



# “Illegal” Gold Mining Operations in Ghana: Implication for Climate-Smart Agriculture in Northwestern Ghana

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### Specialty section:

This article was submitted to  
Land, Livelihoods and Food Security,  
a section of the journal  
Frontiers in Sustainable Food Systems

Received: 21 July 2021

Accepted: 08 November 2021

Published: 08 December 2021

### Citation:

Yiridomoh GY (2021) “Illegal” Gold  
Mining Operations in Ghana:  
Implication for Climate-Smart  
Agriculture in Northwestern Ghana.  
*Front. Sustain. Food Syst.* 5:745317.  
doi: 10.3389/fsufs.2021.745317

Globally, climate-smart agriculture is highly recognized as an approach for sustainable agriculture and food systems. In Africa and other developing countries, climate-smart agriculture is observed to reposition and modify agricultural systems for improved food and nutritional security. Despite the relevance of the approach to sustainable agricultural planning, illegal gold mining in many parts of the society is placing constraints to its implementation and adoption through its contest with agricultural land for space and activities. Illegal gold mining is on the rise due to the lucrateness of the non-regulated gold rush opportunities with hard consequences on sustainable agriculture and resilience food systems. As a result, this study seeks to investigate illegal gold mining and its environmental implication for climate-smart agriculture in Ghana. The study used a single case study using a mixed-methods approach to research. The study adopted purposive and systematic sampling techniques to select the study communities and respondents, respectively. Questionnaire and interviews were used to gather the primary data from respondents at the household level, as the unit of analysis. Descriptive statistics and thematic analysis reveal that known agricultural practices such as terracing, crop rotation, use of domestic waste/manure, and irrigation of crops were affected adversely by activities of illegal mining. The study recommends the need for conscious efforts from the Ministry of Lands and Natural Resources to sustain the ban on illegal mining with intensified monitoring and supervision while a systematic scheme involving relevant stakeholders is developed and implemented to ban illegal mining in Ghana completely. The Ministry of Food and Agriculture needs to develop an approach to support the adoption of climate-smart agricultural practices by smallholder farmers to meet the food demand of their households.

**Keywords:** illegal mining, environment management, environmental sustainability, climate-smart agriculture, food systems

## INTRODUCTION

Mineral resources have become fundamental for economic development throughout the world. In several low- and middle-income countries that are rich in non-fuel mineral resources, mining contributes to national economic development (Addison and Roe, 2018; Ericsson and Löf, 2019). Studies have reported that 10 of the 20 countries where mining contributes most have moved up

one or two steps of the World Bank's countries classification between 1996 and 2016 (Ericsson and Löf, 2017, 2019; Addison and Roe, 2018). In particular, African countries have benefitted. Thus, socio-economic development indicators show signs of progress for African mineral-rich countries. In Guinea, for instance, the Papua New Guinea Extractive Industries Transparency Initiative reported that, in 2020, the industries contributed 89% to exports, 29% to gross domestic product (GDP), and 10.1% to corporate tax, salary and wage tax, dividends, and royalties (Yamarak and Parton, 2021). In Kenya, Tanzania and other parts of developing economies where mining operates, whether on a large or small scale has contributed to per capita income through job creation, resulting in improved livelihood status of residents and communities (Apollo et al., 2017; Mwakesi et al., 2020). In Kenya and Cote d'Ivoire, for instance, mining has observed to be an off-farm livelihood activity for farmers and other agriculturalists (Apollo et al., 2017; Mwakesi et al., 2020). Notwithstanding the potential contributions of the mining industry to the economies of many developing countries, it has observed to be detrimental to sustainable development due to its hard implication on environmental sustainability and management (Christmann, 2021; Yamarak and Parton, 2021).

Ghana is home to a number of precious minerals. Over the past decades, the mineral sector has contributed to ~37% of the exports of the country and accounted for ~8.4% of the GDP of the country in 2011 from 6.1% the previous year (Ghana Statistical Service, 2010; Bach, 2014; Ofosu et al., 2020; Atta and Tholana, 2021). In recent years, gold production, for instance, has observed to increase substantially from <20,000 ounces in 1990 to 1.6 million ounces in 2016 (Ofosu et al., 2020). The increase in gold mining in Ghana has also seen some significant improvement in the livelihoods of communities where gold mining is in operation (Ofosu et al., 2020).

In Ghana, the people own the mineral resource with management power vested in the Government. The Ministry of Lands and Natural Resources, through the Geological Survey Department, the Minerals Commission, and Precious Minerals Marketing Cooperation Limited, oversees all aspects of the mineral sector of Ghana. The legislative framework for the mineral sector in Ghana is the minerals and mining act 703 of 2006. Under the provision of the law, no person has the authority to conduct reconnaissance, prospecting, exploration, or mining in Ghana unless the person has a mining license (Ofosu-Mensah, 2010; Benmudez-Lugo, 2016). However, illegal mining (both foreign and Ghanaian nationals) continues unabated in the country despite government efforts to curb these activities (Aryee, 2003; Darimani et al., 2013; Benmudez-Lugo, 2016). Illegal mining is defined locally (Ghanaian context) as mining operations in which miners without a license have no concessions of their own operate uncontrollably within concessions of large-scale mining companies or in areas prohibited for mining (Aryee, 2003; Hilson et al., 2013).

In recent years, with dwindling opportunities for employment in the formal sector and the lucrateness of gold mining, there has been an upsurge of miners, majority of them operating

illegally (Hilson, 2010; Hilson et al., 2013; Kwadwo et al., 2016; Obeng et al., 2019). Studies have already noted illegal gold mining as a way of livelihood diversification (Hilson et al., 2013; Kwadwo et al., 2016), which this paper cannot contest. However, the activities of illegal gold mining is best known for its disastrous effects on the environment particularly agricultural land, causing many to view the activity as dirty, unprofitable, and unsustainable (Ofosu-Mensah, 2010; Schueler et al., 2011; Ericsson and Löf, 2019; Atta and Tholana, 2021). Illegal mining over the years has been into serious competition for agricultural land for its operation (Ansah and Smardon, 2015; Danyo and Osei-Bonsu, 2016; Ndabi, 2017; Atta and Tholana, 2021). Empirical studies have focused on the impact of illegal mining on the environment (Amankwah, 2013; Ansah and Smardon, 2015; Prosper and Guan, 2015) with least attention paid to the environmental implications of the activity on climate-smart agriculture.

With agriculture being the mainstay of livelihood for the majority of people in Ghana (International Fund for Agricultural Development, 2011; Sugden, 2013; Andrieu et al., 2020), sustainable and productive agriculture should be given the necessary attention as its productivity is dependent on access to quality land and water. As estimated by the Environmental protection agency (2016), the quality of land for agricultural use (in mining operation communities) is fast diminishing largely due to the activities of illegal mining.

With illegal mining already diminishing the carrying capacity of the environment and climate change with it posing danger to the agricultural sector, Ghana is at a central point where it needs to pay attention to climate-smart agriculture. Climate-smart agriculture for this paper refers to agricultural practices that help smallholder farmers to sustainably manage systems of agriculture amidst climate change for improved productivity and income (Obeng et al., 2019; Andrieu et al., 2020). Climate change has intensified the challenges faced by rain-fed agricultural systems. This suggests the need to harmonize protection of the environment, invest in smallholder agriculture, and improve food production and productivity.

Nadowli-Kaleo district is one of the districts in the Upper West Region where small-scale mining is in operation. The emergence of the mining extraction in the area has serious impact on the environment to include loss of farmlands, destruction of crops and forest cover, and pollution of water bodies (Prosper and Guan, 2015). The Ghana News Agency (2018) report on "Galamsey activities is eating up Nadowli-Kaleo district" noted that artisanal miners have scarred the landscape with "excavated pits and trenches" particularly in Nanga, Vuuyiri, and Charikpong enclaves, which renders the land unsuitable for agricultural purposes. Literature has also indicated that over 2.5% of cultivable land has been destroyed in the district (Environmental protection agency, 2016; Ministry of Food Agriculture, 2016). Mineral Commission of Ghana (2017) observed that illegal mining has occupied about 3.5% of the land, which had been initially used for agricultural activities. As result, the study aims to investigate the activities of illegal gold mining for climate-smart agriculture in the Nadowli-Kaleo district in the Upper West Region, Ghana. This study is critically important to contribute to literature

on sustainable agriculture, food systems, and climate change adaptation in Ghana, in particular, and in Africa, in general. The rest of the paper is organized as follows: the review of related literature to include climate-smart agriculture and illegal mining and environmental sustainability and climate-smart agriculture in Ghana. The other sections include the study method and materials, results and discussions, and the implication of the study for planning for agriculture and sustainable food systems.

## REVIEW OF RELATED LITERATURE

This section presented existing literature on climate-smart agriculture and illegal mining. The section also presented literature on the need for environmental sustainability and climate-smart agriculture in Ghana.

### Climate-Smart Agriculture and Illegal Mining

Climate change is already modifying production systems and exacerbating critical difficulties, including rising poverty and food insecurity [Intergovernmental Panel on Climate Change (IPCC), 2009; Yiridomoh et al., 2020; Owusu and Yiridomoh, 2021; Waaswa et al., 2021]. This prompted the Paris Climate Change Agreement jointly with the Sustainable Development Goals to set the premise for serious investments in climate change technologies for sustainable future [Food and Agriculture Organization Food and Agricultural Organization (FAO), 2013; Andrieu et al., 2020; Waaswa et al., 2021]. The joint decision recognized the fact that developing countries must develop, prioritize, and invest in climate change technologies for climate risk reduction and adaptation. One approach to respond to the changing climate system is the adoption of climate-smart agriculture (Asrat and Simane, 2017; Abegunde et al., 2019). Climate-smart agriculture is rooted in sustainable agriculture and rural development objectives, which, if reached, will contribute to achieving the sustainable development goals of reducing hunger and improved environmental management (El-Fattal, 2012; Andrieu et al., 2020; Waaswa et al., 2021).

Climate-smart agriculture is an approach that strives to meet the following criteria: (1) increase agricultural productivity in a sustainable manner, (2) improve the resilience of agricultural production and food systems to environmental change, or (3) reduce net greenhouse gas emissions associated with the agriculture and forestry sectors (Sugden, 2013; Angom et al., 2021; Waaswa et al., 2021). Rainforest Alliance (2016) added that climate-smart agriculture is not a defined set of practices or an entirely new type of agriculture, rather an approach that combines different methods under a climate change umbrella. Thus, it assesses the risks and needs of a specific farm or farming community through a climate impact lens and then addresses them using practices chosen for that particular situation. What that means is that climate-smart agriculture is not a universal approach but dependent on individual location. Appropriate practices will vary according to region,

ecosystem, climate, and crop. For instance, common climate-smart practices such as planting diverse crops, composting and soil management for improved soil fertility, and water saving, harvesting, and retention systems, which improve water availability during times of drought, may be adopted depending on the climate and location (El-Fattal, 2012). The practice gives farmers tools and a pathway to make their operations and livelihoods more productive and resilient in the face of the changing climate (Angom et al., 2021). In other words, it creates the technical, policy, and investment conditions for achieving sustainable agriculture.

Although there is a growing interest in environmental sustainability for sustained agricultural productivity, unsustainable environmental practices are noted everywhere in the society. One particular antagonist to environmental management and sustainability is illegal mining. Illegal mining and the environment are linked inextricably with the former having disastrous implications on the later. The problem of illegal mining has been a matter of concern for a long time but it appears the challenges have been enormous and more visible in recent times (Amankwah, 2013; Obeng et al., 2019; Atta and Tholana, 2021). Thus, illegal mining results in extensive land cover changes leading to loss of forest and farmland (Prosper and Guan, 2015). The study of Schueler et al. (2011) on the impact of illegal mining on land use indicated that, apart from eroding the ecosystem services and placing constraints on conservation of natural resource base, illegal mining displaces farmers, thereby triggering increased deforestation, agricultural intensification, and land degradation. With the impact of illegal mining on the environment already observed, resilience and sustainable agricultural practices need to develop to enhance sustainable food systems for sustainable livelihoods of smallholder farmers [Intergovernmental Panel on Climate Change (IPCC), 2009; Sullo et al., 2020; Owusu and Yiridomoh, 2021].

### Arguments for Environmental Sustainability and Climate-Smart Agriculture in Ghana

The environment plays a significant role in the existence of humankind. Thus, economic growth and development, which are at the heart of man's survival, are dependent on the suitability of the environment. Although impossible to define environment (Nasreen et al., 2006), it involves the aggregation of all the external conditions and influences affecting the life and development of a system or organism (Boon et al., 2008). The environment is a home to fundamental resources upon which people depend on for their livelihoods. This is the reason why Opschoor (2007) perceived environment as envelope for range of biotic and a-biotic processes operating in and between the ecosystems, which provides human beings with natural resources and ecosystem services.

The benefits derive from the environment are enormous and therefore call for environmental sustainability. According to Morelli (2011, p. 24), "environmental sustainability is defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither

exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity.”

Achieving environmental sustainability means ensuring sound consistent development that increases the environmental asset base and productivity, reduces and manages environmental risks, and recognizes the long-term implication for the intra and inter-generational equity (Boon et al., 2008). The pains and wounds inflicted on the environment by humankind over the years are well-noted. These environmental concerns have double folded and dramatically expanded in recent years, and the effects on people livelihood are given more discussions at national and international deliberations (World Bank, 2008). To fight for sound environmental management and sustainability involves rethinking development that entails more socially and environmentally responsibility (Boon et al., 2008). With the interest in environmental sustainability increasing day in and out, more systems, individuals, communities, and nations are realizing the fundamentals of analyzing the impact of human activities on the environment and sustainable development [World Commission on Environment and Development (WCED), 1997].

Our environment is undergoing a cataclysm either by natural means or through anthropogenic forces [Intergovernmental Panel on Climate Change (IPCC), 2009; Yiridomoh et al., 2021]. This particularly places serious threat to the agricultural sector which must feed the world population projected to increase to 9.8 billion by 2050 (Food Agriculture Organization of the United Nations, 2013). This suggests pragmatic and innovative technologies and programs to ensuring that the world meets its food demand without placing much burden on the environment. Climate-smart agriculture is the right way to go to fight the magnitude, immediacy, and effect of climate and environmental change. The climate-smart agriculture approach is designed to

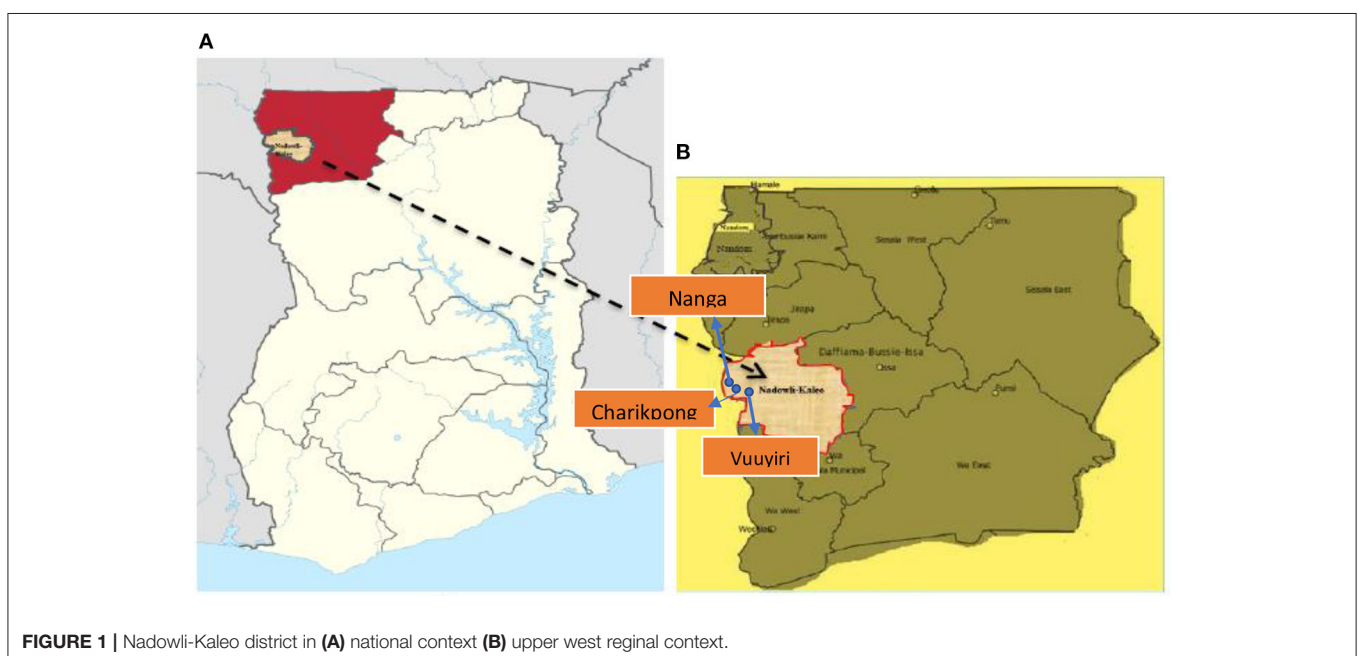
identify and operationalize sustainable agricultural development for improved livelihoods and food security, especially among smallholder farmers, by improving the management and use of natural resources and adopting appropriate methods and technologies for production of agricultural goods (Food and Agricultural Organization (FAO), 2013; Andrieu et al., 2020; Waaswa et al., 2021). A key component of the climate-smart agriculture is the integrated landscape approach that follows the principles of ecosystem management and sustainable land and water use. Climate-smart agriculture seeks to support countries to put in place the necessary policy and the technical and financial means to mainstream climate change considerations into agricultural sectors and to provide a basis for operationalizing sustainable agricultural development under changing conditions (Food and Agricultural Organization (FAO), 2013).

## METHODS AND MATERIALS

The method and material section of the paper presented issues on study setting, the study design, data collection instruments, and approaches to data analysis.

### Study Setting

The Nadowli District is one of the districts along the Black Volta corridor in the Upper West Region (see **Figure 1**). In line with the decentralization policy of Ghana, which came into being in the 1988 (Ghana Statistical Service, 2010), Nadowli-Kaleo became a district in 2012 under Legislative Instrument 2101 with Nadowli as its capital. The Assembly is empowered as the highest political and administrative body in the district charged with the responsibility of facilitating the implementation of national policies. Under section 10 of the Local Government Act 1993 (Act 462), the Assembly exercises deliberative, legislative, and executive functions in the district. By this act, the Assembly is



**FIGURE 1** | Nadowli-Kaleo district in (A) national context (B) upper west regional context.

responsible for the overall development of the district through the preparation of development plans and budgets and other development initiatives.

According to the Ghana Statistical Service (2010), the Nadwoli-Kaleo District has 61,561 residents. The northwestern enclave of the district, which constitutes Charikpong, Saan, Zukpiri, Nanga, and Vuuyiri, assumes 10% of the total population of the district. These communities are located along the Black Volta River of which about 85% of the total land area is covered by vegetation and underlain by hydrothermal gold deposition. The presence of the gold deposit in the area has seen some activities of mining in the area over the last decade. The concession was given to Azumah Resources Limited, a Perth-based ASX listed Company, headquartered in Australia (Prosper and Guan, 2015). Despite the official award of the concession to the mining company, illegal miners have forced their way into the area, depleting and devastating the whole environment due to poor mining practices. For regulating the activities of mining for environmental sustainability and management, the government of Ghana imposed ban on illegal mining with the popular phrase “operation vanguard.” Operation Vanguard is a military police joint task force set up by the President of Ghana in 2017 to combat the operation of galamsey in Ghana. However, the purpose of the operation vanguard was defeated as many illegal mining activities still went on before, during, and after the launch of the “operation vanguard.” Activities of illegal miners in the district have dreadful implication for activities of agriculture due to the majority of the dependents of the residents on agriculture for their livelihood. Mining as an economic activity is essential for the local economic development; however, it has severe environmental consequences and, if not properly managed, can conflict with existing community livelihood. For instance, surface mining with the support of mercury, which is non-degradable pollutant, is used by the illegal miners for the extraction of the gold, which has both short- and long-term implication for the communities and the district at large.

## Study Design

The study adopted mixed-methods case study. According to Creswell (2007), mixed methods helps build on the synergies of the two approaches (qualitative and quantitative) to give relevant and comprehensive findings on the subject under investigation, which, in this case, the implication of activities of illegal mining on sustainable environment and climate-smart agriculture in a district that is already vulnerable to climate change. Again, given the complexity of illegal mining and climate change and their replicate effects on the environment and agriculture, mixed methods provided the best approach for the study as the method allowed for the generation of in-depth information and involving a relatively larger number of participants in the study. This particularly afforded the study the opportunity to explain vividly the viewpoints of the participants on illegal mining and its implication on climate-smart agriculture in the Nadwoli-Kaleo district.

A criterion purposive sampling strategy (Patton, 2015) was used to select the study communities. Criterion sampling involves searching for cases that meet a certain criterion, which,

in this case, communities hugely involve in activities of illegal mining in the Nadwoli Kaleo District. The reason for the adoption of the criterion sampling is to help make a sound decision about explanations most plausible to contribute to climate-smart agriculture amidst illegal mining and climate change in the study area. On the basis of the criterion purposive sampling, Nanga, Vuuyiri, and Charikpong communities were selected on the basis of their hugely involvement in illegal mining in the district. Again, in each of the three communities, systematic sampling (proportionate) was used to select household heads or their representatives for the study. On the basis of a reconnaissance survey conducted 21 January 2019, households with farming as their primary activity from each community were listed. The compiled register of households for each community was then arranged in alphabetical order, and one in three sampling ratio was applied to obtain the households. To ensure validity and accuracy of the process, a simple random sampling method was applied to determine the starting position for the selection of a household. On the basis of the systematic method of sampling, 111 (47 of 53 from Charikpong, 32 of 37 from Nanga, and 32 of 35 from Vuuyiri) smallholder food crop farmers were recruited for the study.

Questionnaire and interviews were conducted with the participants in all the three selected communities in May 2019. The questionnaires were granted to household heads who were involved in activities of farming, whereas the interviews were granted to the chiefs of the three communities: one officer at the Environmental Protection Management, one officer at the MOFA, one mineral commissioner, and four illegal miners as represented by **Table 1**. Maximum variation purposive sampling approach was adopted to recruit the respondents for the interviews. Maximum variation involves selecting highly qualified persons who cover the spectrum of position and perspectives in relation to a phenomenon (activities of illegal mining, environmental sustainability, and climate-smart agriculture). On the basis of the maximum variation purposive sampling principle, 10 key informant interviews were conducted. The study main objective guided the development of the questionnaires and the interviews. Particular areas covered by the questionnaires and interview were the effects of illegal mining on the environment and implication of the environmental impact on climate-smart agriculture. All the questionnaires and the interviews were held with participants at their homes with each questionnaire and interview lasting for 40 and 47 min, respectively. Questionnaire and interview guides developed were in English language but translated into Dagaare (local language of participant) during the interview for easy understanding and for appropriate responses.

Descriptive statistics were used to analyze the questionnaires. Thus, data collected from the field were well-sorted out and fed into statistical package for social sciences for analysis. Analyzed data were represented using charts and tables. For qualitative data, thematic analysis was used to analyze the interviews. Thus, field data collected were transcribed, and the transcriptions were read repeatedly to identify common themes about illegal mining and its implication on climate-smart agriculture. The first two

**TABLE 1** | List of interviewees.

| Interviewee                                      | Sex    | Role   | Pseudo |
|--|--------|--|--------|
| Chief of Nanga                                   | Male   | Oversees the management of natural resources in his area   | A1     |
| Chief of Cherikpong                              | Male   | Oversees the management of natural resources in his area   | A2     |
| Chief of Vuuyiri                                 | Male   | Oversees the management of natural resources in his area   | A3     |
| Field officer of environmental protection agency | Male   | Provide environmental management support                   | A4     |
| District field extension agent (MOFA)            | Male   | Support activities of agriculture in the district          | A5     |
| Field supervisor of mineral commission           | Male   | Supervises the activities of mining in the district/region | A6     |
| Illegal miner 1                                  | Male   | Involves in activities of mining                           | B1     |
| Illegal miner 2                                  | Female | Involves in the activities of mining                       | B2     |
| Illegal miner 3                                  | Male   | Involves in the activities of mining                       | B3     |
| Illegal miner 4                                  | Female | Involves in the activities of mining                       | B4     |

steps of thematic analysis outlined by Attride-Stirling (2001) and Braun and Clarke (2006) such as familiarization with transcript and themes identification guided the analysis.

## RESULTS AND DISCUSSION

This section of the paper presented results on the demographic characteristics of respondents, the effects of illegal mining on the environment, climate-smart agriculture practices of the area, and the implication of illegal mining on climate-smart agriculture. This section also presented results on the relationship between climate-smart agricultural practices and the factors of sustainable agriculture and food systems (soil, land, and water management).

### Demographic Characteristics of Respondents

The demographic assessment of the respondents revealed that 64% were male and 36% were female. For age, majority of the respondents, which represented 33%, were within the age category of 40–49, 29% of the respondents were within age category of 50–59, 23% of the respondents were within the age category of 30–39, and 14% were 60 years and above. On the level of education of the respondents, 61% had no formal education, which implies that they did not go to school, 25% had basic education, 8% had secondary education, and 5% had tertiary education.

### Effects of Illegal Mining on the Environment in the Nadowli-Kaleo District

Table 2 presents the results on the effects of illegal mining on the environment. The study revealed that surface exploration and mining of the gold deposit in the Nadwoli-Kaleo district by the illegal miners have resulted in the loss of biodiversity, formation of sinkholes, contamination of soil and ground, and surface water pollution. Over the years, illegal mining has been a subject of discussion due to its perceived implications now and in the future with respect to environmental sustainability and agricultural land management (Kwadwo et al., 2016; Apollo et al., 2017; Mwakesi et al., 2020; Christmann, 2021). To determine the implication of illegal mining on the environment and its replicate effects on climate-smart agriculture, residents were asked to indicate the

**TABLE 2** | Effects of illegal mining on the environment in the Nadowli-Kaleo district.

| Variable                           | Frequency | Percentage |
|------------------------------------|-----------|------------|
| Ground and surface water pollution | 26        | 23         |
| Contamination of soil              | 22        | 20         |
| Loss of biodiversity               | 30        | 27         |
| Formation of sinkholes             | 33        | 30         |
| Total                              | 111       | 100        |

environmental effects of illegal mining on their environment. As represented by Table 2, 30% of the respondents reported that the activities of illegal mining have resulted in the formation of sinkholes, which initially were not present due to the absence of the mining activity. Again, 27% of the respondents revealed that illegal mining has led to the loss of the biodiversity around the study communities. Furthermore, 20% of the residents observed that the presence of illegal mining in the areas has led to the contamination of the soil, which previously was good for food crop production, and, lastly, 23% of the residents reported that illegal mining has led to ground and surface water pollution.

The interview with the chiefs confirmed that illegal mining places serious threat to their environment and their agricultural land. The chiefs in all the three communities observed that, since the inception of the activities of illegal mining, it has led to the depletion of the forest cover. They added that illegal mining has resulted in loss of biodiversity around the area especially animal and mammal species that were predominant at the Black Volta river corridor, and the pollutants discharged by illegal miners destroyed microorganisms and cause loss of fauna and flora, as succinctly captured by A2:

*“My son, some years back, if my memory can still set me right, our land was forested, especially along the Black Volta corridor. Today, due to the emergence of illegal mining, the community has lost that stretch of forested land to activities of illegal mining operators” (4 June 2020)*

Again, the chiefs referred to their streams and the Black Volta River where some years back served as sources of drinking water. The chiefs indicated that the high demand for water by miners in extraction, processing, and waste disposal pollutes water sources nearby and depletes freshwater supplies in the region surrounding the mine. The use of mercury for gold processing as confirmed by four of the miners during the interview indicated that the use of mercury has affected water quality. The miners reported that the use of the mercury is because it is cheap, dependable, and portable operation for concentrating and extracting gold from low-grade ores, as captured by B4.

*“Mercury is the main chemical we in extracting the gold here. They are others chemicals but they are too expensive for us with limited financial capacity. We know the environmental consequences of the chemical (referring to mercury) but we cannot also stop using it because the alternative is not there” (4 June 2020).*

An interview with one of the officers at the EPA revealed that illegal mining in the areas has led to the formation of sinkholes as artisanal miners cleared the vegetation and dug for mineral-bearing ore. This accordingly has scarred the landscape with excavated pits and trenches, which, in turn, renders the land unsuitable for any other purpose. At the district agricultural office, one of the agricultural extension agents during the interview reported that illegal mining has caused a serious damage to the arable land with the possibility to affect food security of households who depend on farming. The officer indicated that every portion of the land of these three communities over decades were cultivable; however, over 9% of the land has been lost due to the activities of the illegal mining. In the officers own words, it was captured as follows:

*“Before the emergence of the mining activities in these communities, every part of the land was cultivable, today as we speak, there are some portions of the land you cannot grow crops” (Interviewee A5, 4 June 2020).*

The results from the respondents agreed with the literature. Illegal mining, a low-technology and labor-intensive mining activity (Kwadwo et al., 2016) in Ghana, has come under serious scrutiny due to its implication on agricultural land and other livelihood sources (Amankwah, 2013; Okoh, 2014; Ofofu et al., 2020; Atta and Tholana, 2021). Studies have found that illegal mining has scarred the landscape with excavated pits and trenches in its operation areas, which, in turn, renders the land unsuitable for any other purpose (Ofofu et al., 2020; Atta and Tholana, 2021). Studies have also observed that the activities of illegal mining has contributed to water pollution due to the high demand for water by miners in extraction, processing, and waste disposal (Amankwah, 2013; Ndabi, 2017). From the study, the results indicated that the activities of mining in the study communities have resulted to environmental resources depletion. As reported by the residents of the three communities, the MOFA, and the EPA, illegal mining in the areas has resulted to unnecessary competition between agriculturalists and the miners for land. The activities of illegal mining will continue

unabated because of its importance to the mining operators and communities (Hilson et al., 2013; Kwadwo et al., 2016; Obeng et al., 2019; Yamarak and Parton, 2021). In fact, the literature has observed illegal mining as livelihood diversification (Hilson et al., 2013; Kwadwo et al., 2016) and argued that the formalization of mining sector will do people good (Kwadwo et al., 2016). Although this study completely agreed with their proposal, it is also important that we do not create much room for activities of illegal gold mining such that sustainable agricultural activities have to compromise.

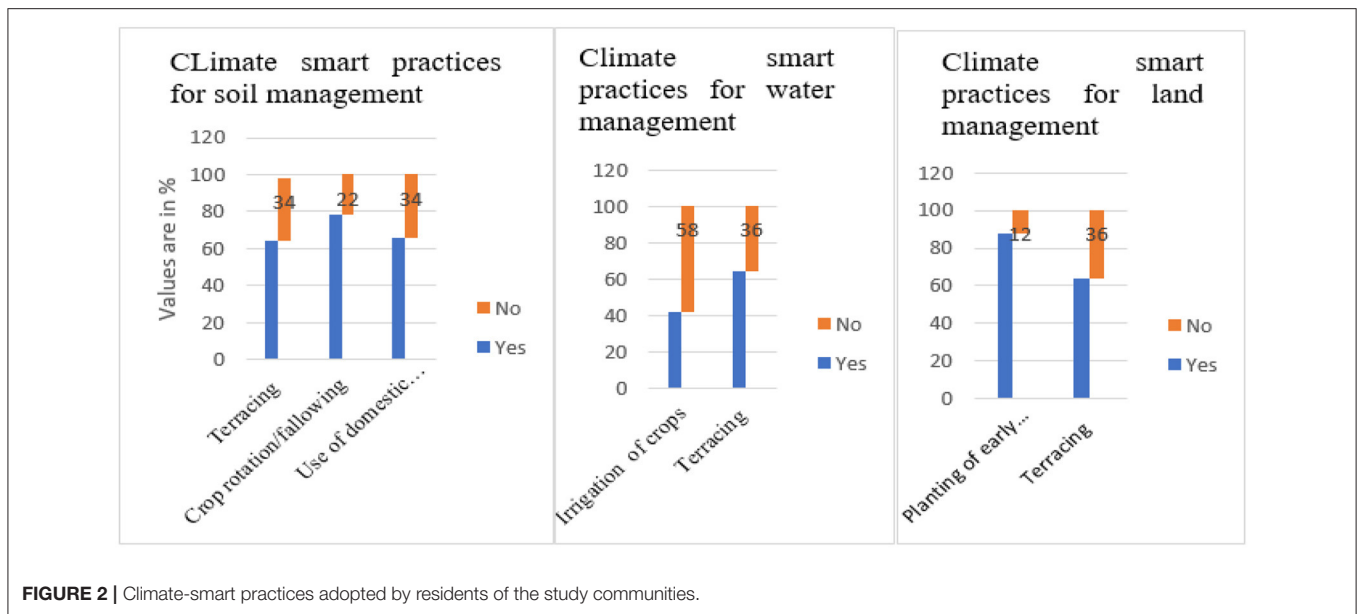
## **Illegal Mining and Its Environmental Implications for Climate-Smart Agriculture in Nadowli-Kaleo District**

### **Climate-Smart Agricultural Practices Adopted by Respondents**

As part of the assessment of the implication of illegal mining on climate-smart agriculture, **Figure 2** presents climate-smart agricultural practices that are engaged by the communities. From the assessment of the climate-smart practices, the study observed that smallholder farmers have specific climate-smart agricultural practices for soil, water, and land management.

For soil management, specifically, 66% of the respondents reported that application or use of domestic waste/manure for improved soil fertility for improved crop productivity was dominant, whereas 34% indicated that they do not use the practice. Again, 64% of the farmers also reported that they practice terracing, whereas 36% of them indicated that they do not practice terracing on the farmlands to maintain soil fertility. For crop rotation as climate-smart agriculture practice to soil management, 78% of them reported that they are involved in the practice, whereas 12% held a contrast view. Soil management has been observed to play a critical role in sustainable agriculture. Earlier studies have found that, to improve soil quality for improved food systems, application of manure, composting, terracing, and crop rotation or fallowing are real ingredients to support the process (Maguza-Tembo et al., 2017; Nyasimi et al., 2017). Maguza-Tembo et al. (2017) on the determinants and impact of climate-smart agriculture technology adoption on the welfare of smallholder farmers in Malawi reported that the adoption of manure application, crop rotation, and terracing by the farmers has aided in sustaining the fertility of soil.

In addition, the assessment of water management practices in response to the changing climate revealed that 42% of the respondents revealed they irrigate their farms, whereas 58% indicated that they did not irrigate their farms. For terracing to ensure water percolation and retention, 64% of the respondents indicated that the practice is an old one among them. Lastly, for land management, the assessment revealed that 88% of the respondents indicated that planting of early resistant crop varieties was highest among them in response to the changing climate system, whereas 12% indicated that they did not adopt planting of drought resistant crop varieties. For terracing to ensure land management, 64% indicated that the practice has been with them for long, whereas 12% indicated that they did not adopt the practice. Farm level irrigation and adoption of



early maturing crop varieties are important strategies to support climate change adaptation (Yiridomoh et al., 2020; Angom et al., 2021). In a systematic review of climate-smart agricultural practices among smallholder farmers in Aravalli district, Gujarat, India, Angom et al. (2021) observed that farm level irrigation and planting of earlier maturing crop varieties have helped the farmers to put their land and water into good use for sustained agricultural activities. This implies that these climate-smart agricultural activities in Ghana must be promoted for sustainable environment and agriculture.

### Relationship Between Climate-Smart Agricultural Practices and Soil, Water, and Land Management for Activities of Farming

To establish the relationship between climate-smart agricultural practices and soil, water, and land management, the results as represented by **Table 3** revealed that crop rotation/fallowing was strongly associated with soil management at 1% with \*p-value 3.891. In addition, the use of domestic/manure and terracing as climate-smart agricultural practices was significant with soil management at 5% with p-values 4.218 and 2.197, respectively. Irrigation of crops and terracing of farm plots as climate-smart practices were significantly associated with water management at 5% with p-values 3.021 and 2.971, respectively. Finally, planting of earlier maturing crop varieties and terracing were significantly associated with land management at 1 and 5% with p-values 5.180 and 3.017, respectively. Earlier studies have found that the use of domestic waste, terracing, and crop rotation/fallowing have promising qualities to improve soil quality for activities of farming (Partey et al., 2018; Andrieu et al., 2020; Mensah et al., 2020). The study of Andrieu et al. (2020) on mapping favorable zones for uptake of climate-smart agricultural practices in West Africa reported that crop rotation as a climate-smart practice has the potential to support sustainable agriculture through improved soil fertility. Other studies have found that

sustainable land management practices such as terracing could support sustainable food production and food systems (Issahaku and Abdulai, 2020; Mensah et al., 2020; Angom et al., 2021; Waaswa et al., 2021). The study of Waaswa et al. (2021) on climate-smart agriculture dissemination pathways among smallholder potato farmers in Kenya reported that crop rotation, composting, terracing, and irrigation have helped improve the quality of soil, water, and land for agricultural activities. Climate-smart agricultural practices are known to contribute to achieving sustainable development through improved sustainable food systems. This implies that climate-smart agriculture need to be prioritized and promoted especially in developing economies to assist farmers meet their households food need.

### Implication of Environmental Effects of Illegal Mining to Climate-Smart Agriculture

Soil, water, and land management are central to climate-smart agriculture in northern Ghana (Center for Scientific and Industrial Research, 2017; Issahaku and Abdulai, 2020). Traditional soil, water, and land management practices adopted by smallholder farmers (to improve soil fertility and water moisture content) such as use of domestic waste/manure on farm lands, terracing to ensure soil retention and water percolation, and crop rotation/land fallowing to maintain soil fertility and irrigation are under a serious threat. Application of organic domestic waste/manure has noted for their importance; improved soil fertility, structure, and soil moisture retention (Maguza-Tembo et al., 2017; Nyasimi et al., 2017; Partey et al., 2018; Waaswa et al., 2021). Terracing is noted for its water conservation and soil erosion reduction especially farmlands that are located on steep slopes (see **Figure 3**). Crop rotation/land fallowing helps reduce incidences of pests and diseases of crops and improve soil structure and soil fertility through nitrogen



**TABLE 3** | Relationship between climate-smart agricultural practices and water, land, and soil management.

| Component of environmental management | Climate-smart practices                     | Adoption | Non-adoption | Total     | $\chi^2$ value |
|---------------------------------------|---|----------|--------------|-----------|----------------|
| Soil management                       | Use of domestic waste/manure                | 73(66)   | 38(34)       | 111 (100) | 4.218***       |
|                                       | Terracing                                   | 71 (64)  | 40 (36)      | 111(100)  | 2.197**        |
|                                       | Crop rotation/fallowing                     | 87 (78)  | 14 (12)      | 111 (100) | 3.891***       |
| Water management                      | Irrigation of crops                         | 47 (42)  | 64 (58)      | 111 (100) | 3.021**        |
|                                       | Terracing                                   | 71 (64)  | 40 (36)      | 111 (100) | 2.971**        |
| Land management                       | Planting of earlier maturing crop varieties | 98 (88)  | 3 (12)       | 111 (100) | 5.180***       |
|                                       | Terracing                                   | 71 (64)  | 40(36)       | 111 (100) | 3.017**        |

\*\*\*Denotes significant at 1% level, \*\*denotes significant at 5% level, and \*denote significant at 10% level. Values in parenthesis are percentages.



**FIGURE 3** | Terracing as climate-smart agricultural practice identified in all the four study communities. Terracing is one of the oldest methods of managing soil and water—an agricultural practice, which involves collecting surface runoff water (thus increasing the infiltration and controlling water erosion known from ancient history) to transform landscape in hilly or mountainous regions or areas. Terracing is important for its considerable reduction in soil and water erosion, thus, if correctly planned, constructed, and properly maintained. However, terracing, if not properly maintained, could cause land degradation.

fixing crops (Maguza-Tembo et al., 2017; Nyasimi et al., 2017; Angom et al., 2021; Waaswa et al., 2021).

Although these practices are sound consistent to promote climate-smart agriculture, the results of the study suggest that the activities of illegal mining have had great implication on agriculture. Thus, illegal mining contests for agriculture space, and such contest affects the livelihood of people engage in agriculture. For instance, the formation of sinkholes as reported by the respondents due to illegal gold mining makes the land and soil unproductive and, therefore, affects agricultural food production. The scarcity of the land for agricultural activities due to competition

from illegal mining will also affect traditional crop rotation and fallowing (Ndabi, 2017; Ofofu et al., 2020; Atta and Tholana, 2021). For instance, at Nanga, the chief reported the following:

*“Our farming and food security is under serious threat due to activities of mining. For the past 10 years, it has become extremely difficult to practice farm rotation or fallowing which is one of our traditional farming practices to replenish our deteriorated soil fertility. This is due to competition for land by miners and food crop farmers. Two year ago, I got to my only farmland and saw it vandalize by these miners. As I speak with you, I have to beg for*

*land from other families every year to farm. How then do I practice climate smart agriculture like farm rotation or land fallowing?" (Interviewee A1, 4 June 2020)*

Furthermore, the activities of illegal mining in the area have accounted for soil and water contamination and give rise to water turbidity as reported by the residents, the miners, the Mineral Commission, and the EPA and through the reconnaissance field survey of the researcher. What that means is that the high turbidity levels will affect primary productivity with consequence effect on the life of biodiversity (Millennium Ecosystem Assessment, 2005; Opschoor, 2007; Ndabi, 2017). Thus, if the biodiversity depletes due to activities of illegal mining, then it will affect the services of the ecosystem such as provisioning, regulatory, and supporting (Millennium Ecosystem Assessment, 2005). Again, water and soil contamination may constraint irrigation activities in the study communities, which is recognized as one of the most reliable and transformed ways of responding to the changing climate system. For instance, at Charikpong, the chief reported the following:

*"Our few streams are completely contaminated with mercury and other chemicals. Our main river (The Black Volta River) is under serious threat of pollution. We cannot collect and drink water from the few streams around us nor use the water to irrigate our farms. This has made it very difficult for some of us who undertake dry season gardening to supplement our already diminishing farm produce" (Interviewee A2, 4 June 2020).*

Agriculture must undergo a major transformation to meet the challenges of food security, reducing poverty while responding to the changing climate system. Water and land are likely to present the greatest challenges on the food supply side, given the diminishing carrying capacity of arable land and water resources (Amankwah, 2013; Adiyah, 2014; Poku, 2016). This is because many of the smallholder farmers and pastoralists that form the backbone of agriculture in northern Ghana are utilizing a degraded environment partly due to illegal mining. The ecosystems that provide healthy surface water and groundwater as well as food, fodder, and fiber are fast deteriorating in the Nadowli-Kaleo district due to illegal mining (Prosper and Guan, 2015; Environmental protection agency, 2016; Ghana News Agency, 2018). With these challenges, agriculture cannot proceed as a business-as-usual manner. Studies have reported on the devastating effect of activities of illegal mining on agricultural land to include conversion of agriculture lands for its operations (Schueler et al., 2011; Environmental protection agency, 2016). Agriculture and its activities need quality soil, water, and land resources to thrive well. Although these are prerequisite for sustainable agriculture, due to the emergence of illegal gold mining in the area, known agricultural practices in response to the already changing climate have been affected.

## CONCLUSION

Agriculture remains the beacon of the economy of Ghana, and its development has serious implications for poverty reduction

and food security in Northern Ghana. It is obvious that mining do not contribute to the economy of Ghana. The argument here is its dreadful consequences on sustainable agriculture and food systems due to its detrimental effects on the environment that support climate-smart agriculture. The study aim was to investigate illegal gold mining and the environmental implication on climate-smart agriculture in the Upper West Region of Ghana. The study found that the activities of illegal mining have resulted in formation of sinkholes, contamination of soil, ground, and surface water pollution, and loss of biodiversity. The study further revealed that known agricultural practices such as use of domestic waste and manure, terracing, crop rotation/land fallowing, irrigation of crops, and planting of early resistant crop varieties have been affected by the activities of illegal gold mining in the area with the adoption of climate-smart agricultural practices remains extremely difficult. In Ghana and other developing countries, key issues threatening food security and sustainable agriculture are linked invariably to land use. Soil degradation, water quality, and biodiversity all have a land use components that affect activities of farmers, and land use planning with an agricultural lens will help protect farmland, farmers, and their livelihood and, at the same time, ensure environmental sustainability through improved soil fertility and water management. The author of this paper states that conscious efforts by the Ministry of Lands and Natural Resources and its subsidiary agencies and departments are needed to sustain the ban on illegal gold mining with intensified supervision and monitoring while a systematic scheme involving relevant stakeholders is developed and implemented to ban illegal mining in Ghana completely. Again, there is the need for the Mineral Commission of Ghana together with the district assemblies and traditional authorities to prepare short- to medium-term training programs to continuous to disseminate the impact of illegal gold mining activities on the environment and sustainable agriculture and food systems. The Ministry of Lands and Natural Resources and the Ministries of Food and Agriculture need to engage more with relevant stakeholders including academics, non-governmental organizations, researchers, the Parliament of Ghana, traditional authorities, and youth groups to work at better regulations of the mining activity to protect the environment and support sustainable climate-smart agricultural production in Ghana. Finally, The MOFA needs to develop an approach to support the adoption of climate-smart agricultural practices by smallholder farmers to meet the food demand of their households.

## STRENGTHS AND LIMITATIONS OF THE STUDY

The study was a single case study using Nadowli-kaleo district. Including other districts, especially those in the southern Ghana, would have provided some more evidence on illegal gold mining and the implications of their activities on climate-smart agriculture in Ghana. Hence, policy decisions with respect to promoting climate-smart agriculture may be limited to the case study area. However, with limited studies of this

caliber in the region and Ghana, the study would provide a perfect first-hand information on activities of illegal gold mining and climate-smart agriculture in a region known to have high indices of poverty and highly vulnerable to climate change. Going forward as a country, it will serve us better, if a more comprehensive study covering all the mining communities in Ghana is under similar investigation to help roll out policies, programs, and projects that are more detailed on climate-smart agriculture for sustainable food systems and production.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author/s.

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## ETHICS STATEMENT

Ethical review and approval was not required for this study with human participants, in accordance with the local legislation and institutional requirements.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

## ACKNOWLEDGMENTS

The author wishes to acknowledge the respondents for the information. We also wish to thank all the field assistance for their good work during the fieldwork.

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