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Climate change, artisanal and small-scale mining, and livelihood diversification: Whither the agrarian workforce?

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ABSTRACT

This article explores the dynamics of climate change and artisanal and small-scale mining (ASM), and its manifestations in livelihood diversification in the agriculture sector. Integrating the concept of 'livelihood diversification' with discussions on 'cocoa-climate variations' in Ghana, we empirically examine how climate effects have created a space and conditions for labour shifts from the agrarian to the ASM economy. The article offers explanatory power to explore how climate-related shocks can become key push factors of farmers' diversification strategies, highlighting their consequences for the environment and farm yields, and, in turn, their implications for livelihoods.

1. Introduction

In recent decades, discussions on climate change have evolved from an environmental to a complex development issue (Dietz et al., 2004; Peri and Robert-Nicoud, 2021). The complexity of the issue continues to assume greater significance as concerns about global climate variations take centre stage (IPCC, 2023, 2019). Climate variations continue to have widespread adverse impacts and related losses to important economic activities including agricultural production (Dietz et al., 2004; Wiebe et al., 2015). Increasing weather and climate extreme events have exposed millions of people to acute food and water insecurity, with the largest adverse impacts observed in many locations in Africa and Asia, and, globally, for food producers and low-income households (IPCC et al., 2023).

In Ghana, estimates suggest that the agricultural sector contributes about 30% of Gross Domestic Product (GDP) and employs approximately 50% of the economically active labour force (Vigneri and Kolavalli, 2017). One major contributor to agriculture's share of Ghana's GDP is the cocoa sub-sector, estimated to contribute about 10% (Abbadi et al., 2019; Vigneri and Kolavalli, 2017). Although agricultural production and agrarian modes of livelihood have largely served as the backbone of the Ghanaian economy (Bymolt et al., 2018; Vigneri and Kolavalli, 2017), in recent times, agrarian fortunes have been observed to be declining - what is commonly referred to as 'agricultural poverty' syndrome (Bryceson, 2002; Hilson and Garforth, 2012).

Also, due to the negative effects of climate change, agronomic challenges are increasing, with farming, especially cocoa production, under threat (Ehiakpor et al., 2016; Läderach et al., 2013). Being a weather-dependent activity, cocoa production in most parts of Ghana has become most vulnerable to the effects of climate change (Asante et al., 2017; Dietz et al., 2004; Hashmiu et al., 2022). Rural inhabitants in most areas in Ghana who heavily depend on subsistence agriculture base for the provision of food and income have also thus become vulnerable (Dietz et al., 2004; Ehiakpor et al., 2016).

Amidst high levels of climate-related uncertainty, many farmers have embraced 'adaptation' (Stringer et al., 2009) and livelihood diversification strategies including 'branching out' into non-agricultural sectors in an attempt to secure their livelihoods (Hilson and Garforth, 2013; Siaw et al., 2023). In this regard, in the ASM-agriculture nexus literature, the evidence suggests that one of the main sectors that has provided a safe haven for most farmers seeking income diversification away from agricultural activities has been the artisanal and small-scale mining (ASM) sector (Hilson and Garforth, 2013; Mkodzongi and Spiegel, 2019; Ofosu et al., 2020).

ASM is broadly defined as individual or collective labour-intensive mineral extraction with limited capital investments (Jønsson and Bryceson, 2009). Despite the highly rudimentary nature of most operations, the sector is known to have broader distributional effects,

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providing employment opportunities for many people (Arthur-Holmes and Abrefa Busia, 2022; Banchirigah, 2008; Ofosu and Sarpong, 2022). Several studies on farmers' participation in ASM highlight that push factors including 'agricultural poverty' and pull factors of ASM 'wealth' have underpinned farmers' diversification into ASM (Hilson and Garforth, 2013; Okoh and Hilson, 2011). Surprisingly though, scholars seem to have remained silent on the important issue of how climate-related shocks have become key push factors of farmers' diversification away from the agrarian sector and into the ASM economy. The exception, though, has been the study by Bansah et al. (2023), which explicates how climate change mechanisms have affected most agrarian communities in the semi-arid regions of Guinea, thereby driving many smallholder farmers into ASM.

In this regard, this present study, in large parts, seeks to complement the empirical findings from Guinea (Bansah et al., 2023). Our point of departure however is that our study focuses on the cocoa sector in the moist cocoa regions of Eastern Ghana to highlight the climate-cocoa-ASM conundrum. In this vein, our purpose in this study is to examine how the negative effects of climate change may contribute to conditions where farmers seek alternative sources of livelihood or strategies of livelihood diversification. Examining the issues in the context of mining and farming communities in Eastern Ghana, the question driving our empirical enquiry is: how are farmers strategising to deal with climate change and its impact on farming and, in turn, livelihoods? Our findings suggest that the dramatic changes in weather patterns, resulting in consistently low crop yields, and in turn, reduced income, have forced farmers and landowners to turn to ASM as an alternative way of exploiting their lands. This turn to ASM however has consequences for the environment and farm yields (Siaw et al., 2023). This issue is particularly important given that the Ghanaian government's ability to capture the full and real benefits of the cocoa economy is predicated heavily on the contribution of Ghana′s cocoa producers and their best farm practices (Eberhard et al., 2022). Our findings echo the long-standing calls for technical and material support for agricultural production and ASM operations; the findings also go a long way to filling the current gaps in the climate change-agriculture-ASM nexus literature, and have policy implications for sustainable agriculture, ASM, and livelihood diversification.

2. Climate change: Providing the context

Climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2023, 2019). Climate scientists argue that human industrial and commercial activities are increasing the amount of greenhouse gas in the atmosphere (IPCC et al., 2023). Greenhouse gas reflects heat back to earth, warming the surface of the earth, and, as a consequence, the average temperature of the earth is rising (Dietz et al., 2004). While some effects of global climate change will be positive (such as prolonged growing seasons and warmer climates in Europe and North America), changes for economies near the tropics will be mostly negative, including longer and more frequent droughts, and more severe heatwaves (Castells-Quintana et al., 2021; IPCC et al., 2023). These climate-related disruptions will tend to exacerbate existing challenges for the poor, and other urban populations (Castells-Quintana et al., 2021; Fragkos, 2020).

Notwithstanding the global commitments to solving climate change-related issues, there appears to be a worsening crisis of climate change across entire regions of sub-Saharan Africa (WMO,2021). This is particularly true for Ghana, where there is already evidence of the direct manifestations of climate change, i.e., increasing temperatures and rainfall variability, including unpredictable extreme events and a rise in sea-level (MESTI, 2013; Owusu et al., 2008; The World Bank Group, 2022). These manifestations continue to affect various facets of Ghana's economic structure, especially with its high reliance on sectors that are particularly sensitive to climate change, such as agriculture (Asante et al., 2017; MESTI, 2013). Also, climate change disruptions are beginning to have serious repercussions for and far-reaching transformations in energy, land, and other industries (Lacombe et al., 2012; MESTI, 2013).

According to the Ministry of Environment, Science, Technology and Innovation (MESTI), the analysis of national data (1960–2000) shows a progressive rise in temperature and a decrease in mean annual rainfall in all agro-ecological zones in Ghana (MESTI, 2013). The average rate of the increase in temperature has been 0.21°C per decade, with a more rapid increase in the northern regions of the country (MESTI, 2013). There are clear signals of warming with an increase of 1°C observed over the past 40 years (1960–2000); projected estimates of average temperature rise are 0.6°C, 2.0°C, and 3.9°C by the year 2020, 2050 and 2080, respectively (MESTI, 2013).

Generally, West Africa has undergone a period of diminished rainfall punctuated by a series of severe droughts and marked by a shift in rainfall regime (Owusu et al., 2008). In Ghana, generally, rainfall decreases from the south to the north. From the 40-year dataset, rainfall levels generally have been reducing, with the rainfall patterns becoming increasingly erratic in all ecological zones in Ghana (Lacombe et al., 2012; MESTI, 2013). Scenarios of climate change development have shown a sea level rise of 2.1 mm per year over the last 40 years in Ghana, with potential increases of 5.8 cm, 16.5 cm, and 34.5 cm by 2030, 2050, and 2080, respectively (MESTI, 2013).

In a related development, The World Bank (2022) reports that since 1960, average annual mean temperature in Ghana has increased by around 1 ° Celsius. The average number of 'hot' days has increased by 13 %, while the number of hot nights per year increased by 20 %. This is highly significant for a country with a tropical climate, an average annual temperature of 28 ° Celsius, and relative humidity between 77% and 85%. Rainfall has also become more erratic. Sea level rise and changing hydrodynamics along the West Africa coast have led to increased coastal erosion. As a result, weather and climate extremes have increased in frequency and magnitude (The World Bank Group, 2022, p. 3)

3. Climate change, agriculture production, and adaptation strategies

Climate is very important in agriculture as it largely determines the limit for agricultural activities (Picot et al., 2024; Wang et al., 2025). Favourable climate - adequate rainfall and moderate temperatures - serve as incentive for farming (IPCC et al., 2023; Wang et al., 2025). In recent times however, changes in climatic parameters are known to be altering the development of farming activities globally (Wang et al., 2025; T. Wang et al., 2024). Unpredictable, random shocks, caused by extreme weather events is rendering agricultural production highly vulnerable and unproductive (H. Wang et al., 2024). Particularly in sub-Saharan Africa, increased climatic change impacts have resulted in decreases in farm yields, thus increasing the vulnerabilities of smallholder farmers - known for the bulk production of food and cash crops - making them more susceptible to poverty (Adjei-Nsiah and Kermah, 2012; Tubiello and Fischer, 2007).

For most cocoa growing regions in the world, the cocoa sector is very important in terms of socioeconomic development (Bymolt et al., 2018; Vigneri and Kolavalli, 2017). In Ghana, for example, for most smallholder cocoa farmers, income from cocoa production represents about 70–100% of their annual household incomes (Asante et al., 2017; Ntiamoah and Afrane, 2008). This notwithstanding, cocoa farming systems are still dependent on the weather to achieve production outputs (Asante et al., 2017). Cocoa is highly susceptible to drought and the pattern of cropping of cocoa is related to rainfall distribution (Asante et al., 2017; Ntiamoah and Afrane, 2008). Rainfall therefore tends to be the single most important factor driving the distribution of cocoa in Ghana. Rather than the total annual rainfall, the distribution of rain, especially in the dry season, is the most important element for the

production of cocoa (Asante et al., 2017; Bymolt et al., 2018; Ntiamoah and Afrane, 2008). In this regard, it is well established that climate change effects continue to alter the rates and stages of development of cocoa production (Afele et al., 2024; Asante et al., 2017; Asitoakor et al., 2022).

Faced with income disparities due to climate shocks, households often resort to climate change adaptation mechanisms and economic responses to weather shocks (Wang et al., 2025). Adaptation is broadly described as those responses by individuals and groups to climatic change or other stimuli that are used to reduce their vulnerability or susceptibility to adverse impacts or damage potential (Bradshaw et al., 2004). For resource-constrained farmers, adaptation is recognized as an important intervention often utilised to address the threats posed by climate change and thereby increase household resilience and food security (Antwi-Agyei et al., 2021a; Kori et al., 2020)

For some households, non-farm employment represents a crucial adaptation strategy to mitigate the impact of climate-related income shocks (Blakeslee et al., 2020; Musungu et al., 2024; Wang et al., 2025). Other farmers engage in various climate change coping and adaptation strategies such as varying planting dates, crop diversification, irrigation, adoption of drought resistant crop varieties, and migrating to new communities for alternative livelihoods (Ahmed et al., 2022; Aniah et al., 2019; Kori et al., 2020). With regards to cocoa production Asante et al. (2017) observed, among other adaptive responses, that some farmers plant about three times the plantain suckers they usually plant, to provide a dense temporary shade over cocoa seedlings, and resort to planting more cocoa seedlings randomly per unit area on new farms as a form of insurance against seedling mortality. Elsewhere Amfo and Ali (2020) highlight similar cocoa farmers adaptation strategies including crop and livestock diversification.

Farmers and households in economically developed countries usually demonstrate high agricultural resilience when confronted with climate shocks because they mostly benefit from financial and technical resources (Bradshaw et al., 2004; Li et al., 2017). In contrast, farmers in developing countries lack infrastructure and technical support, making them particularly vulnerable to sudden climate shocks (Aragón et al., 2021; Bryan et al., 2013). Hence in low-income countries dominated by subsistence farming, climate shock-induced poverty may force farmers to adopt temporary migration as a coping mechanism (Rana and Qaim, 2024; Thiede, 2023). There may also be other forms of employment, moving to the city in search for jobs, doing work in transport, service etc. (Rana and Qaim, 2024; Sugden et al., 2022; Tiwari et al., 2022). Farmers may also diversify or move into ASM, where the farmers believe it to be less vulnerable to climatic stressors (Bansah et al., 2023; Okoh and Hilson, 2011). This diversification mechanism is also occasioned by the fact that ASM offers high rewards as compared to farming (Okoh and Hilson, 2011).

In sum, we conclude this section by highlighting that while the negative effects of climate change are undeniable, there are adaptation strategies to address climate change effects. In the case of agriculture, diversification, be it increasing the variety of production locations, crops, enterprises, or income sources, is one adaptation that has been often identified as a potential response to climatic variability and change (Bradshaw et al., 2004; Kelly and Adger, 2000; Mendelsohn, 2000). Strategies and avenues for farmers adaptation to climate change also hint to a potential avenue to go into ASM as a potential strategy (Bansah et al., 2023; Hilson and Garforth, 2013).

4. Livelihood diversification as an adaptation strategy

Livelihood diversification is commonly defined as the process by which families and households put together a diverse portfolio of economic activities and social support capabilities in their attempt to survive and in order to improve their standard of living (Bryceson, 2018; Ellis, 1998). According to Hussein and Nelson (1998), livelihood diversification refers to attempts by households to explore new ways to raise incomes and reduce risks. Supported by considerable empirical evidence, it is often argued that livelihood diversification is a good poverty reduction strategy (Asfaw et al., 2019; Ellis, 1998; Ellis and Allison, 2004; Loison, 2015). Diversification can help households to insulate themselves from economic and environmental shocks (Ellis and Allison, 2004; Kassie et al., 2017). Diversification can also provide the platform for accruing assets that allow individuals and households to construct their escape routes out of poverty (Ellis and Allison, 2004; Martin and Lorenzen, 2016).

The positive effects of diversification happen because diversification widens people's economic options, minimises reliance on particular physical resources, and encourages spatially diverse portfolios (Ellis and Allison, 2004; Lay et al., 2008). The diverse portfolios are mostly made up of economic activities beyond the realm of the agricultural sector, and include both high-return and low-return activities such as services, construction, mining etc. (Gautam and Andersen, 2016; Lay et al., 2008; Start, 2001). In contrast to the common knowledge that most households, especially in sub-Saharan Africa, rely on agricultural activities for subsistence, scholars have observed that households in sub-Saharan Africa derive their income from diverse sources with non-farm activities accounting for a significant share of overall income (Barrett et al., 2001; Bryceson, 2002; Ellis, 2006; Haggblade et al., 2010; Reardon, 1997).

According to Loison (2015), households and individuals usually diversify their economic activities and incomes in response to incentives that may be classified as 'push' and 'pull' factors. Push factors are negative factors that may force households and individuals to pursue additional livelihood activities outside or within their primary economic activity (Loison, 2015). Contrarily, pull factors are positive and may attract, for example, farm households to seek additional livelihood opportunities to improve their standards of living (Loison, 2015). Underpinning most research works on livelihood diversification, especially in sub-Saharan Africa, is the broader issue that structural adjustment programmes and inadequate funds from governmental sectors have resulted in 'de-agrarianisation' – a push of livelihoods away from the agricultural sector – and subsequent unemployment (Bryceson, 2018; Hilson and Garforth, 2013). According to Banchirigah and Hilson, de-agrarianisation has resulted in pushing many youths into ASM in many resource-rich regions including Ghana (Banchirigah and Hilson, 2010; Banchirigah, 2006).

Livelihood diversification into ASM is also generally pursued because of the 'pull' belief that more revenues can be earned from the sector (Hilson and Garforth, 2012). Also some farmers are geared to diversify and work in ASM simply to supplement revenues (Cartier and Bürge, 2011; Hilson, 2016). The issue of livelihood diversification, in recent times, has become more imperative due to the negative impacts of climate change on agricultural production and agrarian livelihoods.

5. Research context – Ghana's cocoa sector

We develop our contribution in the context of the cocoa sector in Ghana. Over the years, the cocoa industry has been the backbone of Ghana's economic growth (Bymolt et al., 2018; Vigneri and Kolavalli, 2017). Indeed, Ghana is the second biggest producer and exporter of cocoa in the world, after Ivory Coast, and accounted for about 16.3% of global cocoa bean production in 2020 (Boysen et al., 2023; Van Den Broeck and Akaribo, 2024). Cocoa is typically cultivated by smallholder farmers with average cocoa land areas of around ten acres and yield levels of about 300 kg/ha (Van Den Broeck and Akaribo, 2024; van Vliet et al., 2021). The sector is estimated to employ over 800,000 farmers (Bymolt et al., 2018; Vigneri and Kolavalli, 2017).

While the global cocoa market is expected to increase, achieving global cocoa production would depend heavily on the contribution of Ghana's cocoa producers (Ansah et al., 2020; Glavee-Geo et al., 2020). However, Ghana's cocoa sector faces a wide range of issues, including farmer poverty, and a weak supply chain governance framework

(Fountain and Hütz-Adams, 2018; Ollivier de Leth and Ros-Tonen, 2022). In addition, low producer prices and pest infestation have become drawbacks affecting the production of Ghana's cocoa beans (Amankwah-Amoah et al., 2018; Bryant and Mitchell, 2021; Quarmine et al., 2012). Of particular concern is farmer poverty, which is seen as a key driver of other issues, such as poor working conditions (Fountain and Hütz-Adams, 2018; Van Den Broeck and Akaribo, 2024).

Although Ghana has been a reliable supplier of cocoa beans to the world market, with the country regularly selling one year forward of about 80% of its crop, which usually totals 750,000–850,000 tons, the country recorded one of the lowest rates of cocoa production in recent times in the 2023/24 season (Ghanaweb, 2024; Reuters, 2025). Cocoa output for the season fell significantly, with an estimated 40% shortfall from the target of about 820, 000 metric tons (myjoyonline.com, 2024; Reuters, 2025). To a significant extent, this is a result of continuous drought and erratic rainfall patterns affecting cocoa pods in the cocoa-growing regions in Ghana (Ghanaweb, 2024).

6. Methodology

6.1. Research design and data collection

In seeking to analyse climate change impacts on Ghana's cocoa sector, and farmers' transitions from cocoa production to ASM, data for the empirical inquiry come from semi-structured interviews with some of the major industry players (including farmers), officials at the Ghana Cocoa Board (COCOBOD) and some licensed cocoa buying companies. Data collection took place between May-August 2021. The selected districts were Atiwa, Atiwa West, and East Akim. These districts were chosen because they have notable populations of cocoa farmers and ASM operators in the area.

Employing the snowballing technique, we were able to identify a farmer who had recently sold his land and gone into ASM. An initial interview was conducted with this informant, who then served as the point of contact for identifying other participants, especially cocoa farmers, and other local people who have transitioned into artisanal mining. All participants who consented to participate in the study were interviewed, and these interviewees helped to recruit additional participants within the research sites.

In all, a total of 42 interviews were conducted with cocoa farmers (15), COCOBOD officials (5), licensed cocoa-buying companies (7), and artisanal miners (15). Following the collection of the biographical information from our participants, our interviews focused on getting our participants to explicate their understanding of the climate impact on cocoa production, and their perception of transitioning from cocoa farming into mining. We then drilled down into how climate change has come to shift their opportunities in cocoa production, and the challenges they face in integrating into artisanal mining, and the land selling arrangements.

The interviews were mainly conducted in Twi and English. Where the cocoa farmers and artisanal miners consulted opted to speak Twi (the local language), the interviews were conducted in the local language. Interviews with other respondents such as officials from COCOBOD and the produce buyers were all conducted in English and Twi. However, all responses from the interviewees were written in English to ensure content validity and for easy understanding. The first author who conducted the on-site interviews is fluent in both Twi and English so there was no major challenge with interviewing and transcription.

For participants who were uncomfortable with the written informed consent forms, only oral consent was used. Confidentiality and anonymity of interviewees were assured throughout the research, given the sensitive nature of their responses and the risks that some farmers could potentially face from their transition into ASM. Each interview lasted for at least 45 min, and all the interviews were recorded and transcribed within 24 h of data collection. Table 1 is a summary of the data collected.

Table 1
Data summary.

No.	Actors	Number of actors interviewed
1	Farmers	15
2	The Ghana Cocoa Board	5
3	Produce buying companies	7
4	Artisanal Miners	15
	Total	**42**

Other data sources and information retrieved

No.	Data Sources	Information retrieved
1	Social media (YouTube)	Documentaries on climate change and its impact on the cocoa sector.
2	Archival Documents: Ghana web, bbc.co.uk	Publications on cocoa farmers moving into artisanal mining, COCOBOD reports on low cocoa production due to artisanal mining, UN climate pack, climate change concern to west Africa cocoa producers.

We supplemented the interview data with publicly available documentary data and information on climate change and its impact on Ghana's cocoa sector, which we collated from social media such as YouTube,[45] as well as some source-auditable online publications. These secondary data sources helped to build up a solid baseline understanding of the climate change challenges and the farmland selling arrangements of cocoa farmers in Ghana.

7. Data analysis

Our data analysis followed several salient analytical steps. First, our initial textual analysis focused on reading the full interview transcripts, interview notes, and publicly downloaded documents. The study of each transcript and the public records followed an iterative-staged process (Bryman and Burgess, 1994). This process began with the interview guide as a preliminary framework. The transcribed data was read and re-read to develop familiarity with the dataset and ensure that it provided an accurate representation of respondents' accounts (Corbin and Strauss, 2014). We tried to strictly adhere to respondents' terms, making little attempt to distil categories, hence the number of categories became large (Gioia et al., 2013). Iteratively, transcripts were then reviewed for common words, phrases, and sentences that could form prospective first-order codes (Creswell and Poth, 2016; Gioia et al., 2013).

After the initial identification of first-order codes, the next stage moved into a more conceptual level that involved the generation of second-order theoretical categories (Corbin and Strauss, 2014; Gioia et al., 2013). The goal of this stage was to condense the number of first-order concepts into comprehensive higher-order categories. Here, a constant comparison technique was undertaken by comparing first-order codes and grouping similar codes into a single category. The recurring first-order codes were thus sorted, aggregated and clustered into more theoretical second-order categories (Magnani and Gioia, 2023). The third stage involved a re-evaluation of the first- and second-order categories to generate the 'aggregate dimensions' that encapsulate the outcomes or effects of the respondents' diversification and exit strategies relating to climate change impacts on the agrarian sector. Overall, the study followed an iterative process of refining categories while ensuring that they remained true to the underlying data collected. An overview of the data analysis is presented in Table 2.

[4] https://www.youtube.com/watch?v=kvOSmdAPh0o (CTGN Africa, 2023; Cocoa production in Ghana likely to plunge due to drought)

[5] https://www.youtube.com/watch?v=6Ip0pJn6hto (GhanaWeb TV, 2023; Climate change having a huge impact on Ghana's cocoa industry-COCOBOD)

Table 2
Overview of data Analysis.

First order codes	Categories	Aggregate dimensions
▪ In search of supplementary income ▪ High temperatures and irregular rain patterns ▪ Unproductive farming and Low farm yields	Farmers transition to ASM	Minimize or abandon farming to work in ASM
▪ Escaping farming pressures and uncertainties ▪ Rising cost of farm input ▪ Immediate and lucrative financial security	Farmland selling arrangement	Sell farmlands to ASM operators
▪ Mineral extraction through illegal mining ▪ Use of toxic chemicals ▪ Clear-cutting vast tracts of land for excavation	Unsustainable mining practices	Destruction of land and water bodies

8. Research Findings

8.1. The diversification strategy: Minimising or abandoning farming to work in ASM

Smallholder farmers in Ghana historically have been highly mobile, moving to seek supplemental income from non-agricultural jobs and in response to seasonal variations and climatic disruptions (Asante et al., 2017; Picot et al., 2024). Our study revealed that high temperatures and erratic rainfall patterns, which have led to agricultural unproductivity, have been a major factor 'pushing' cocoa farmers to transition into ASM in the communities in the study area. Even though some farmers in the area indicated that they had moved into ASM due to the 'agricultural poverty' syndrome (see, for example, (Hilson and Garforth, 2013, 2012), and the financial and high cost of farm inputs their operations face, the majority of interviewees were of the view that rising temperatures and erratic rainfall were the driving force behind their transition to ASM.

A female farmer, age 46, reflected:

> Cocoa farming was my main job. However, the unpredictable rainfall patterns have disrupted cocoa productivity for some years now. Thus, I have not stopped cocoa farming, but that is not my main job now. I decided to join the miners so that I can get some cash to support the family in case the cocoa harvest fails this year, too. [Farmer miner]

A male farmer, age 45, from Adesewase shared a similar view:

> For some years now, the rains do not come as expected, and, you know, cocoa is a seasonal crop. Looking at the inputs and the outputs of yield for a season, it was unable to sustain me and my family, so I decided to personally enter into mining. I know other farmers have sold their farms and the land; I have not sold my land but have also engaged some miners to mine on other portions of my land, while I farm on a small portion. [Farmer miner].

A 42-year-old male cocoa farmer who had become a miner admitted that erratic rainfall and high temperatures had affected his farms and had resulted in low production, and that had caused him to enter into mining and sell a portion of his farm. He remarked:

> I am a farmer but also a miner. Large portions of the cocoa farm were dying due to erratic rainfall, so I sold a portion of the farm to an artisanal miner at a very good price. I used the money to hire some people and buy some equipment so that I could mine on some of my lands. I will say artisanal mining is my main job now. [Farmer miner]

One artisanal miner age 50 who had completely abandoned farming and transitioned into artisanal mining revealed how climate-induced factors such as erratic rainfall had affected his farm so that it was producing a very low yield:

> I started farming 22 years ago, and we could get a bumper harvest at the time. For a long time, farming was a good venture. Now, it is not good to farm. We don't have enough rain again and our land is becoming dry that we can't plant anything. So, I sold my farm and diverted into artisanal mining. [Artisanal miner]

Another female miner, age 37 shared her opinion on how she ventured into ASM.

> I have lived in this community for fifteen years and I have a large family, and cocoa farming has been the only source of livelihood until two years ago when this ASM company came to our community. I ventured into it to support my family as farm yields have reduced due to inconsistent rainfall patterns in the area. I have not regretted entering into ASM, at least every week I get money to support my family [Farmer miner].

In an interview with a purchasing clerk of Federated Commodities, a local licensed cocoa-buying company (LBC), it was revealed:

> Most of the farmers have moved into gold mining, and others have sold their lands to artisanal miners. Erratic rainfall patterns are making cocoa production expensive; some farmers even have to buy water to irrigate their farms. So, to them, the best way is to move into ASM where they get their quick money. But it also has huge implications for our operations as an LBC; now we have to close most of our cocoa sheds because we are not getting enough produce from the farmers. [Produce buyer]

8.2. The exit strategy: The new turn to selling farmlands to ASM operators

Our interview evidence suggests that the unproductive farm phenomenon had caused most smallholder farmers not only to reduce their engagement in farming but to sell their farmlands and shift to ASM or seek opportunities in the non-farm sector. The interviews with some cocoa farmers and other actors revealed that due to the impact of climate variations in recent years, they (farmers) were unable to capture the full benefits from their production, and that had compelled some of them to sell their cocoa farms. A 56-year-old female cocoa farmer who had sold her farmland shared the following:

> The high temperatures and the irregular rainfall patterns over the past years adversely affected my cocoa farm. It also affected my yields; with my two-acre cocoa farm, I was able to produce only

seven bags at the end of the cocoa season. The rains do not come as expected, thereby causing damage to immature pods. It was expensive to maintain the farm, so I sold it. [Farmer]

One male cocoa farmer, age 62, at Apedwa lamented that he and his family for some years had had to carry gallons of water from home to spray and irrigate his farm - an unsustainable practice. Due to this, he began negotiations with some miners to sell his farmland, and eventually sold it.

High temperatures and disruptive rainfall patterns have really affected us here. I had to let my kids forgo school sometimes and help me with gallons of water to irrigate and spray my cocoa farms; the streams are drying up. This practice was expensive and stressful, and the yield at the end of the season was not encouraging at all, so I began negotiating with some miners. Eventually, I got a good offer and, therefore, sold the whole farmlands. [Former farmer]

A 45-year-old farmer recounted the impact of climate disruptions on his farm:

I do subsistence farming in addition to cocoa production. The yields from the subsistence farming are what I use to feed my family and also sell some of the produce to maintain my farm. For over three years now, there are no regular rains as it used to be 10 or 15 years ago when I came to this community. I am struggling this time, so I have decided to sell the farm and start a retail business. [Farmer]

Similarly, another farmer at Ekoso in the Atiwa West district, who is involved in cocoa and maize farming, emphasized that he and his family rely on the maize for subsistence, and that is what keeps his family going. However, due to the lack of rainfall, he experienced low production and incurred huge losses. He has, therefore, thought of selling some of the land. This cocoa farmer, age 52, remarked:

If I take you through my farm, you will notice that most of the old cocoa trees are dying due to the high temperatures. Maize and cocoa are what sustain me and my family, but for some time now, I don't get the required yields. I am looking for a buyer [and] will sell the farmlands because I am not making any profit. [Farmer]

These comments from the farmers suggest that climate change has caused a drastic reduction in agricultural production and has become a contributing factor to farmers' decision to sell their farmlands and diversify into other businesses. Even though some farmers indicated that they are selling their farms and entering into other ventures, it appears that most of these farmers would end up in ASM, which has become a common practice among smallholder farmers in the rural communities in the study area.

9. ASM and the challenges of environmental degradation

Across our research sites, we found that ASM represents an important means of income diversification for many farmers. Nevertheless, our data show how ASM activities in the rural communities contribute to environmental degradation challenges, see also (Donkor et al., 2024). This is because in the quest to mine, the land is deforested and made bare. One senior officer at COCOBOD revealed how ASM activities are affecting the environment.

Over the years, we have relied on the rain and dry seasons for our cocoa production. However, activities of miners are causing huge challenges to our cocoa farmlands. The miners have taken over the cocoa farmlands; they are cutting down all the trees which serve as shade to the available farms. This, we believe, has also resulted in the rise in temperatures. [COCOBOD Executive]

Another official with a local produce buying company shared thoughts similar to the COCOBOD official. He stated:

The impact of environmental degradation by artisanal miners on agricultural production is evident throughout our communities. This has caused a drastic reduction in crop yield. We have now closed most of our cocoa sheds because we don't get the required beans to purchase. [Produce buyer]

Others expressed similar concerns about the destruction of the landscape by artisanal miners. One farmer shared with us the extent to which artisanal mining activities have contributed to deforestation, which also poses a severe threat to the ecological system and their livelihood.

This area was once a beautiful flat piece of land with a variety of trees, abundant grazing areas, and very rich and productive farming lands, but it's all gone in the name of mining. Even though we all want an alternative work to support our livelihood, we have noticed that mining is also a major driver of deforestation. All our water bodies are drying up; there's no water to even irrigate our farms. [Farmer]

In some communities in the Atiwa East District, the degradation of land and water sources threatens food security. In these areas, the impact of mining is so severe that chiefs and community members have lamented the loss of nearly all their agricultural land. A member of the community said:

The destruction of these lands threatens food security and drives up food prices, as families lose their primary means of subsistence. The water bodies are also drying up, causing severe havoc to farms and livestock. We are calling for responsible mining practices and greater community involvement in the artisanal miners' decision-making.

Indeed, interviews undertaken among farmers and other actors in our study sites confirmed that the extraction of mineral resources without the least regard for sustainability concerns continues to harm the lives of indigenous people. Our data further show that climate variations seem to exacerbate such impacts and increase the risks attached to ASM activities, thereby increasing the vulnerability of rural livelihoods.

10. Discussion and conclusion

It is appropriate to conclude this paper in the climate change, agriculture, and ASM contexts with which it began: climate scientists agree that human industrial and commercial activities are increasing the amount of greenhouse gas in the atmosphere (IPCC et al., 2023). Hence, changes for agrarian economies near the tropics especially have been mostly negative (IPCC, 2019). These climate-related disruptions have tended to exacerbate existing challenges for poor and agrarian-dependent populations across the globe (Asante et al., 2017; Wiebe et al., 2015).

In this regard, our study sought to add to the climate-related empirical findings (Asante et al., 2017; Bansah et al., 2023; Picot et al., 2024) and contribute to the broader discussions on climate change, mining, and agrarian economies. Bringing evidence from the cocoa sector in Eastern Ghana, our findings indicate that the negative impacts of climate change have created room for the pursuit of alternative sources of livelihood or strategies of livelihood diversification far beyond the agrarian economy. These issues have implications for the policy and practice of both agriculture and ASM.

Bringing the empirical details of our study to bear on our understanding of the climate-agriculture-ASM dynamics, we present Fig. 1 as a framework highlighting the interactivity and interconnectedness of the entities. First, high temperatures and erratic rainfall patterns (climate change) are a challenge to farmlands and farm yields, threatening livelihoods because of the reduction in farm yields. The reduction in farm yields invariably constitutes a major threat to agrarian livelihoods through the decrease in farmers' income levels. However, some of the

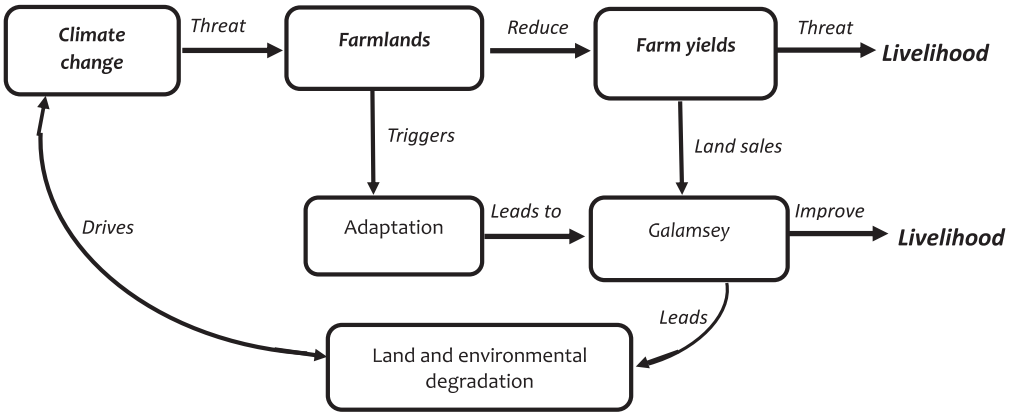

Fig. 1. Climate-agriculture-ASM 'system' nexu.

farmlands could alternatively be deployed for the small-scale production of minerals. However, even though mineral extraction can be productive, some of the long-term effects of mining activities can have a diminishing effect on farmers' production and livelihoods. This is because the use of lands for ASM could lead to land and environmental degradation, thus threatening food security (Nunoo et al., 2023; Siaw et al., 2025, 2023). Over time, the depletion of minerals and the consequent degradation of forest lands, including farmlands, threaten the livelihood of communities.

To help address issues of climate change, policymakers are working to develop solutions to reduce carbon emissions. In broader terms, these solutions must connect with comprehensive policies that seek to address the longstanding challenges associated with agricultural production and ASM in sub-Saharan Africa generally and in Ghana particularly. It is worthy of note that even without climate change disruptions, some of the challenges raised by the cocoa farmers during our research work had persisted for quite some time (Friedman et al., 2019; Hirons et al., 2018). Generally, the agricultural sector in Ghana and in most regions in sub-Saharan Africa has not been stable (Bryceson, 2018; Hilson and Garforth, 2012). The cocoa sector, for example, is riddled with other challenges including land scarcity and the difficulty of securing youth labourers (Bryant and Mitchell, 2021; Tease et al., 2023). These challenges are due, in part, to structural adjustment programmes that abolished, for example, basic subsidies for agricultural purposes, resulting in a drastic undermining of most farmers' capitalised production (Banchirigah, 2006; Bryceson, 2002; Hilson and Garforth, 2013).

Thus, although climate change disruptions might have intensified the challenges associated with agricultural production, the general issue of de-agrarianisation and low agricultural output have long persisted. This requires urgent policy considerations to help address the structural difficulties in the agricultural sector. Basically, investments are needed which would necessitate quick and far-reaching transformations in agriculture, especially cocoa production. To increase the likelihood of farmers maintaining high yields even in the face of unfavourable conditions due to climate change, irrigation practices in cocoa-growing communities and the cultivation and provision of drought-resistant seedlings ought to be prioritised. COCOBOD should continue to provide improved rewards, i.e., increments in the premium price of cocoa, as a way of incentivising farmers to remain in the cocoa industry.

Government policy should also intensify the provision of extension services to support the production and climate adaptation of cocoa and food crops. Studies in Ghana have consistently found that the ability of Ghanaian farmers to adapt their cocoa and food crop production to the impacts of climate change is partly shaped by access to agricultural extension services (Antwi-Agyei et al., 2021b; Asare-Nuamah et al., 2019; Picot et al., 2024). Extension services should therefore encapsulate climate adaptation measures including offering education to improve climate change awareness, providing technical advice, and promoting strategies such as crop diversification and the use of improved varieties (Anang et al., 2020; Antwi-Agyei and Stringer, 2021; Emmanuel et al., 2016; Picot et al., 2024).

Considering the umbilical linkages between the agriculture sector and the ASM industry, it is imperative that investments and policy developments in the agriculture sector be interwoven and interconnected with those in the ASM industry. In this regard, this study supports the longstanding calls for ASM to be supported to help the industry achieve its development potential goals (Hilson and Maconachie, 2020). In this vein, governmental and mining policy, as has been extensively highlighted elsewhere (Arthur-Holmes and Ofosu, 2024; Geenen, 2012; Hilson et al., 2020; Ofosu and Arthur-Holmes, 2025), should find ways to provide technical and financial support and properly demarcate mineral-rich areas to accommodate ASM operators. This is because in seeking answers to the question 'Whither the agrarian workforce in the era of climate change?', the 'to which place' arrow, at least in the context of this present study, points to the ASM industry.

Finally, on limitations of our study and directions for future research. While our study emphasises climate-induced livelihood diversification, it does not empirically examine the role of cocoa price volatility, particularly the recent reduction in Ghana's producer prices. The Government of Ghana has recently reduced the producer price of cocoa from about Gh3625 (ca.$320) (per 64 kg of cocoa) to Gh2587 (Bruce and Akorlie, 2026; Ghanaweb, 2026). According to the government, the drop reflects the drop of the price of cocoa on the world market. Although identified as an emerging concern, this dimension remains analytically underexplored. Given that diversification decisions are shaped by both environmental shocks and market incentives, this omission represents a significant analytical gap. We therefore encourage future research to investigate how farmers respond to producer price reductions, how cocoa price shocks interact with climate pressures in accelerating transitions into ASM, and whether declining global cocoa prices intensify farmland sales and permanent exits from agriculture.

CRediT authorship contribution statement

David Sarpong: Writing – review & editing, Validation, Formal analysis, Conceptualization. **George Ofosu:** Writing – review & editing, Validation, Formal analysis, Conceptualization. **Daniel Siaw:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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