that artisanal gold mining had a negative effect on the overall quality of surface water. Reference [23] suggest that artisanal gold mining negatively affects surface and groundwater resources, endangering the livelihoods of marginalized farmers in downstream areas. Artisanal gold mining has been discovered to cause changes in land cover and land use patterns in developing countries [19]–[24]. Reference [18] discovered that the existence of artisanal gold mining operations on agricultural lands leads to increased tensions and conflicts between agricultural communities and artisanal gold miners.

Reference [22] state that the artisanal and small-scale mining (ASM) industry in Ghana provides employment to a substantial number of individuals, with more than 1 million people directly involved in this sector. Furthermore, it indirectly sustains the means of living for over 4.5 million individuals. Artisanal and small-scale mining (ASM) is distinguished by its dependence on manual labor and its use of basic technology for extracting and processing minerals [11]–[27]. ASM operations primarily employ a workforce composed of individuals with limited specialized skills, leading to a decrease in the unemployment rate, particularly among young people living in rural mining communities. Reference [28] found that this phenomenon results in a reduction in occurrences of armed robbery and social vices. In Ghana, the interaction between money and work in the agricultural and small-scale mining industries has enabled the development of the growth of farming operations, the enhancement of living conditions, and the establishment of entrepreneurial endeavors. Nevertheless, it is crucial to acknowledge that the close proximity of mining operations to agricultural lands has sparked apprehension regarding the adverse impact on soil fertility and water resources, thereby presenting potential risks to food security [16]–[27]. Furthermore, multiple studies [29]–[34] have identified positive externalities associated with artisanal and small-scale mining (ASM). These factors encompass the widespread occurrence of child labor, bias based on gender, the deterioration of land quality, the disappearance of wildlife species, the presence of harmful substances in the air, and the pollution of sediments, surface water, and groundwater with toxic heavy metals. Ghana’s arable land is exposed to adverse climatic conditions, such as elevated temperatures, erosion, and strong winds, due to the substantial loss of forest and vegetation. Several governments have enacted a range of laws and policies to reduce the negative effects caused by artisanal and small-scale mining (ASM), especially those that harm the environment. The laws and policies governing mineral extraction in Ghana consist of various legal instruments, including the Mineral Ordinance (CAP 185), Minerals Act, 1962 (Act 126), Legislative Instrument 1970 (LI 665), which was subsequently amended by LI 689, Small Scale Mining Law, 1989 (PNDCL 218), Mineral Commission Act, 1993 (Act 450), Environmental Protection Agency Act, 1996 (Act 490), and Minerals and Mining Act, 2006 (Act 703), among others [28]–[35].

Ghana’s mining sector policy framework has primarily emphasized the development of large-scale mining operations while also making efforts to legalize and support artisanal and small-scale mining (ASM). The endeavors encompass the reclassification of licensing procedures, the establishment of a mining cadaster system, and the execution of geological investigations to pinpoint regions with promising prospects for ASM activities [36]. Although national and local government departments have implemented community outreach programmes, these initiatives do not directly address the challenges related to ASM. Furthermore, there is a deficiency in the implementation of productive cooperation among these governmental entities, and the concerns of ASM are insufficiently incorporated into comprehensive development plans at the district or municipal level. Consequently, the participation of miners in influencing local policies and decision-making processes is restricted, leading to an inadequate fulfillment of the growth potential and assistance for artisanal and small-scale mining (ASM) at the local level [30]–[37].

The Small-Scale Gold Mining Act (PNDCL Law 218) was established in 1989 to provide the legal structure for granting licenses for artisanal and small-scale mining (ASM) in Ghana. This legislation has been cited by several scholars, including [38]–[40]. This represented the first attempt to formalize and establish regulations regarding the artisanal and small-scale mining (ASM) of gold in the country. The formalization of ASM aimed to foster inclusivity, eliminate child labor, and prevent individuals from violating...
social and environmental regulations [9]. However, the government’s lack of capacity to regulate the artisanal and small-scale mining (ASM) sub-sector has hindered efforts to formalize it [36]–[41]. Consequently, the regulation of the sector has not been adequately addressed by relevant governmental organizations. Hence, artisanal and small-scale mining (ASM) frequently overlap with illegal mining activities. The Ghanaian government implemented a ban on illegal mining activities in 2017 due to the harmful environmental effects caused by these activities. This ban affected operators involved in artisanal and small-scale mining (ASM) [28]–[30].

The Small-Scale Gold Mining Act (PNDC Law 218) of 1989, the Minerals and Mining Act of 2006 (Act 703), and the Minerals Commission Act of 1993 (Act 450) are the main legal frameworks in Ghana that regulate the mining industry. The Minerals and Mining Act of 2006, referred to as Act 703, was modified in 2015 by the Minerals and Mining Act, Act 900. Additional revisions were subsequently implemented in 2019, as recorded by [27]–[31]. The legislation covers multiple facets, including state ownership of minerals in their natural state, regulations regarding licensing, the allocation of mineral rights, and the statutory authority given to governing bodies responsible for overseeing the artisanal and small-scale mining (ASM) sector. Sections 82-89 of Act 703 deal with the regulation of Artisanal and Small-Scale Mining (ASM), covering topics such as licensing, the organization and duties of district mining offices, requirements placed on miners, and the allocation and use of mercury. Moreover, the regulatory framework that governs artisanal and small-scale mining (ASM) includes multiple legal provisions. These include policies aimed at preserving forests, laws protecting water resources and controlling their use, tax laws, customary laws concerning land ownership, corporate laws, contract laws, and administrative principles controlling the use of government power. The legal instruments mentioned, as cited by [27]–[37], provide guidance for the operations and activities of ASM.

The process of formalizing ASM land access aims to be straightforward; however, operators encounter difficulties in obtaining permits due to their limited expertise in geology, inadequate funding, substantial expenses, and bureaucratic obstacles [8]–[43]. Moreover, it has been noted that some artisanal and small-scale mining (ASM) operators in Ghana and other parts of Africa do not have any intention to legalize their activities [44]. The persistent problem of marginalization of artisanal and small-scale mining (ASM) in terms of its ability to access mineral-rich land is emphasized due to its connection with large-scale mining operations [45].

The lack of sufficient data on the role and impact of small-scale gold mining operations in Ghana’s socioeconomic development has led to differing viewpoints and discussions on the actual extent of small-scale mining’s contribution to socioeconomic progress. The employment opportunities resulting from artisanal and small-scale mining (ASM) activities are clearly advantageous for marginalized rural inhabitants who rely primarily on agriculture for their livelihood despite the adverse environmental consequences associated with these activities [27]–[32]. The present circumstances are highly alarming as the considerable consequences of recent variations in weather patterns have greatly affected rural farmers, especially those engaged in small-scale production. The increase in illegal mining activities can be attributed to mining regulations implemented by the government that prioritize the protection of commercial mining companies at the expense of small-scale mining operations.

The study seeks to examine the impact of Artisanal and Small-Scale Mining (ASM) on agriculture and soil fertility in both the study area and Ghana as a whole. The findings of this study will aid in developing strategies to alleviate the adverse impacts of small-scale mining on livelihoods, agriculture, and soil fertility. This will enhance rural transformation by tackling the substantial influence of artisanal and small-scale mining (ASM) operations on rural livelihoods and the environment.

2. Materials and Methods

2.1. Study Area

The study was carried out in the Upper Denkyira East Municipality to examine the effects of artisanal and small-scale mining (ASM) operations on agriculture and soil quality. The Upper Denkyira East Municipal spans 1700 km², which represents around 17% of the Central Region’s total land area. It is situated between latitudes 5°.58’ 01.12” and 1°.46’ 59.02” N and longitudes 1° W and 2° W. It shares borders with Adansi South to the north, Assin Central Municipal to the east, Twifo Atti Morkwa District to the west, and Upper Denkyira West Municipal to the northwest [46]. The selection of this location was based on its significant occurrence of ASM activities and the potential ecological and social ramifications linked to them. The researchers conducted this study with the objective of enhancing the comprehension of ASM’s impact on the region and offering valuable perspectives for sustainable development and resource management. Based on [46], the population of the municipality is 110,141, consisting of 55,280 (50.19%) females and 54,861 (49.81%) males. Approximately 52% of individuals between the ages of 15 and 64 comprise the potential labor force, leading to an age dependence ratio of 1.9%. The district’s young population presents a potential for growth in terms of labor supply. However, this necessitates the implementation of initiatives to enhance education, foster skill development, and promote human resource development.

Fig. 1 displays a map of the Upper Denkyira Municipal, indicating the presence of forested regions, rivers, and the specific locations of artisanal and small-scale mining (ASM) communities. The map was utilized to ascertain and choose mining communities for the investigation, as well as to visually represent the closeness of these activities to significant ecological features such as forests and rivers. The selection of mining communities within the Upper Denkyira East Municipality for this study was conducted using a random sampling method. A comprehensive compilation of all documented mining communities in the area was created, and a simple random sampling technique was employed to choose a representative sample. This method
ensured that the communities chosen were diverse in terms of location, size, and level of ASM activity, allowing for a thorough analysis of the impacts across different contexts.

The municipality’s vegetation cover consists primarily of tropical forests, which have undergone significant degradation due to the combined effects of climate change and human economic activities such as agriculture, logging, and mining [9]. These activities have resulted in the clearing of forests, destruction of habitats, and reduction in biodiversity. Climate change has additionally contributed to elevated temperatures, modified rainfall patterns, and more frequent occurrences of extreme weather events. These factors further worsen the degradation of the Municipal tropical forest [47], [48]. The reduction in vegetation cover has detrimental effects on ecosystem services, including carbon sequestration, water regulation, and soil fertility. Furthermore, the illegal mining and chainsaw operations in the Municipality have caused the devastation of wildlife and forest reserves, leading to an imbalance in the ecosystem and endangering the existence of numerous species [45]. According to [49], these activities have resulted in the annual loss of thousands of hectares of forest cover. Habitat destruction, soil erosion, and the emission of greenhouse gases have occurred as a consequence of the expansion of agricultural land and the extraction of timber and minerals [30]–[50]. The results emphasize the immediate requirement for implementing sustainable land use methods and enforcing effective regulations on economic activities to safeguard the tropical forest vegetation in the Upper Denkyira Municipality. The Ministry of Food and Agriculture (MOFA) and other civil society organizations (CSOs) have expressed concern regarding their inability to discover a sustainable resolution to the predicament.

The vast cultivable terrain in Upper Denkyira offers a favorable prospect for the adoption of sustainable agricultural methods, which have the capacity to improve food security and mitigate poverty among rural communities. The Municipality is well-known for its cultivation of highly profitable agricultural commodities, including cocoa, coffee, timber, and cashews, as well as vital staple crops such as maize, yam, cassava, and plantain. However, the increase in small-scale mining activities in recent years has led to the deterioration of ecosystems and the pollution of water bodies with toxic substances like mercury and cyanide. The transformation of agricultural land into small-scale mining areas has been driven by a combination of unfavorable weather variations and insufficient government interventions. In addition, the reduced crop yield resulting from continuous farming on a specific piece of land has compelled farmers to lease their land for the purpose of engaging in small-scale mining. Some individuals involved in illegal mining have taken advantage of insufficient law enforcement and lenient mining regulations to encroach upon untouched forest areas. These aggravate the already unusual situation in the municipality.

2.2. Methodology

2.2.1. X-ray Fluorescence (XRF) for Sampled Soil Analyses

XRF (X-ray fluorescence) is a non-destructive analytical method used to determine the elemental makeup of materials. XRF is an analytical method to determine the chemical composition of all kinds of materials. The materials can be in solid, liquid, powder, filtered or other form. The method is fast, accurate, and non-destructive and usually requires only a minimum of sample preparation. The method is fast, accurate, and non-destructive and usually requires only a minimum of sample preparation. XRF analyzers assess the chemistry of a sample by measuring the fluorescence (or secondary) X-ray generated by a sample when stimulated by a main X-ray source [51]. Each element in a sample emits a unique set of distinctive fluorescence X-rays (“a fingerprint”), which is why XRF spectroscopy is an ideal tool for qualitative and quantitative material composition investigation. The XRF was used to examine heavy metal concentrations in soil samples from mining sites, and the results are shown in Table I.
2.2.2. Weighted Average Index

The study also used the Weighted Average Index (WAI) to assess and analyze information from key informants to ascertain information received from the miners and farmers constituting the respondents. The total number of respondents for the key informant interview was 150. The key informant interview was comprised of 60 officials from the Mineral Commission, EPA, Forestry Commission, and MOFA, 30 members of different NGOs, and 60 members of the Farmer Based Organization (FBO). Secondary data were gathered from the Ministry of Food and Agriculture, the Municipal Assembly, the Mineral Commission, and the Forest Commission.

Weighted Average Index (WAI) was used to assess the impacts of artisanal and small-scale mining (ASM) on agriculture and the environment using the following variables: water pollution, deforestation, soil pollution, land tenure, and loss of biodiversity on the scale of 0–3 (0—not sure, 1—low, 2—moderate, 3—high). WAI was also used to assess perceived measures to address the impact of mining on the environment on a scale of 0–3 (0—not, 1—low, 2—moderate, 3—high). WAI was also used to assess perceived measures to address the impact of mining on the environment on a scale of 0–3 (0—not sure, 1—low, 2—moderate, 3—high). A study involving the use of the Weighted Average Index (WAI) to examine the understanding of the opinions/perceptions of participants related to a single ‘latent’ variable (the phenomenon of interest) was proven to be efficient [52]. The WAI of the respondents’ variables was computed using the formula below:

\[ WAI = \frac{\sum FiWi}{\sum Fi} \]  

where \( W \) is the weight of each assessed variable on the scale, \( Fi \) is frequency of variables, \( i \) is response on the scale (e.g., 3—high, 2—moderate, 1—not sure, 0—low).

3. Results and Discussion

3.1. Impacts of Small-Scale Gold Mining on Soils

Heavy metals such as arsenic, cadmium, iron (Fe), cobalt, manganese, zinc, copper, and nickel, which are harmful to human health and pollute the environment, were examined in soil samples obtained from artisanal and small-scale mining sites. Heavy metals in soils and water bodies, depending on their concentration level, have been shown to impact cropping and drinking [53], [54]. The study, as indicated in Table I below, showed that average Cu concentrations at ASM sites, non-mining sites, and farmland in the communities sampled (Akropong, Buabenso, Kyekyewere, Opponso, and Pokukrom) were below the FAO/WHO-required cropping soil guideline values. Comparisons with the WHO/FAO heavy metal required levels in farming soils indicated that all the sampled soils at the non-mining site, the mining site, and the farms were below the WHO/FAO threshold values (5–30 mg/kg). This implies that the soils in the study area do not pose any excess Cu consumption threat. Excess copper can restrict root growth, affect seed germination, and reduce plant vigour. High levels of copper can compete with plant uptake of iron and sometimes molybdenum or zinc [55]. The study further revealed that the concentrations in sampled soils at non-mining sites, mining sites, and farmland in Akropong were 1.6 mg/kg, 11.6 mg/kg, and 3.4 mg/kg, respectively. Comparing the values to the FAO/WHO required value (0.1–10 mg/kg) stipulates that the concentration in the soil at the mining site in Akropong is high and, therefore, likely to pose a health threat if crops are cultivated on this soil. According to [56], [57], high concentrations of As in soil find their way into crops, which create health issues when such crops are consumed over time. The study showed that the concentrations of As in sampled soils at non-mining sites, mining sites, and farmland in Buabenso were 2.11 mg/kg, 15.4 mg/kg, and 2.11 mg/kg, respectively. Comparisons of the analysed soil samples revealed that the concentration at the mining site of Buabenso is higher than the FAO/WHO guideline value (0.1–10 mg/kg). This implies that ASM activities in this community pollute soils with As. Studies of arsenic’s impact on farm soils have proven that arsenic affects soil structure and destroys microorganisms that boost soil fertility [58]. According to the data analyses shown in Table I, the concentrations of As in the mining sites at Kyekyewere, Opponso, and Pokukrom were 9.04 mg/kg, 21.7 mg/kg, and 16.1 mg/kg, respectively. This implies that ASM activities at Opponso and Pokukrom pollute the soils within this environment. The high concentration of As in this area does not make it safe for farming activities. This could be a result of the incriminating use of A to process soil samples containing gold. Analyses of chromium concentration at non-mining sites, ASM sites, and farmland in all the communities revealed that the concentration of Cr in soils was higher than the FAO/WHO threshold values (0.05–0.1 mg/kg). Interaction with the indigenes, farmers, and small-scale miners in these communities established that the source of the high Cr concentration could be attributed to the geology and natural soil formation process in these communities.

TABLE I: Heavy Metal Concentration in Soil from Different Site

<table>
<thead>
<tr>
<th>Community</th>
<th>Soil sample</th>
<th>Non MS site (mg/l)</th>
<th>ASM site (mg/l)</th>
<th>Farmland (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu</td>
<td>As</td>
<td>Fe</td>
<td>Cr</td>
</tr>
<tr>
<td>Akropong</td>
<td>Sample A</td>
<td>0.314</td>
<td>1.64</td>
<td>4.53</td>
</tr>
<tr>
<td>Buabenso</td>
<td>Sample B</td>
<td>0.40</td>
<td>2.11</td>
<td>6.34</td>
</tr>
<tr>
<td>Kyekyewere</td>
<td>Sample C</td>
<td>5.69</td>
<td>2.43</td>
<td>4.65</td>
</tr>
<tr>
<td>Opponso</td>
<td>Sample D</td>
<td>2.78</td>
<td>3.4</td>
<td>8.65</td>
</tr>
<tr>
<td>Pokukrom</td>
<td>Sample E</td>
<td>3.65</td>
<td>1.67</td>
<td>8.75</td>
</tr>
</tbody>
</table>

4. Impact of ASM on Agriculture and Environment

The study analyses using the weighted average index (WAI) as shown in Table III indicated that water pollution (WAI-1.78) was perceived as the most serious impact of ASM in the study area, which generates ripple effects on their livelihood. Interactions with the indigenes revealed that most of the streams and rivers serving as sources of water for drinking and other domestic uses are considered dead water due to high concentrations of chemicals and other foreign particles. Personal observation indicated that the turbidity of the water bodies within the study is very high due to the high concentration of particle matter from the usage of these water bodies for gold processing. Deforestation (WAI-1.70) was also discovered to be one of the effects of ASM activities, wreaking havoc on indigenous peoples as well as the environment. Mining activities have led to the loss of valuable economic trees, including cocoa, shea, mahogany, and rosewood [30]–[49]. Trees act as carbon sequesters and provide fresh air for human survival. Therefore, continuous depletion of forest resources contributes to greenhouse gas emissions and poor habitat health. Forests hold about 64GT of carbon stock and other foreign particles. 

The study further revealed that Pb concentration in soil from the ASM site in all the communities under study, with the exception of Pokukrom, was higher than the FAO/WHO soil guideline of 15–40 mg/kg. Interactions with farmers and small-scale miners in the study area established that higher Pb concentrations in these areas could be a result of excessive use of chemicals used in ASM activities, including the extraction and processing of gold. The low concentration of Pb in Pokukrom ASM soil samples could be attributed to the use of low-concentration chemicals in gold processing. Studies have proven that lead toxicity causes inhibition of ATP production and also prevents root elongation, seedling development, transpiration, chlorophyll production, water content, and protein content [59]. The study indicated that Pb concentration in soil from the ASM site in all the communities under study, with the exception of Pokukrom, was higher than the FAO/WHO soil guideline of 15–40 mg/kg. Interactions with farmers and small-scale miners in the study area established that higher Pb concentrations in these areas could be a result of excessive use of chemicals used in ASM activities, including the extraction and processing of gold. The low concentration of Pb in Pokukrom ASM soil samples could be attributed to the use of low-concentration chemicals in gold processing. Studies have proven that lead toxicity causes inhibition of ATP production and also prevents root elongation, seedling development, transpiration, chlorophyll production, water content, and protein content [59]. The study indicates that Zn and Ni concentrations in soils within the environs of the study area are lower than the FAO/WHO threshold, as indicated in Table II. Low concentrations of zinc and nickel could be a result of low usage of chemicals containing zinc and nickel in mining and non-mining areas, including farmland. The study analyses established that Hg concentrations in soils at all the mining sites in the study area were far higher than the FAO/WHO threshold (0.03 mg/kg).

<table>
<thead>
<tr>
<th>Heavy metals in soils</th>
<th>WHO/FAO guide line values/thresholds (mg/kg)</th>
<th>Effect of higher heavy metals concentration in soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (Cu)</td>
<td>5–30 mg/kg</td>
<td>Excess copper restrict root growth, affect seed germination and plant vigor. High levels of copper can compete with plant uptake of iron and sometimes molybdenum or zinc.</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>0.1–10 mg/kg</td>
<td>Arsenic destroy microorganisms which help in boosting soil fertility. High concentration of As in soil find it ways in crops which create health issues when such crops are consumed over a period.</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>0.05–0.1 mg/kg</td>
<td>Reduces plant growth by inducing ultrastructural modifications of cell membrane and chloroplast hence damaging root cells, reducing pigment content and affecting transpiration.</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>0.03 mg/kg</td>
<td>Hinder utilization, uptake and transport of essential nutrients and water leading to tissue death.</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>0.3–30 mg/kg</td>
<td>Lead toxicity causes inhibition of ATP production. It inhibit root elongation, seedling development transpiration, chlorophyll production, water and protein content.</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>30–67.9 mg/kg</td>
<td>Affects nutrient absorption by roots, impairs plant metabolism, and inhibits photosynthesis and transpiration. This result in poor crop yield</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>120–270 mg/kg</td>
<td>Zinc is an important component of various enzymes that are driving metabolism in plants. Zinc toxicity leads to reduced yield, stunted growth and reduced photo assimilates from leaves to roots.</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.3 mg/kg</td>
<td>Reduced photosynthesis, transpiration, water uptake, chlorophyll synthesis and increased lipid peroxidation.</td>
</tr>
</tbody>
</table>

TABLE III: IMPACTS OF ARTISANAL AND SMALL-SCALE MINING (ASM) ON AGRICULTURE AND THE ENVIRONMENT

<table>
<thead>
<tr>
<th>Variables</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
<th>Not sure</th>
<th>WAI</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water pollution</td>
<td>57</td>
<td>38</td>
<td>20</td>
<td>35</td>
<td>1.78</td>
<td>1</td>
</tr>
<tr>
<td>Deforestation</td>
<td>54</td>
<td>34</td>
<td>26</td>
<td>36</td>
<td>1.70</td>
<td>2</td>
</tr>
<tr>
<td>Soil pollution</td>
<td>52</td>
<td>32</td>
<td>31</td>
<td>35</td>
<td>1.67</td>
<td>3</td>
</tr>
<tr>
<td>Land tenure issues</td>
<td>49</td>
<td>32</td>
<td>36</td>
<td>33</td>
<td>1.64</td>
<td>4</td>
</tr>
<tr>
<td>Biodiversity loss</td>
<td>44</td>
<td>36</td>
<td>40</td>
<td>30</td>
<td>1.62</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: Key informants interview (2022).

worsen the food insecurity issues in the study area as a result of the extension of mining activities in farming areas.

Land tenure issues (WAI-1.64) were perceived as one of the serious threats to ASM. As a result of mining activities, land ownership has become a critical issue for those whose livelihoods depend on land resources. As a result of indiscriminate land encroachment by small-scale miners, most farmers face challenges with farm expansion. Personal observation indicates that the reduction in farm size as a result of mining, coupled with high population growth, has led to food security challenges in the study area and its environs. The study indicated that loss of biodiversity (WAI-1.62) was seen as one of the serious repercussions of mining in the study area. Focus group discussions and personal observation revealed that, as a result of ASM, the most valuable economic trees and other living organisms that help improve the ecosystem were endangered. According to the indigenes, certain trees and wildlife species, including antelope, buffaloes, chimpanzees, rosewood, and acacia, are extinct due to prolonged ASM activities in the study area.

5. Measures to Address Artisanal and Small-Scale Challenges

The research examined strategies to address ASM activities in the study area, and its environs. According to the key informant interview analyses as shown in Table IV, ASM issues in the study area and the country as a whole could be curbed if the strategies are well implemented and enforced. Alternative livelihood (WAI-1.79) can help address the challenges ASM poses to the environment as well as the inhabitants. The key informant discussions revealed that due to the impact of climate change on agriculture, which is the main source of livelihood for the indigenes, mining is used to complement their small-scale farming. The study further ascertained that most of the miners were cocoa farmers who engaged in mining to complement poor yields due to unpredictable weather conditions and the high cost of farming coupled with poor farming incentives. Research finding by [14]–[38] and the study results examined showed that alternative livelihood activities, including agriculture, beekeeping, agro processing, trading, and handicraft, could help the inhabitants shift focus from ASM activities to other sustainable livelihood activities. The study results also established that law enforcement (WAI-1.72) to punish illegal miners using inappropriate technology to mine in water bodies, forest zones, and unapproved places would address the environmental degradation posed by ASM activities. The study discussions indicated that most of the miners use chemicals such as mercury and arsenic indiscriminately to process their gold in water bodies without considering the chemicals impact on the water resources. With the help of water pumping machines, some miners draw water from streams, rivers, and lakes nearby and direct all the contaminated water generated in the process back into these water bodies. Personal observation ascertains that most of the water bodies in the mining areas are heavily polluted with chemicals, hence considered dead water, which cannot support aquatic life. Training and support (WAI-1.62), perceived as one of the formidable strategies that could help address the ASM challenges in the Upper Denkyira Municipality and Ghana at large. The key informant discussions indicated that effective capacity building of small-scale miners and resourcing them with needed support will enhance efficiency using appropriate mining technology. This would go a long way towards reducing the adverse impact of ASM on the environment. A study has indicated that training and supporting small-scale miners enhances mining skills, efficiency, and output, as well as reducing environmental degradation [9]–[23]. The study analyses indicated that access to mining concessions (WAI-1.55) could help address the adverse impact of ASM on the environment. The informant interview revealed that most of the small-scale miners have no mining permits and hence operate illegally. As a result of difficulties and bureaucracies involving small-scale mining concessions and permits, the youth mine illegally in deep forest areas to avoid any confrontation with officers from the Environmental Protection Agency (EPA), Forestry Commission, and Mineral Commission. Studies have proven that easy access to concessions and permits enhances transparency, accountability, and regulation of mining activities [18]–[45]. Interactions with the indigenes established that high costs coupled with difficulties in getting permits and mining concessions from the Mineral Commission and EPA compel most ASM miners to risk operating illegally in forest areas and near water bodies. Though they are aware of their activities’ impact on the environment, they are motivated by the high returns on gold. This implies that easy access to permits and concessions would ensure that small-scale miners use appropriate technology at places earmarked for mining. This will prevent mining in water bodies, farms, and forest reserves. The study established that efficient monitoring of mining activities (WAI-1.53) ensures mining companies use the appropriate technology, mine at concessionary sites, and follow due diligence in mining operations. The key informants asserted that effective monitoring of mining activities would enable mining regulatory authorities to identify and sanction miners whose activities pollute the environment, including water bodies, soil, and farms. Effective monitoring would help the government generate enough revenues through taxation and other concessionary charges. The communities would also get adequate royalties and compensations, which could be used for community development projects. Studies have proven that effective monitoring ensures effective environmental impact assessment (EIA) and land reclamation to enhance efficient mining and environmental protection [4]–[28]. Institutional collaborations ensure
that all the government agencies that are stakeholders in the mining industry coordinate activities to ensure efficient mining activities. The study indicated that among the strategies to address mining challenges, institutional collaboration (WA1-1.46) was perceived as one of the critical strategies that could be used to address mining issues in the study area as well as in Ghana. The key informant discussion indicated that effective institutional collaboration would promote sustainable mineral exploration, extraction, processing, and livelihood empowerment. This will ensure that mining is done at designated places with appropriate technology that does not degrade biodiversity and the ecosystem.

6. Conclusion

Artisanal and small-scale gold mining has served as a major means of sustenance for rural communities worldwide despite its detrimental effects on water resources, soil biodiversity, and other environmental aspects. The study found that the excessive presence of toxic metals, such as lead, mercury, arsenic, and copper, in soils and water bodies resulted from the uncontrolled application of chemicals during mineral processing. The study discovered that the expansion of artisanal and small-scale mining (ASM) operations into farming areas has had a negative impact on the yield of important crops like cocoa, coffee, and shea nuts. Furthermore, the cultivation of various essential crops such as maize, cassava, yams, plantains, and vegetables has been significantly impacted. The transformation of extensive cultivable land into artisanal and small-scale mining (ASM) operations indicates that the local inhabitants have become increasingly attracted to gold mining as a result of its significant economic worth. Abundant evidence indicates that the constraints faced by some farmers in adapting to their environment force the majority of local inhabitants to engage in small-scale mining alongside farming in order to enhance their quality of life. Hence, it is imperative for the government to offer alternative means of earning a living, such as providing incentives to the agricultural industry to render it more financially rewarding for the labor force, particularly the younger generation. It is, therefore, prudent to conduct additional research to assess the viability of such adaptation strategies before they are incorporated into national agricultural policies and farming systems used to improve farmers’ livelihoods in mining communities. According to one study, poor technology and the use of obsolete devices in ASM activities have contributed to environmental degradation, including soil and water pollution. The study determined that alternative livelihoods, law enforcement, training, and access to mining concessions were identified as the strategies that effectively address the challenges posed by ASM to the environment. Hence, it is imperative for the government to establish avenues for providing training and resources to individuals and groups involved in small-scale mining. Facilitating the collaboration between EPA, MOFA, the Mineral Commission, the Forestry Commission, and other environmental NGOs could effectively tackle the issue of illegal mining in forest reserves, water bodies, farming areas, and non-concessionary sites.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

References

Artsinal and Small-Scale Gold Mining Impact on Soil and Agriculture


