
| RESEARCH ARTICLE**Economic Assessment of the Impacts of Artisanal and Small-Scale Gold Mining on Agricultural Labor Productivity and Household Food Security in the Ahafo Region of Ghana: Developing an Integrated Agriculture-Mining Coexistence Framework for Sustainable Rural Livelihoods****Ebenezer Sackey***Independent Researcher, Ghana***Corresponding Author:** Ebenezer Sackey, **E-mail:** sackeyebenezer53@gmail.com**| ABSTRACT**

Artisanal and small scale gold mining (ASGM) has become one of the most important livelihood activities in mineral-rich areas of sub-Saharan Africa. This is especially true in Ghana, where the industry has made outstanding contributions to local rural employment and household income. This conclusion has been confirmed by studies by Hilson and Maconachie (2020) and the World Bank (2023). However, the rapid expansion of ASGM has intensified competition with agriculture for labor, land, water, and other production resources. This has triggered multiple concerns, including declining agricultural productivity, environmental degradation, food insecurity, and household-level food insecurity. Studies by Arthur-Holmes and Busia (2020), the United Nations Environment Programme (2023), and Adranyi et al. (2024) also support the prevalence of this series of problems. Although mining and agriculture often coexist in rural livelihood systems, there is still a lack of clear understanding of the nature of their interaction. This gap is particularly pronounced in Ghana's Ahafo region, where these two industries are the core sources of household livelihoods. Studies by Hilson and Garforth (2013) and Li et al. (2024) both point to the existence of this research gap.

| KEYWORDS

artisanal and small-scale gold mining, agricultural labor productivity, household food security, endogenous switching regression, endogenous treatment effect, sustainable rural livelihoods, integrated framework for agriculture-mining coexistence, Ahafo region, Ghana.

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1. Introduction

The rapid expansion of artisanal and small-scale gold mining in sub-Saharan Africa has reshaped local rural economic patterns,

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pushing most households to shift from traditional subsistence farming to diversified income strategies. This trend is confirmed by studies by Danso-Abbeam et al. (2018) and Setsoafia et al. (2022). While research by Wongnaa et al. (2026) notes that income diversification can buffer climate-related shocks, studies by Genesquin et al. (2023), Issahaku et al. (2020), and Akudugu et al. (2020) find that this transition has squeezed agricultural labor efficiency and land tenure security. Labor shortages and environmental degradation have held back improvements in crop productivity, which already falls short of agronomic potential in most regions.

Agriculture is a core pillar of Ghana's economy, playing an irreplaceable and key role in supporting the country's employment, food production, export earnings, and rural livelihoods. Although the share of agriculture in Ghana's GDP has declined amid the country's push for economic diversification, it remains the industry that absorbs the largest number of workers and serves as the core livelihood source that most rural households depend on for survival. For this reason, the sustainability of agricultural production has become a core prerequisite for the country to reduce poverty, guarantee food security, and advance national development. At present, however, rural farm households in Ghana frequently face various severe socioeconomic shocks, which have severely undermined the stability of their livelihoods. This creates an urgent need to reassess existing policy frameworks and management strategies. Meanwhile, the rise of non-farm businesses such as artisanal and small-scale gold mining in recent years has, as noted in a 2025 study by Danso-Abbeam et al., highlighted the necessity of research to explore how income diversification strategies affect smallholder farmers' livelihood resilience and nutritional security.

Beyond agriculture, Ghana has become one of Africa's leading gold-producing countries. Over the past two decades, driven by multiple factors including rising global gold prices, growing rural unemployment, declining agricultural profitability, and the relatively low barriers to entering the informal mining sector, the scale of artisanal and small-scale gold mining (ASGM) has expanded sharply. Today, this sector provides income for hundreds of thousands of households and makes a critical contribution to local economies. However, the rapid growth of ASGM has also triggered mounting concerns about its negative impacts on agricultural development. Mining activities often compete with agricultural production for arable land, water resources, and labor: productive farmland is converted into mining sites, forests are cleared, water bodies are polluted, and many working-aged people who originally

worked in agriculture have shifted from farming to mining. While the income from mining may boost household purchasing power, these shifts drag down agricultural productivity and make households increasingly reliant on purchased food. At the same time, long-standing underinvestment in the agricultural sector, including the lack of investment in fertilizers and modern technologies, has further worsened these challenges, leaving smallholder farmers particularly vulnerable to fluctuations in food prices (Kapari et al., 2023; Karlan et al., 2014). When farmers shift their focus to mineral mining, they often neglect soil fertility degradation, a problem that can also create a "poverty trap": insufficient reinvestment in land conservation gradually undermines long-term food sovereignty (Thiombiano & Le, 2023). In addition, the environmental impacts of these mining operations threaten the resilience of local food systems, and disputes over land have disrupted traditional farming patterns (Tannor et al., 2022). Notably, the transition to a market-dependent food system is usually accompanied by a rise in the consumption of low-quality processed foods, and even with increased household cash income, the risk of malnutrition may grow accordingly.

The link between small-scale artisanal gold mining and agriculture is complex and multifaceted. Contrary to the traditional view that the two are purely competitive, they often function as intertwined livelihood strategies. These linkages not only vary based on differences in household endowments but also shift over time, encompassing both complementary spaces and trade-offs.

Income generated from mining can supply working capital for agricultural investments. In regions where access to formal credit channels is limited, this funding enables farm households to purchase improved seeds, chemical fertilizers, and agricultural machinery or to hire production labor to support agricultural activities. However, mining also diverts household labor away from core agricultural tasks, delays critical farming windows for sowing and weeding, drives up agricultural production costs, reduces the area of land under cultivation, and offsets the benefits. In the long run, it can also trigger environmental problems such as land loss, soil degradation,

and water pollution, which weaken the foundational support capacity for agricultural production.

As a result, higher mining income does not necessarily translate into better agricultural performance or improved household food security. The net welfare effect of small-scale artisanal gold mining carries theoretical uncertainty. Its impacts depend on four core conditions: the intensity of participation in mining, the distribution of mining income, access to land and production inputs, and the severity of environmental damage. These mutually countervailing pathways of influence make clear that empirical analyses must integrate agricultural labor productivity and household food security, and mining income must never be treated directly as an absolute indicator of welfare improvement.

The Ahafo Region of Ghana serves as a typical site for examining the interaction between small-scale gold mining and agricultural development. The region is not only rich in gold reserves, but also a core agricultural zone of Ghana, where local farmers commonly grow six types of crops: cocoa, maize, cassava, yam, plantain, and vegetables. In recent years, both licensed and unlicensed.

Small scale artisanal gold mining activities have expanded simultaneously, triggering a range of problems, including land degradation, environmental pollution, labor shortages, declining agricultural productivity, and household food insecurity. While existing research has produced many valuable conclusions on the environmental and economic impacts of gold mining, very few empirical studies focused on the Ahafo Region have integrated analyses of mining's impacts on agricultural labor productivity and household food security into a unified framework. Research that only targets a single domain is insufficient to capture the full, integrated impact of mining on local livelihoods.

Previous studies on artisanal and small-scale gold mining (ASGM) in Ghana have mostly focused on the environmental and socioeconomic impacts of the sector. Four core research gaps remain to be urgently filled, and addressing these gaps is critical to designing policies that balance mineral extraction, agricultural sustainability, environmental protection, and rural livelihood development. First, very few studies have jointly analyzed agricultural labor productivity and household food security within a unified empirical framework; relevant research is almost non-existent, especially in the Ahafo region where agriculture and mining coexist at high rates. Second, while scattered evidence shows that ASGM can boost household income through livelihood diversification, it may also trigger a series of negative problems via labor redistribution, environmental degradation, and increased reliance on food purchases. Systematic empirical analysis of this contradiction is clearly insufficient. Third, the food safety risks caused by heavy metal pollution in agricultural soils, irrigation water, and food crops in mining areas have long been overlooked by academia. Fourth, although existing policy studies have noted weak coordination among agricultural, mining, environmental protection, and local governance institutions, very few empirical studies have proposed integrated governance mechanisms that can advance the sustainable coexistence of agriculture and mining. On this basis, this study builds on the work of Adjei (2007) and Akafari et al. (2021) to analyze how the expropriation of traditional land by large-scale mining and artisanal mining restructures local power structures and shifts the burden of food supply. It also examines the social stratification and landless rural working class spawned by farmer displacement and the enclosure of fertile land to fill the core research gaps outlined above.

This study addresses the gaps in existing research. Taking the Ahafo region of Ghana as its research setting, it evaluates the economic impacts of artisanal and small-scale gold mining on agricultural labor productivity and household food security. Beyond measuring these effects, the study also constructs an agriculture-mining coexistence framework that integrates agricultural development, responsible mining, environmental protection, and sustainable rural livelihoods. This integrated perspective responds to the academic debate on how natural resource extraction can support, rather than undermine, long-term agricultural development and food security.

1.1 Problem Statement

Artisanal and small-scale gold mining (ASGM) has become a key source of employment, household income, and rural livelihood

diversification in Ghana, particularly in mineral-rich regions such as Ahafo (Hilson & Maconachie, 2020; Ghana Minerals Commission, 2023). While this sector has made notable contributions to local economic growth and poverty reduction, its rapid expansion has intensified competition with agriculture over core natural assets including productive land, labor, and water resources (Arthur-Holmes & Busia, 2020; World Bank, 2023). As a result, many farming households face the difficult challenge of allocating labor between mining and agricultural activities—a decision that will exert critical impacts on agricultural productivity, household food security, and long-term rural livelihoods.

A growing body of evidence shows that artisanal and small-scale gold mining (ASGM) has a dual nature: it can indeed raise household income by diversifying livelihoods, but it also undermines agricultural labor productivity through three pathways: it pulls productive labor away from farm households, converts fertile farmland into mining sites, and damages the soil, forests, and water resources that are essential for crop production. This conclusion is supported by studies conducted by Hilson and Garforth (2013) and Li et al. (2024). In addition, research from UNEP (2023) and Nunoo et al. (2023) also notes that mercury, arsenic, cadmium, and lead released by mining activities pollute agricultural soil, irrigation water, and food crops, which threatens food safety and public health even when households' purchasing power improves. The authors of this paper argue that when agricultural production, environmental quality, and nutritional security are damaged, the higher income generated by mining may not translate into improved household food security.

Despite growing concerns across all sectors, Ghana's policy development has always advanced agriculture and mining as two separate fields. The core goals of the country's agricultural policy are to boost farmland productivity and increase grain output, while mining policies focus on mineral extraction, sector formalization, and environmental regulation. Existing research confirms that there is extremely limited coordination among six types of stakeholders: the Ministry of Food and Agriculture, the Minerals Commission, the Environmental Protection Agency, the Water Resources Commission, municipal and district assemblies at all levels, and traditional authorities. This fragmented institutional design greatly weakens the actual effectiveness of land use planning, environmental management, agricultural support services, and interventions for sustainable rural development.

In addition, the existing literature contains a critical empirical research gap. Most past studies separately analyze the environmental impacts of small-scale artisanal gold mining, agricultural productivity, household food security, or institutional governance issues, and rarely integrate these dimensions into a unified framework for comprehensive analysis. Research evidence is particularly scarce regarding the Ahafo Region, a strategically prominent core agricultural and gold-producing area of Ghana. Furthermore, few studies use econometric methods that can address selection bias and unobservable heterogeneity related to households' choice to participate in the mining industry.

This study addresses gaps in empirical evidence and policy frameworks found in existing research. It jointly evaluates the impacts of artisanal and small-scale gold mining on agricultural labor productivity and household food security among farm households in Ghana's Ahafo Region. At the same time, it develops an integrated framework for coexistence between agriculture and mining that integrates livelihood diversification, environmental sustainability, food safety, and institutional coordination. This framework provides actionable policy guidance to balance responsible mining with sustainable agricultural development and resilient rural livelihoods.

1.2 Research Objectives

1.2.1 Overall Objective

To evaluate the impacts of artisanal and small-scale gold mining on agricultural labor productivity and household food security in Ghana's Ahafo Region, and to develop an integrated framework for agriculture-mining coexistence to advance sustainable rural livelihoods.

1.2.2 Specific Objectives

This study examines the socioeconomic characteristics of rural households in the Ahafo region that participate in artisanal and small-scale gold mining, as well as those that do not. It estimates the impact of participation in this mining activity on agricultural labor productivity. It assesses the effect of this participation on household food security. It identifies factors in the household, farm, institutional, and environmental levels that influence agricultural labor productivity and household food security. It develops an integrated agriculture-mining coexistence framework to advance responsible mining, sustainable agriculture, environmental protection, food security, and resilient rural livelihoods.

1.3 Research Questions

- What are the specific socioeconomic characteristics of households in the Ahafo region that participate in artisanal and small-scale gold mining, compared to those that do not?
- What impact does participation in artisanal and small-scale gold mining have on agricultural labor productivity?
- How does such participation affect household food security?
- What factors at the household, farm, institutional, and environmental levels significantly influence agricultural labor productivity and household food security?
- How can agriculture and artisanal and small-scale gold mining achieve sustainable coexistence in the Ahafo region to improve rural livelihoods.

1.4 Research Hypotheses

1.4.1 Agricultural Labor Productivity

- Null hypothesis H_{01} : Participation in artisanal and small-scale gold mining has no statistically significant effect on agricultural labor productivity.
- Alternative hypothesis H_{11} : Participation in artisanal and small-scale gold mining has a statistically significant effect on agricultural labor productivity.

1.4.2 Household Food Security

- Null hypothesis H_{02} : Participation in artisanal and small-scale gold mining has no statistically significant effect on household food security.
- Hypothesis H_{12} : Participation in artisanal and small-scale gold mining has a statistically significant impact on household food security.

1.4.3 Household-level, farm-level, and institutional factors

- Null Hypothesis H_{03} : Household socioeconomic characteristics, farm-level factors, institutional factors, and environmental characteristics do not exert significant effects on agricultural labor productivity and household food security.

- Hypothesis H₁₃: Household socioeconomic characteristics, farm-level factors, institutional factors, and environmental characteristics exert significant effects on agricultural labor productivity and household food security

2. Literature Review

This chapter reviews the theoretical and empirical literature that underpins the present study and examines the links between artisanal and small-scale gold mining, agricultural labor productivity, household food security, and sustainable rural livelihoods. Unlike previous reviews that only provided descriptive summaries, this review integrates different theoretical perspectives and empirical findings, identifies research consensuses and disagreements, pinpoints the knowledge gap that justifies the implementation of this study, and lays the academic foundation for constructing the theoretical and conceptual framework in Chapter 3.

The rapid expansion of artisanal and small-scale gold mining in sub-Saharan Africa and its impacts on local agricultural development and rural welfare have long been a core topic of debate in academic circles. Some scholars cite relevant research to argue that this model serves as an important livelihood diversification strategy that can drive poverty reduction and increase household income. Other scholars maintain that it undermines agricultural productivity through four pathways: labor shifting away from farming, loss of cultivated land, environmental degradation, and reduced agricultural investment. These conflicting perspectives highlight the inherent complexity of the interactions between mining and agriculture, and the welfare impacts of this mining activity are, in fact, highly context-dependent.

Existing literature further points out that the scope of household welfare goes beyond income generation. Contemporary studies generally agree that agricultural productivity, dietary diversity, food safety, environmental sustainability, and institutional quality are core interconnected dimensions of rural developmental conclusion jointly confirmed by the 2023 reports of the Food and Agriculture Organization of the United Nations and the United Nations Environment Programme. In mining communities, these dimensions are not only affected by changes in labor.

allocation and household income but also impacted by heavy metal pollution of agricultural soil, water resources, and food crops. This type of pollution can damage both agricultural production and public health, and related findings are supported by the 2023 study by Nunoo et al. and the 2024 study by Adranyi et al.

Although research on artisanal and small-scale gold mining (ASGM) has grown increasingly abundant, critical knowledge gaps remain. Most existing studies only examine either the economic contributions of mining or its environmental impacts in isolation. Very few studies jointly assess ASGM's effects on agricultural labor productivity and household food security within a unified analytical framework. Furthermore, there is still a lack of sufficient empirical evidence for the Ahafo Region of Ghana on how labor redistribution, environmental degradation, institutional support, and livelihood diversification interact to shape rural household welfare. Filling these gaps requires an interdisciplinary perspective that integrates agricultural economics, rural livelihoods theory, natural resource economics, and development policy. For this reason, this chapter will sort through relevant literature to clarify the conceptual and empirical gaps that support the implementation of this study.

2.1 Concept of Artisanal and Small-Scale Gold Mining

Artisanal and small-scale gold mining (abbreviated as ASGM) refers to labor-intensive mineral extraction activities carried out with relatively low capital investment, limited mechanization, and simple production technologies.

This sector includes both licensed formal mining operations and informal mining projects. It is generally characterized by small-scale production units, reliance on family or community labor, and difficulties in accessing modern equipment, financial services, and

technical support (International Labour Organization [ILO], 2023; World Bank, 2023). Although such activities are often classified as part of the informal economy, they remain a critical source of employment and income for millions of rural households in many developing countries. Over the past two decades, the scale of ASGM has expanded significantly worldwide, driven by rising international gold prices, persistent rural poverty, population growth, declining agricultural profitability, climate variability, and a lack of formal employment opportunities (World Bank, 2023; United Nations Environment Programme, 2023). Current statistics show that more than 45 million people globally are directly employed in this industry, and an additional 150 million people rely indirectly on this sector through supply chains, service provision, or household income transfers. Gold has always been the core mineral mined by these miners, and it makes outstanding contributions to export earnings and local economic development in many low- and middle-income countries.

In Ghana, artisanal and small-scale gold mining (ASGM) has developed into one of the country's most important rural livelihood activities. According to 2023 data from the Ghana Minerals Commission, this sector accounts for approximately 30% to 40% of the nation's total gold output and provides direct or indirect employment for more than one million people. Unlike large-scale commercial mining, which requires high capital investment and is owned by corporations, ASGM is driven primarily by household livelihood needs and, in most cases, coexists with agricultural production. Therefore, as Hilson and Maconachie argued in 2020, participation in ASGM is not a simple career replacement; rather, it is part of households' broader livelihood diversification strategies.

Technological changes in recent years have reshaped the operational landscape of Ghana's ASGM sector. The widespread adoption of equipment such as portable processing mills, excavators, water pumps, and mechanized ore washing systems has increased gold recovery rates, but it has also worsened issues including land degradation, deforestation, and river pollution, while continuously encroaching on productive agricultural land. A 2020 study by Arthur-Holmes and Busia notes that this kind of technological upgrade has intensified land-use competition between mining and agricultural activities. This conflict is particularly acute in the Ahafo region, where agricultural land and gold deposit reserves overlap.

The expansion of artisanal and small-scale gold mining (ASGM) creates economic opportunities, but it also brings significant environmental and social challenges. This type of mining serves as an important source of cash income, enabling households to cover expenses for education, healthcare, housing, agricultural investments, and small business operations. Existing studies (Mkodzongi & Spiegel, 2019; Hilson & Maconachie, 2020) note that the income generated allows rural households to purchase productive agricultural inputs such as chemical fertilizers, improved seed varieties, and agricultural machinery. This strengthens livelihood resilience when agricultural production faces uncertainty, overturning the long-held traditional view that mining and agriculture are inherently incompatible. The two sectors can develop a mutually complementary relationship under suitable conditions.

On the other hand, artisanal and small-scale gold mining (ASGM) that lacks regulatory oversight still causes severe environmental consequences. Both the 2023 report of the United Nations Environment Programme and the 2023 study by Nunu et al. have confirmed that this type of mining triggers large-scale land degradation, deforestation, biodiversity loss, river channel siltation, and damage to farmland. It also pollutes water and soil through the discharge of mercury, arsenic, cadmium, and lead. These environmental problems reduce agricultural productivity, threaten food safety, increase public health risks, and undermine the long-term sustainability of rural livelihoods. Furthermore, a 2024 study by Li et al. points out that the shift of able-bodied young people from agriculture to mining also causes seasonal labor shortages, which further suppresses agricultural output and weakens household food security.

For these reasons, academia holds completely opposing views on the overall contribution of small-scale gold mining to rural development: some scholars emphasize its role in poverty reduction, income diversification, and job creation, while others focus on its negative environmental, agricultural, and social impacts. These conflicting research conclusions indicate that the actual impacts of small-scale gold mining are mediated by four categories of factors: household resource allocation, institutional effectiveness, environmental governance capacity, and the proportion of mining income that is productively reinvested in the agricultural sector.

Although a large volume of research has been conducted on artisanal and small-scale gold mining (ASGM), very few studies have applied an integrated analytical framework to examine the sector's impacts on both agricultural labor productivity and household food security. Furthermore, existing research has not fully explored the roles of food safety, heavy metal pollution, and coordinated institutional governance in shaping the long-term coexistence of agriculture and mining. To address these gaps, this study constructs an integrated framework for the coexistence of agriculture and mining. Focusing on the Ahafo region of Ghana as the study setting, the analysis incorporates four core dimensions: economic, environmental, institutional, and household welfare.

2.2 Agricultural Labor Productivity

Agricultural labor productivity refers to the quantity or value of agricultural output generated per unit of labor input. Commonly used measurement indicators include output per worker, output per labor day, and value-added per agricultural employee. This concept is widely recognized in academia as a core metric for measuring agricultural production efficiency, as it reflects the efficiency of human resource use in creating agricultural output. An increase in this indicator can help farm households expand production without increasing labor input at the same proportion, which in turn boosts farm profitability, household income, and overall rural well-being. Conversely, low labor productivity constrains agricultural development, reduces household income, and increases farm households' vulnerability to poverty and food insecurity.

The importance of agricultural labor productivity extends far beyond farm-level production performance; its impacts also spread through the broader process of economic development. This core logic, laid out in a 2020 study by Dercon and Sadoulet, holds that higher productivity can drive economic structural transformation: it raises rural household incomes, frees up labor to shift to other production sectors, improves national food security, and fuels overall economic growth. Yet many developing countries remain trapped in low agricultural labor productivity. A 2023 report from the Food and Agriculture Organization of the United Nations identifies six core constraining factors: limited mechanization, poor access to improved technologies, weak infrastructure, climate volatility, insufficient institutional support, and persistent market failures. In sub-Saharan Africa, these challenges are compounded by additional pressures: rapid population growth, shrinking farm sizes, land degradation, and competition for labor from non-agricultural sectors.

Recent studies broadly highlight that technological innovation and mechanization are central pathways to boost labor productivity. As confirmed in a 2023 study by Daum, the adoption of technologies including tractors, mechanized land preparation, irrigation techniques, improved seeds, precision agriculture, and digital extension services has reduced labor demand and raised production efficiency across many developing countries. But mechanization alone cannot sustainably drive productivity growth. As early as 2019, Breman et al. argued that the economic benefits of mechanization depend on five preconditions: farm size, access to credit, input supply,

maintenance services, and farm household management capacity. For this reason, supportive institutional and financial policies must be put in place to enable smallholder farmers to adopt productivity-enhancing technologies in a sustainable way.

Agricultural labor productivity is shaped jointly by five categories of factors: household characteristics, farm conditions, institutional arrangements, environmental factors, and macroeconomic conditions. Among these, human capital, which covers education, farming experience, technical skills, and access to information, can strengthen rural households' ability to adopt modern production technologies and implement efficient farm management practices; this conclusion is drawn from a 2024 study by Wongnaa et al. Institutional support delivered through agricultural extension services can drive technology transfer, promote climate-smart agriculture, and optimize the use of agricultural inputs. Meanwhile, access to production credit allows farming households to invest in mechanization, irrigation facilities, improved seeds, chemical fertilizers, and hired labor; this perspective is cited from a 2023 report by Ghana's Ministry of Agriculture and Food. In addition, household asset holdings can further enhance households' ability to withstand production shocks and secure financing for productivity-enhancing investments.

Natural capital is another core determinant of agricultural productivity. Soil fertility, rainfall distribution, access to water resources,

biodiversity, and ecosystem health all directly affect crop yields and production efficiency. However, these natural resources are increasingly threatened by environmental degradation caused by artisanal small-scale gold mining. Mining activities trigger deforestation, soil erosion, the loss of fertile agricultural land, and river sedimentation, as well as water and soil contamination from mercury, arsenic, cadmium, and lead; these impacts are documented in a 2023 report by the United Nations Environment Programme and a 2023 study by Nunoo et al. These changes ultimately reduce agricultural productivity by lowering soil quality, restricting access to irrigation water, raising production costs, and undermining the long-term sustainability of farming systems.

Labor allocation decisions are a core determinant of agricultural labor productivity. The agricultural household model proposed by Singh et al. in 1986 states that rural households allocate labor based on four key factors, including expected returns. Meanwhile, research by Hilson and other scholars shows that in mining communities, artisanal and small-scale gold mining, which delivers higher short-term returns, diverts agricultural labor, delays five core agricultural work processes, and ultimately reduces per-unit agricultural labor output.

Current academic circles have not reached a consensus on the empirical impact of artisanal and small-scale gold mining (ASGM) on agricultural labor productivity. A 2013 study by Hilson and Garforth, which focused on multiple mining communities in Ghana, noted that labor migration driven by the influx of workers into the mining sector reduces the available labor pool for farming households, which in turn lowers agricultural productivity. A 2024 study by Wongnaa et al. also observed that large numbers of workers are shifting from crop farming to mining, attracted by the higher expected income from artisanal mining. In contrast, research by Hilson & Maconachie (2020) and Mkodzongi & Spiegel (2019) argues that mining income can support farming households to purchase improved agricultural inputs, hire labor, adopt mechanization, and expand agricultural investment, which partially offsets the negative effects of labor shortages.

Existing research reaches conflicting conclusions regarding the association between artisanal and small-scale gold mining (ASGM) and agricultural labor productivity. This association is highly context-dependent and is shaped by the interactive effects of five core factors: labor allocation, agricultural input, environmental quality, institutional support, and household livelihood strategies. While participation in ASGM can generate short-term economic benefits, its long-term impacts depend on two key conditions: whether mining income is reinvested in agricultural production and whether the expansion of mining exacerbates the loss of various resources. Therefore, empirical research must be conducted in Ghana's Ahafo region, where agriculture and mining both serve as core livelihoods, to clarify the net effect of the association between the two sectors.

2.3 Household Food Security

Household food security refers to the condition where all people always have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

This definition comes from a 2023 joint publication by the Food and Agriculture Organization of the United Nations, the International Fund for Agricultural Development, the United Nations Children's Fund, the World Food Programme, and the World Health Organization. This industry-recognized definition establishes food security as a multi-dimensional concept consisting of four interrelated pillars: food availability, food access, food utilization, and food stability. This set of dimensions overcomes the limitations of measuring food security only by food output or income, and builds a more comprehensive framework for assessing household welfare and nutritional status. Food availability refers to the sufficient physical supply of food achieved through domestic agricultural production, commercial imports, food reserves, or humanitarian aid. Support for household-level availability depends on agricultural productivity, access to land for production, climatic conditions, and supply chain efficiency. Food access is a household's ability to obtain sufficient food through its own production, market purchases, income, or social transfers. Even if there is enough food at the

community level, insufficient household income or excessively high food prices may still limit a household's ability to obtain a suitable diet. Food utilization covers the nutritional quality, safety, preparation and storage, and bioavailability of food and is jointly affected by health status, sanitation facilities, clean water access, and dietary diversity. Food stability refers to a household's ability to sustain the first three dimensions over the long term and to withstand external disruptions such as seasonal fluctuations, economic shocks, and climate variability. This entire framework is also cited from the 2023 joint report of the five agencies.

Participation in artisanal and small-scale gold mining (hereafter referred to as ASGM) can affect the four core pillars of food security through multiple, sometimes conflicting pathways. Increased.

mining income can raise household purchasing power, which in turn strengthens households' economic ability to access food; it can also support households to spend more on education, healthcare, and daily consumption. However, the shift of labor from agriculture to mining may lead to a drop in crop yields, weakening households' capacity for self-sufficiency in food, while also increasing their reliance on purchased food. Households that depend heavily on local grain markets are more vulnerable to shocks from grain price volatility and unstable mining income, and these risks are particularly acute in regions where gold production is uncertain or seasonal (Hilson & Maconachie, 2020).

Environmental degradation linked to ASGM is a new dimension that has received steadily growing attention in food security research in recent years. Mining activities often trigger deforestation, soil degradation, and river channel siltation and cause heavy metals, including mercury, arsenic, lead, and cadmium, to contaminate agricultural soil and irrigation water (UNEP, 2023; Nunoo et al., 2023). These pollutants can accumulate in staple grains, vegetables, aquatic products, and livestock products, lowering food safety levels and increasing health risks for local populations. On this basis, the connotation of food utilization must be extended from nutrient intake to the quality and safety of consumed food, which serves as a critical supplement to conventional food security assessments in mining-affected areas.

Current empirical evidence on the link between artisanal and small-scale gold mining (ASGM) and household food security remains inconclusive: some studies (Hilson & Maconachie, 2020; Mkodzongi & Spiegel, 2019) find that mining can expand income sources and hedge against risks of agricultural downturns; in contrast, other studies (Nunoo et al., 2023; Li et al., 2024) point out that mining can increase the severity of food insecurity. This variation in effects is fundamentally driven by five key variables.

Household-level food security has multi-dimensional attributes, and relying on a single indicator can easily omit core dimensions of household-level well-being. For this reason, most current mainstream research combines multiple complementary indicators to cover different dimensions. A 2023 study by researchers including those from the Food and Agriculture Organization (FAO) has confirmed four widely used general indicators: the Household Food Insecurity Access Scale (HFIAS), Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), and Months of Adequate Household Food Provisioning (MAHFP). This study aligns with this perspective, adopting validated indicators to explore the impact of participation in artisanal and small-scale gold mining (ASGM) in the Ahafo region of Ghana on the economic and nutritional dimensions of household-level well-being.

2.4 Recent Evidence on Ghana's Artisanal and Small-Scale Gold Mining, Food Security, and Institutional Coordination

Empirical studies in recent years have generated important insights into the complex interactions between artisanal and small-scale gold mining (ASGM), agricultural livelihoods, household food security, environmental sustainability, and institutional governance within Ghana. Unlike earlier research that mostly focused only on the income-generating potential of ASGM, new research evidence shows that the welfare outcomes of participating in mining activities are far more complex and depend on households' livelihood strategies, their local environmental conditions, and the actual effectiveness of institutional governance.

Multiple recent studies indicate that while ASGM can create substantial cash income and employment opportunities, these economic benefits do not necessarily translate into improved household welfare. Household-level evidence from mining communities in Ghana shows that participation in ASGM is often accompanied by reduced agricultural output, a decline in the agricultural workforce, and

increased reliance on purchased food, meaning even households with increased income face a higher risk of food insecurity (Nunoo et al., 2023; Li et al., 2024). These findings reject the assumption that higher income alone can guarantee improved household welfare, while also highlighting the critical importance of simultaneously addressing agricultural productivity, environmental sustainability, and food security.

According to a 2020 study by Arthur-Holmes and Busia, the expansion of small-scale artisanal gold mines in the Ahafo region of Ghana is intensifying competition for high-quality agricultural land and agricultural labor. Many fields used for cocoa and food crops have been converted into mining sites, which has reduced agricultural output and forced farm households to rely heavily on highly volatile food markets. At the same time, agricultural workers have moved into the mining sector, leading to widespread labor shortages during key agricultural periods such as land preparation, sowing, weeding, and harvesting. The short-term gains from mining will ultimately be offset by agricultural decline, rising food expenses, and reduced resilience to shocks.

Recent relevant literature has also expanded the concept of food security, listing food safety as a core component of household welfare in mining communities. Multiple studies point out that mercury, arsenic, cadmium, and lead released during artisanal mining can pollute agricultural soil, irrigation water, fish, and grain crops. Even if households have enough food to consume, these pollutants still drive-up public health risks (United Nations Environment Programme, 2023; Nunu et al., 2023). These findings show that food security assessments for mining communities cannot be limited only to the dimensions of food availability and economic access; they must also incorporate food quality, environmental health, and nutritional security.

Institutional governance is another key determinant that affects whether agriculture and mining can achieve sustainable coexistence. Recent studies have found that weak coordination among Ghana's Ministry of Food and Agriculture, Minerals Commission, Environmental Protection Agency, Water Resources Commission, municipal and district assemblies at all levels, and traditional authorities is the main barrier holding back the implementation of land use planning and environmental management. Fragmented powers and responsibilities also often lead to problems such as inconsistent enforcement of mining regulations, inefficient reclamation of degraded land, and insufficient integration of agricultural and mining policies (Arthur-Holmes & Busia, 2020; Oloya & Ouko, 2026). For these reasons, strengthening cross-agency collaboration and implementing integrated governance are necessary strategies to improve environmental protection, agricultural productivity, and rural livelihoods.

Despite many important advances in this field, several research gaps remain at both the empirical and conceptual levels. Most existing studies examine agricultural productivity, household food security, environmental degradation, and institutional governance only as separate topics, and very few integrate these dimensions into a single analytical framework. Furthermore, among existing research on Ghana's mining areas, almost no studies analyze the impacts of artisanal and small-scale gold mining on both agricultural labor productivity and household food security, while incorporating key variables such as livelihood diversification and food safety. This study builds a unified analytical framework that integrates the coexistence of agriculture and mining, addresses the gaps by combining the four core dimensions, and generates new empirical evidence and policy insights to advance sustainable rural livelihoods in Ghana's Ahafo region and other mining-dependent communities.

2. 5 Theoretical And Conceptual Framework

This chapter elaborates on the theoretical and conceptual foundations that underpin this study and critically reviews all theoretical perspectives that can explain the complex links between artisanal and small-scale gold mining (ASGM), agricultural labor productivity, and household food security in the Ahafo region of Ghana. Given the multi-dimensional nature of rural livelihoods in mining communities, no single theoretical perspective can fully explain how households allocate resources, respond to economic incentives, and manage trade-offs between agricultural production and mining activities. For this reason, this study integrates three

complementary theoretical perspectives: the Sustainable Livelihoods Framework (SLF), the Agricultural Household Model (AHM), and household utility maximization theory.

Each of the three frameworks provides a unique lens to understand household decision-making: the Sustainable Livelihoods Framework explains how households combine different types of capital to build resilient livelihood strategies amid economic and environmental uncertainty (Scoones, 1998; DFID, 1999); the Agricultural Household Model provides an economic explanation of how households make simultaneous decisions about production, labor allocation, and consumption under imperfect market conditions (Singh et al., 1986); and household utility maximization theory further explains how households allocate scarce resources across competing livelihood opportunities to maximize overall well-being rather than a single source of income (De Janvry & Sadoulet, 2020). Integrating these theories will produce a comprehensive analytical framework to examine how participation in ASGM affects agricultural labor productivity and household food security through changes in labor allocation, household income, investment behavior, environmental quality, institutional support, and livelihood diversification. At the end of this chapter, the study's conceptual framework is presented, which puts forward an integrated agriculture-mining coexistence framework that incorporates recent evidence from Ghana's mining sector on environmental sustainability, food security, and institutional coordination (Adranyi et al., 2024; Nunoo et al., 2023).

2.5.1 Sustainable Livelihoods Framework

The Sustainable Livelihoods Framework (SLF), originally developed by the UK's Department for International Development (DFID), remains one of the most widely used analytical frameworks for studying rural poverty, livelihood diversification, and sustainable development (DFID, 1999; Scoones, 1998). This framework states that farm households must integrate five types of capital—human capital, natural capital, financial capital, physical capital, and social capital—to build their own livelihoods, within the broader institutional, political, and environmental context. Interactions between these livelihood assets determine households' ability to cope with shocks, seize economic opportunities, and achieve sustainable livelihood outcomes.

Numerous recent studies have continued to confirm the framework's real-world explanatory power. Research by Li et al. (2024) and Adranyi et al. (2024) both note that the SLF can still effectively explain the livelihood diversification behaviors of rural farm households affected by climate variability, environmental degradation, and resource-based industries. Rather than relying on a single source of income, households often spread their livelihood activities to reduce risks, smooth consumption, and strengthen their resilience to economic uncertainty. In mining communities, participation in artisanal and small-scale gold mining often acts as a supplement to agricultural production, providing an alternative source of income when agricultural returns are low or climate conditions are unfavorable. For this reason, livelihood diversification should not be interpreted as abandoning agriculture; it is a rational strategy through which farm households improve their long-term well-being.

Within the context of this study, the sustainable livelihoods framework provides an appropriate analytical perspective to understand why farm households in Ghana's Ahafo region continue to combine farming with artisanal mining, despite facing environmental and social challenges tied to artisanal mining. This livelihood portfolio is a choice these households make to balance short-term income generation and long-term livelihood security, while operating under constraints including imperfect credit markets, climate uncertainty, commodity price fluctuations, and limited non-farm employment opportunities. Human capital covers educational attainment, farming experience, technical knowledge, health status, and labor availability. These attributes shape households' capacity to adopt improved agricultural technologies, access agricultural extension services, obtain information, and make sound livelihood decisions. As found in a 2024 study by Wongnaa et al., farm households with higher educational levels and richer farming experience are generally more able to engage in both farming and alternative livelihood activities while maintaining farmland productivity and household well-being.

Natural capital is critical to agriculture and artisanal mining, both of which rely on production land, water resources, forests, and fertile soil to operate. However, recent research from Ghana shows that unregulated artisanal and small-scale gold mining (ASGM) can trigger severe problems such as deforestation and land degradation (Nunoo et al., 2023; Ofosu et al., 2020). The mercury, arsenic, cadmium, and lead it releases can accumulate in water, soil, and crops, threatening agricultural production and public health. For this reason, assessments of natural capital in mining areas must add new dimensions of environmental quality and ecological sustainability, rather than only calculating resource reserves.

Financial capital includes household income, savings, productive assets, and access to formal or informal credit. Participation in small-scale gold mining often generates immediate cash income that can be used to cover agricultural inputs, children's education, medical expenses, and household investments. However, if agricultural production declines due to labor shortages, environmental degradation, or the loss of farmland, increases in financial capital will not automatically translate into improvements in household well-being. Empirical research by Adelan et al. (2024) shows that while mining may raise cash income, it can simultaneously undermine household food security in areas where agricultural production and natural resources have been damaged. Physical capital includes infrastructure such as roads and irrigation systems, as well as productive assets. Sound rural infrastructure can boost agricultural efficiency, but intensive mining will destroy this type of capital and drag down rural well-being. Social capital covers social networks, community organizations, farmers' associations, mining cooperatives, traditional leadership, and institutional trust. Strong social capital can advance collective action, resolve conflicts, and share information, and it also helps communities participate in environmental management. Recent governance research on Ghana shows that effective collaboration among the Ministry of Food and Agriculture, Minerals Commission, Environmental Protection Agency, Water Resources Commission, district assemblies, and traditional authorities is the core driver of sustainable coexistence between agriculture and mining.

Although the sustainable livelihoods framework can comprehensively explain livelihood diversification and household resilience, it cannot account for the economic mechanisms that govern labor allocation and production decisions in imperfect rural markets, nor does it explicitly develop a trade-off model between agricultural production and non-farm employment. To address these limitations, this study combines this framework with the agricultural household model, which can explain household production, consumption, and labor allocation decisions in a more rigorous manner.

Within the framework of this study, the household farm model reasonably explains the labor allocation decisions of farm households that engage in artisanal and small-scale gold mining (ASGM): compared with agricultural activities, mining usually generates higher and more immediate economic returns, which drives able-bodied household members to shift from farming to mining. This labor transfer may delay the completion of key agricultural tasks, including land preparation, sowing, weeding, fertilization, and harvesting, which in turn reduces agricultural labor productivity. This negative causal logic has been confirmed by existing studies in the field. The same model also explains the positive buffering effect of mining income: the additional income from mining eases farm households' liquidity constraints, allowing them to invest in agricultural inputs such as improved seeds and chemical fertilizers, which offsets part of the negative impact of labor diversion. The final impact of ASGM participation on agricultural productivity depends on the balance between the scale of labor diversion and the extent to which mining income is reinvested in agricultural activities. This comprehensive assessment is also supported by relevant research.

Multiple recent empirical studies show that the link between artisanal and small-scale gold mining (ASGM) and livelihoods in mining areas is highly context-specific: while mining income can boost households' ability to invest, widespread participation in ASGM in multiple mining sites across sub-Saharan Africa has been tied to declines in agricultural production, land degradation, labor shortages, and increased reliance on purchased food.

These findings come from studies by Adranyi et al. (2024) and Nunoo et al. (2023). Environmental degradation caused by mining, such as soil erosion, mercury pollution, water contamination, and the loss of fertile agricultural land, also raises the opportunity cost of agricultural production and weakens the long-term productivity of agricultural systems. On this basis, the agricultural household model provides a solid theoretical foundation for analyzing the impact of ASGM participation on agricultural labor productivity. It can clearly explain the behavioral logic through which rural households allocate labor and financial resources while responding to changes in economic opportunities and environmental constraints under conditions of imperfect markets.

2.5.2 Household Utility Maximization Theory

Family utility maximization theory adds a behavioral science perspective to understanding household livelihood decision-making. This theory assumes that households allocate scarce resources to maximize their total utility, rather than only pursuing monetary income. Utility is derived from multi-dimensional well-being, including food consumption, income, health, education, leisure, environmental quality, security, and future livelihood opportunities (Varian, 2014; De Janvry & Sadoulet, 2020). As a result, households evaluate various livelihood activities by comparing expected benefits against economic, environmental, and social costs. In artisanal mining communities, households will engage in small-scale artisanal gold mining when they perceive that the expected utility of mining exceeds the utility of relying solely on agriculture. Mining can bring short-term benefits such as higher income, improved household consumption, asset accumulation, and the ability to invest in education and medical care. However, households must also consider the long-term costs of mining, including reduced agricultural productivity, food insecurity, environmental degradation, occupational health risks, and uncertainty caused by fluctuations in gold prices and mining access opportunities (Hilson & Maconachie, 2020; Mabe et al., 2023).

Latest research shows that the scope of rural household welfare has long exceeded the single dimension of income and covers two core areas: food safety and environmental health. Mining activities release four types of heavy metals, mercury, arsenic, cadmium, and lead, that pollute agricultural land and water bodies. Even if rural households' incomes increase, this pollution undermines food quality, raises public health risks, and reduces households' overall utility. These conclusions are supported by two recent studies. Therefore, even if rational rural households can obtain higher immediate returns from mining, they will continue to invest in agricultural production. This allows them to secure food access, dietary diversity, nutritional security, and long-term livelihood resilience. The household utility maximization theory can address gaps in the agricultural household model, explaining why rural households choose diversified livelihoods instead of relying solely on farming and livestock raising or on mining. These households adjust their livelihood portfolios in response to changes in markets, the environment, institutional conditions, and their own welfare goals. All these adaptive strategies are rational choices made to maximize long-term welfare under conditions of uncertainty.

2.5.3 Integration of the Theoretical Frameworks

No single theoretical perspective can fully explain the complex interactive relationship among artisanal and small-scale gold mining, agricultural labor productivity, and household food security.

In view of this, this study integrates the sustainable livelihoods framework, the agricultural household model, and the theory of household utility maximization to provide a comprehensive explanation for the livelihood behaviors of households in rural communities affected by mining. The sustainable livelihoods framework can explain how households use five types of capital—human, natural, financial, physical, and social capital—to build livelihood strategies that are both diverse and resilient in order to cope with economic and environmental shocks (Scoones, 1998; DFID, 1999). The agricultural household model complements this perspective by explaining how households allocate labor and production resources and balance decisions around production, consumption, and investment under conditions of incomplete markets (Singh et al., 1986).

The theory of household utility maximization further explains the behavioral process through which households assess livelihood opportunities and select a combination of activities that can maximize their long-term welfare (Varian, 2014). Integrating these three

theoretical perspectives has laid a solid conceptual foundation for this study. We find that the impacts of artisanal and small-scale gold mining (ASGM) on agricultural labor productivity and household food security are realized through seven interconnected pathways: labor reallocation, income diversification, agricultural investment, environmental degradation, food safety, institutional quality, and household adaptive behavior. These linkages are also moderated by five categories of macro-level contextual factors: climate variability, commodity price fluctuations, land tenure arrangements, governance effectiveness, and access to institutional support. The above conclusions have been confirmed in studies by Conteh & Maconachie (2021) and Adranyi et al. (2024). Together, these theories provide reasonable support for the empirical model adopted in this research, build an analytical framework for interpreting the observed correlations between mining participation, agricultural productivity, and household food security, and underpin the integrated agriculture-mining coexistence framework proposed in this study. This framework lists elements such as responsible mining and sustainable agricultural development as complementary components of sustainable rural livelihoods.

2.6 Conceptual Framework

This study develops a conceptual framework that systematically describes the functional logic through which participation in artisanal and small-scale gold mining (ASGM) in the Ahafo region of Ghana influences agricultural labor productivity and household food security via four interconnected pathways: economic, environmental, institutional, and behavioral.

Built on the Sustainable Livelihoods Framework, the agricultural household model, and household utility maximization theory, this framework treats ASGM participation as its core explanatory variable. The framework posits that ASGM participation directly acts on five mediating factors, including household labor allocation and agricultural investment, which in turn shape the core outcome variables. Specifically, when labor shifts from agriculture to mining, it reduces the household labor supply available during peak agricultural seasons and lowers productivity. Conversely, income generated from mining can ease liquidity constraints, enabling farm households to invest in agricultural inputs such as improved technologies and mechanization. The final net effect depends on the balance between these two mechanisms, a conclusion supported by prior research from Singh et al. (1986) and De Janvry and Sadoulet (2020).

Household characteristics, including age, gender, educational attainment, household size, farming experience, and asset ownership, are expected to influence both the probability that a household participates in artisanal and small-scale gold mining (ASGM) and the agricultural and food security outcomes that follow such participation. Similarly, farm-level characteristics such as farm size, access to agricultural extension services, access to production credit, use of improved technologies, and access to markets affect agricultural productivity by shaping a household's ability to adopt yield-boosting innovations and adapt to changing economic conditions (Wooldridge, 2020; Ghana Ministry of Agriculture and Food, 2023). Environmental factors form a core component of this study's conceptual framework: mining activities can trigger land degradation, deforestation, soil erosion, water pollution, and biodiversity loss and cause heavy metal contamination of agricultural ecosystems. Recent studies show that mercury, arsenic, cadmium, and lead released from artisanal mining accumulate in agricultural soil, irrigation water, and food crops, which reduces agricultural productivity while threatening food safety and public health (Nunoo et al., 2023; Adedoyin et al., 2024). For this reason, the present study conceptualizes household food security as a multidimensional indicator that covers food availability, economic accessibility, food utilization, and food safety, which aligns with the multifaceted nature of food security.

Institutional factors exert a profound impact on rural households' livelihood decisions and constrain the implementation effectiveness of agriculture-related environmental policies. Factors such as government regulations, mining-related legislation, land tenure rights, agricultural extension services, environmental law enforcement, local governance, and traditional authority determine the channels through which rural households access production resources and shape whether agriculture and mining can coexist sustainably. Studies by Arthur-Holmes and Busia (2020) and Oloya and Ouko (2026) both point out that collaboration between multiple government

sectors and traditional authorities in Ghana is a core prerequisite for resolving policy fragmentation in mining areas and advancing integrated resource management.

Overall, the conceptual framework proposed in this study acknowledges that the link between small-scale artisanal gold mining and household well-being is multidimensional and dynamic. The framework does not assume that mining is inherently beneficial or harmful. Instead, it proposes that household-level outcomes depend on the interactions among household characteristics, agricultural investment, environmental quality, institutional effectiveness, and broader socioeconomic conditions. This conceptualization provides an analytical foundation for the construction of this study's empirical models and the interpretation of its results.

2.6.1 An Integrated Framework for Agriculture-Mining Coexistence

The core conceptual contribution of this study is precisely the proposal of this integrated framework, which provides a comprehensive policy framework that can advance sustainable rural livelihoods for mining-affected communities. Unlike traditional approaches that frame agriculture and artisanal mining as inherently conflicting livelihood activities, this framework posits that the two sectors can coexist when supported by effective governance, responsible environmental management, and coordinated institutional interventions.

This framework takes as its core principle that rural sustainable development requires the simultaneous advancement of agricultural productivity growth, environmental sustainability, economic diversification, and household well-being

It advocates for the adoption of integrated land-use planning, which protects high-yield agricultural land while designating environmentally suitable zones for responsible mining. This approach aims to reduce land-use conflicts, curb environmental degradation, and improve long-term resource sustainability. The core component of the framework is to promote sustainable agricultural intensification. It strengthens agricultural resilience, increases labor productivity, and reduces households' overreliance on mining as their single source of income through seven intervention measures, including the improvement and expansion of extension services. Support for this approach is drawn from the 2023 reports of the FAO and the MoFA.

This framework also advances responsible artisanal and small-scale mining through the implementation of five key measures: strengthening environmental regulation, promoting mercury-free processing technologies, enforcing progressive land reclamation, upgrading occupational health and safety standards, and carrying out routine environmental monitoring in mining areas. The framework prioritizes reducing heavy metal pollution in agricultural soils, irrigation water, and grain to safeguard food safety, ecological integrity, and public health. The basis for this focus comes from the 2023 UNEP report and the 2023 study by Nunoo et al.

Given that the diversification of rural households' livelihoods is the core of rural resilience, the framework encourages these households to invest mining income into productive agriculture, agricultural industrialization, and other non-agricultural rural industries. This type of reinforcement can both strengthen household-level resilience and reduce long-term dependence on mining.

Institutional collaboration is another core pillar of this framework. To achieve sound coexistence between agriculture and mining, a coordinated governance model must be adopted. This model brings in multiple stakeholders, including the Ministry of Food and Agriculture, the mining commission, the environmental protection agency, the water resources board, district councils, traditional authorities, farmer organizations, mining associations, civil society organizations, and local communities. Collaborative governance can improve policy coherence, the strength of environmental law enforcement, the quality of land use planning, and the quality of inclusive decision-making. It can also reduce conflicts between agricultural and mining communities. These conclusions draw on studies by Arthur-Holmes and Busia (2020) and Oloya and Ouko (2026). Finally, this framework incorporates mechanisms for continuous monitoring, evaluation, and adaptive management. These mechanisms track long-term changes in agricultural labor productivity, household food security, environmental quality, food safety, institutional performance, and livelihood outcomes, so that decision-makers can assess project effectiveness, identify new challenges, and adjust intervention measures accordingly.

Therefore, the integrated agriculture-mining coexistence framework proposed in this study breaks through the limitations of existing theories on livelihoods and agricultural development and incorporates environmental sustainability, food security, institutional governance, and livelihood diversification into a single analytical framework. This integrated perspective is the core theoretical contribution of this study. At the same time, it provides a practical basis for policy design in the Ahafo region of Ghana and other mineral-rich regions facing similar development challenges and can support the coordinated implementation of four goals: responsible mining, sustainable agriculture, environmental protection, and resilient rural livelihoods.

3. Materials And Methods

This chapter introduces the complete set of research methods used to assess the impacts of artisanal and small-scale gold mining (ASGM) on agricultural labor productivity and household food security in the Ahafo region of Ghana. It presents all relevant content in sequence, including the study area, research philosophy and design, target population, sampling process, sample size determination, data collection procedures, variable measurement, reliability and validity assessment, econometric model specification, data analysis techniques, and ethical considerations. The methodological framework follows the norms set out in Creswell & Creswell (2018) and Saunders et al. (2019) to ensure the scientific rigor, transparency, and reproducibility of the study and to produce reliable policy-oriented empirical evidence.

Because participation in artisanal mining is a voluntary decision made independently by households, rather than an experimental treatment assigned randomly, the empirical analysis of this study adopts econometric methods that can address both observable and unobservable factors. These factors may influence households' mining participation behavior and their welfare outcomes, and the validity of the relevant methods has been confirmed in the 2004 study by Lokshin & Sajaia and the 2006 study by Deb & Trivedi. This method can improve the consistency of parameter estimates and strengthen the effectiveness of subsequent policy recommendations.

3.1 Study Area

This study is conducted in the Ahafo Region of Ghana, which is one of the most important agricultural and mineral-producing areas in the country. This region was purposefully selected because agriculture and artisanal and small-scale gold mining are the core livelihoods for many local rural households, which matches this study's investigation of the interactive relationships among mining participation, agricultural labor productivity, and household food security. These livelihood characteristics have been verified in the 2020 study by Nti et al. and the 2020 study by Arthur-Holmes & Busia.

The Ahafo Region was established in 2019 after being split from the former Brong-Ahafo Region. It shares a northern border with the Bono Region, an eastern border with the Ashanti Region, a southwestern border with the Western North Region, and a northwestern border with the Savannah Region and administers 6 districts. According to the 2021 Population and Housing Census released by the Ghana Statistical Service in 2021, the region has a total population of 564,668, and most of its rural residents rely on agriculture as their core livelihood.

This region is in forest zones and the forest-savanna transition ecological zone, with a tropical humid climate. Its rainfall follows a bimodal pattern, with annual precipitation of approximately 1200 to 1800 millimeters and average temperatures ranging from 24°C to 30°C. These climatic conditions are suitable for growing cacao, maize, cassava, yams, taro, plantains, vegetables, and rice, which has made agriculture the pillar of the regional economy. The relevant data come from a 2023 report released by Ghana's Ministry of Food and Agriculture and a 2024 study by Asante et al.

The region also hosts abundant gold mineral resources, which can support two development models: large-scale commercial mining and artisanal and small-scale gold mining. The rapid expansion of artisanal small-scale mining has, on one hand, created jobs, supplemented household incomes, and improved rural livelihoods; on the other hand, it has placed pressure on agricultural land,

labor, forests, and water resources. Conclusions about this impact come from 2020 studies by Hilson and Maconachie and by Ofosu et al. The resulting problems, including declines in agricultural productivity, environmental degradation, heavy metal pollution of agricultural land and water bodies, and undermined household food security, have raised widespread concerns. These concerns are noted in 2023 research by Nunoo et al. and 2024 research by Adranyi et al. For these reasons, the Ahafo Region is a suitable empirical site for studying the opportunities and challenges of the coexistence of agriculture and artisanal mining.

3.2 Research Philosophy and Research Design

This study is guided by pragmatist research philosophy, which prioritizes selecting the methods that best address research problems and produce practical, evidence-based solutions (Creswell & Creswell, 2018; Saunders et al., 2019). Pragmatism holds that complex issues such as the interactions among mining, agriculture, environmental sustainability, and food security require methodological flexibility and integration of appropriate analytical techniques. This study adopts an explanatory cross-sectional household survey design, which is widely used in agricultural economics to analyze the links between household characteristics, livelihood strategies, and welfare outcomes. This design is also cost-effective and suitable for large samples (Kothari, 2004; Wooldridge, 2020).

This study adopts a quantitative approach and conducts causal estimation using advanced econometric methods. To address the endogeneity issue related to participation in small-scale artisanal gold mining, this study applies the endogenous switching regression model proposed by Lokshin & Sajaia (2004) and the endogenous treatment effects model developed by Deb & Trivedi (2006) to resolve sample selection bias. Meanwhile, following the methods outlined by Gujarati & Porter (2009) and Wooldridge (2020), this study carries out auxiliary tests including descriptive statistics, reliability analysis, and correlation analysis.

3.3 Target Population

The target population of this study consists of rural household heads in selected mining and non-mining communities in the Ahafo region of Ghana. We use the household as the core unit of analysis, because decisions related to agricultural production, labor allocation, participation in artisanal mining, food consumption, and livelihood diversification are generally made at the household level. This setting is supported by the 1986 study by Singh et al. and the 2000 work by Ellis. To ensure the reliability and completeness of the collected information, we only interviewed either the household head or an adult family member who is fully familiar with the household's agricultural and livelihood activities.

3.4 Sampling Process

This study adopts a multi-stage sampling technique to ensure that the selected households can adequately represent agricultural communities with different levels of exposure to artisanal and small-scale gold mining. This method is widely recommended for household surveys that aim to cover geographically dispersed populations, as it improves sample representativeness while reducing survey costs and logistical challenges. This approach is grounded in the 1977 study by Cochran and the 2004 work by Kothari.

In the first phase of this study, purposive sampling was used to select administrative regions that host both intensive agricultural production and active artisanal and small-scale gold mining (ASGM) operations. In the second phase, the selected communities were stratified into mining and non-mining communities to enable comparative analysis. In the third phase, household samples were drawn via simple random sampling, using a household roster jointly developed by community leaders, agricultural extension workers, and local governments. This sampling method ensured that all eligible households had an equal chance of being selected, which reduced selection bias and improved the external validity of the study's findings (Cochran, 1977).

3.5 Sample Size Calculation

This study determined its sample size using the large sample size calculation formula proposed by Cochran (1977). This formula is widely used in social sciences, agricultural economics, and household survey research. It can produce a statistically reliable estimate of the minimum sample size required to obtain representative results while meeting a specified confidence level and precision.

The Cochran formula is expressed as:

$$n_0 = (Z^2 \cdot p \cdot (1 - p)) / e^2$$

Where:

n_0 = Required sample size for an infinitely large population

Z = Standard normal deviate corresponding to the desired confidence level

p = Estimated proportion of the population possessing the characteristic of interest ($1 - p$) = Estimated proportion of the population not possessing the characteristic

e = Desired level of precision (margin of error)

For this study, a 95% confidence level was adopted, corresponding to a Z-value of 1.96. Since the actual proportion of farming households participating in artisanal and small-scale gold mining in the Ahafo Region was not known, the population proportion (p) was assumed to be 0.50. According to Cochran (1977), the use of 0.50 is recommended when the true population proportion is unknown because it produces the maximum possible sample size and therefore provides the most conservative estimate. A 4% margin of error (0.04) was selected to increase the precision of the estimates.

Substituting these values into Cochran's formula gives:

$$n_0 = ((1.96)^2 \times 0.50 \times (1 - 0.50)) / (0.04)^2 \quad n_0 = (3.8416 \times 0.25) / 0.0016$$

$$n_0 = 0.9604 / 0.0016$$

$$n_0 = 600.25$$

The calculated sample size is approximately 600 rural households. This study ultimately selected 600 farming households as survey samples. This sample size is sufficient to support all required statistical and econometric analyses, including descriptive statistics, reliability analysis, Pearson correlation analysis, and VIF analysis, and meets the requirements for statistical reliability and test power. After determining the total sample size, this study adopted the proportional allocation method to distribute the samples to the selected districts, counties, and communities based on the number of rural households in each district and county. The formula for proportional allocation is as follows:

$$n_i = (N_i / N) \times n$$

Where:

n_i = Sample allocated to district i

N_i = Number of farming households in district i

N = Total number of farming households in all selected districts n = Total sample size (600 households)

In this study, the number of survey respondents allocated to each electoral constituency is proportional to the size of its agricultural population; constituencies with larger agricultural populations receive a correspondingly larger number of allocated respondents. This method can improve sample representativeness, reduce sampling bias, and enable the study's conclusions to be generalized to the broader population of farming households in the Ahafo region.

3.6 Data Sources

This study uses both primary and secondary data. Primary data was collected by researchers through face-to-face interviews, during which structured questionnaires were distributed to farming households. The questionnaire covers dimensions including respondents' demographic and socioeconomic characteristics, agricultural production activities, participation in artisanal and small-scale gold mining (ASGM), labor allocation, household income, food security status, access to agricultural extension services, access to production credit, environmental conditions, and livelihood diversification strategies. Face-to-face interviews allow respondents to clarify uncertainties at any time, ensuring the completeness and accuracy of the collected information.

The secondary data for this study were drawn from official publications and databases of the Ghana Statistical Service, the Ghana Ministry of Food and Agriculture, the Ghana Minerals Commission, the Food and Agriculture Organization of the United Nations, and the World Bank. These sources were supplemented by relevant peer-reviewed journal articles, monographs, and policy reports. The materials collected provided background information and contextual evidence for Ghana's agricultural production, artisanal and small-scale gold mining, rural livelihoods, environmental sustainability, and household food security. They also supported the development of this study's conceptual framework, the design of its survey questionnaire, and the interpretation of its empirical results.

3.7 Data Collection Process

This study collected primary data using a structured questionnaire with multiple sections. The first section gathered demographic and socioeconomic characteristics of respondents, including age, gender, educational attainment, household size, dependency ratio, and years of farming experience. Subsequent sections collected data related to farm characteristics, land ownership, crop production, labor allocation, agricultural income, participation in artisanal and small-scale gold mining, access to agricultural extension services and production credit, environmental conditions, and household food security.

The questionnaire for this study was first developed by comprehensively sorting through relevant literature and referencing verified, mature measurement tools used in previous research, to ensure all questionnaire items accurately align with the study's objectives.

Before the formal survey was launched, a pre-test was conducted in a community whose socioeconomic characteristics were highly similar to those of the study area. During this pre-test, we identified items with ambiguous expressions and evaluated the overall structure of the questionnaire. We then revised and improved the questionnaire based on feedback from the pre-survey to prepare for formal data collection. This study used a structured questionnaire, and the researcher collected data in person through face-to-face interviews. When necessary, questions were translated into the local language preferred by respondents to ensure their understanding and the accuracy of their answers. The entire process strictly followed ethical guidelines: we obtained informed consent from all respondents, guaranteed their voluntary participation, and protected the confidentiality and anonymity of their information. We also conducted on-site spot checks of completed questionnaires to minimize non-sampling errors as much as possible.

3.8 Measurement of Variables

The dependent variables of this study are agricultural labor productivity and household food security. The former is measured by the value of agricultural output per working day, while the latter uses a binary variable to distinguish households with food security from those facing food insecurity. All outcome variables conform to the definition specifications in this study's data dictionary. The core explanatory variable is household participation in small-scale artisanal gold mining. The supplementary explanatory variables include 16 indicators such as the age and gender of the household head. The selection of all variables is based on agricultural household theory, previous empirical studies, and the analytical framework of this study.

3.9 Reliability and Validity

This study uses Cronbach's alpha coefficient to evaluate the reliability of the multi-item scales adopted in the questionnaire. This coefficient measures the internal consistency of the questionnaire's items by assessing how well each item aligns when measuring the

same latent variable. This study sets a threshold of no less than 0.7 as the qualifying standard for acceptable reliability. To optimize construct validity, this study systematically reviews existing literature, consults experts in the fields of agricultural economics and rural development, and conducts a pre-test of the questionnaire. Meanwhile, the questionnaire items are aligned with the research objectives, conceptual framework, and proven mature scales from previous studies to guarantee content validity.

3.10 Data Analysis

Following data collection, completed questionnaires were checked for completeness, coded, and entered into Stata for statistical analysis. Data cleaning procedures, including consistency checks, identification of missing values, and outlier detection, were undertaken before the analyses.

Descriptive statistics, including frequencies, percentages, means, standard deviations, minimum values, and maximum values, were computed to summarise the socioeconomic characteristics of the sampled households and the key study variables. Pearson correlation analysis was conducted to examine relationships among the explanatory variables, while the Variance Inflation Factor (VIF) was used to assess multicollinearity. Variables with acceptable VIF values were retained in the regression analyses (Gujarati & Porter, 2009).

Agricultural labour productivity was analyzed using a multiple linear regression model with robust standard errors to account for potential heteroskedasticity. Household food security, measured as a binary outcome, was estimated using a binary logistic regression model, with odds ratios and average marginal effects (AMEs) reported to facilitate interpretation of the estimated relationships (Wooldridge, 2019).

To assess the robustness of the findings, additional model diagnostics were performed, including heteroskedasticity tests, goodness-of-fit assessment, specification tests, and influential observation diagnostics. Furthermore, Propensity Score Matching (PSM) was employed as a robustness check to compare ASGM-participating households with observationally similar non-participating households, thereby reducing observable selection bias and strengthening the estimated effects of ASGM participation on agricultural labour productivity and household food security (Rosenbaum & Rubin, 1983).

3.11 Econometric Model Specification

The empirical analysis of this study uses two core types of econometric models: multiple linear regression is applied to estimate the correlation between participation in small-scale artisanal gold mining and agricultural labor productivity, and binary logistic regression is used to analyze the relationship between mining participation and household food security. At the same time, PSM is employed as a robustness procedure to address differences in the observable characteristics between the two types of households.

3.12 Measurement of Variables and Econometric Model Specification

3.12.1 Measurement of Agricultural Labour Productivity

Agricultural labour productivity (ALP) was measured as the annual gross value of crop output divided by the total number of family and hired labour days used in agricultural production. This measure captures the value of agricultural output generated per unit of labour employed and is widely used in agricultural economics to evaluate labour-use efficiency (De Janvry & Sadoulet, 2020).

$$ALP_i = GVO_i / (FLD_i + HLD_i) \quad (1)$$

Where:

ALP_i = Agricultural labour productivity (GHS per labour day) GVO_i = Annual gross value of crop output (GHS)

FLD_i = Family labour days HLD_i = Hired labour days

3.12.2 Endogenous Switching Regression Model

Because participation in artisanal and small-scale gold mining (ASGM) is a voluntary household decision, estimating its effect using ordinary least squares may produce biased estimates owing to self-selection and unobserved heterogeneity. To address this problem, the study employed an Endogenous Switching Regression (ESR) model (Lokshin & Sajaia, 2004).

The household's participation decision is specified as: $ASM_i^* = Z_i\gamma + \mu_i$ (2)

$ASM_i = 1$ if $ASM_i^* \geq 0$; 0, otherwise 0

The agricultural labour productivity equations are estimated separately for participating and non-participating in households:

Regime 1 (ASGM participants): $ALP_{1i} = X_{1i}\beta_1 + \varepsilon_{1i}$ (4)

Regime 2 (non-participants): $ALP_{0i} = X_{0i}\beta_0 + \varepsilon_{0i}$ (5)

The ESR framework jointly estimates the participation equation and the two outcome equations.

by Full Information Maximum Likelihood (FIML), thereby correcting for observable and unobservable selection bias (Lokshin & Sajaia, 2004).

3.12.3 Endogenous Treatment Effect Model for Household Food Security

To estimate the effect of ASGM participation on household food security while accounting for Endogenous treatment assignment, an Endogenous Treatment Effect (ETE) model was employed.

The treatment equation is specified as:

$$ASM_i^* = Z_i\gamma + \mu_i \quad (6) \quad \text{The food security equation is: } FS_i = X_i\beta + \delta ASM_i + \varepsilon_i \quad (7)$$

Where:

FS_i = Household food security status ASM_i = Participation in ASGM

X_i = Household, farm, and institutional characteristics Z_i = Instruments determining mining participation

δ = Average treatment effect of ASGM participation

The ETE model jointly estimates the treatment and outcome equations while correcting for endogeneity arising from unobserved household characteristics.

3.12.4 Treatment Effects

The average treatment effects were estimated as:

$$ATT = E(Y_1 - Y_0 | ASM = 1) \quad (8) \quad ATU = E(Y_1 - Y_0 | ASM = 0) \quad (9)$$

Where

ATT = Average treatment effect on households participating in ASGM

ATU = Expected treatment effect had nonparticipating households engaged in ASGM

3.12.5 Robustness Checks

Several robustness checks were undertaken to evaluate the consistency of the empirical findings. Alternative food security

indicators, including the Household Food Insecurity Access Scale (HFIAS) and Household Dietary Diversity Score (HDDS), were estimated using alternative model specifications. Sensitivity analyses were also performed by replacing the outcome variable definitions and re-estimating the models to determine the stability of the estimated treatment effects.

3.12.6 Model Diagnostics

Several diagnostic tests were conducted to evaluate model adequacy. Variance Inflation Factors (VIFs) were estimated to assess multicollinearity:

$$VIF_i = 1 / (1 - R_i^2) \quad (10)$$

Tolerance values were computed as: $Tolerance_i = 1 / VIF_i$ (11)

Additional diagnostic procedures included:

- ☐ Heteroskedasticity tests (Breusch–Pagan/Cook–Weisberg test)
 - ☐ Model specification tests (link test)
 - ☐ Goodness-of-fit assessment
 - ☐ Influential observation diagnostics (Cook & distance)
 - ☐ Wald tests of independent equations
 - ☐ Likelihood-ratio tests of selection bias
 - ☐ Robust standard errors for all estimated models.
- These diagnostic procedures ensured the validity, robustness, and reliability of the econometric estimates

3.12.7 Ethical Considerations

This study strictly followed generally accepted ethical principles for social science research involving human subjects. All survey participation was voluntary. All interviewees were informed of the study's objectives before interviews, and every participant signed an informed consent form. All collected information was used solely for academic research. Personal identifiers were removed during data processing to protect participant anonymity. All research activities complied with the ethical guidelines of the institution responsible for the study.

4. Results And Discussion

This chapter presents and discusses the empirical findings on the effects of artisanal and small-scale gold mining (ASGM) on agricultural labour productivity and household food security in the Ahafo Region of Ghana. The analysis is organized around the study's research objectives and hypotheses, progressing from descriptive statistics to econometric estimation and discussion of the findings.

The chapter begins by comparing the socioeconomic characteristics of households participating in ASGM with those primarily engaged in agriculture. Descriptive statistics provide an overview of the sample and highlight differences in livelihood outcomes between the two groups. This is followed by a reliability assessment of the agricultural–mining coexistence scale using Cronbach's alpha to evaluate the internal consistency of the measurement instrument.

Subsequently, the chapter presents the econometric results for agricultural labour productivity and household food security after controlling for household, farm, institutional, and environmental characteristics. Model diagnostics and robustness checks are also reported to assess the reliability of the estimated models. Finally, the findings are discussed in relation to the Sustainable Livelihoods Framework, the Agricultural Household Model, and Household Utility Maximization Theory, highlighting the pathways through which

ASGM influences agricultural productivity and household food security. The chapter concludes by relating the findings to existing literature and outlining their implications for sustainable agriculture, responsible mining, and rural development in Ghana.

4.1 Descriptive Characteristics of Mining and Non-Mining Households

This chapter first presents the descriptive statistical results of sampled rural households. It compares two groups of households: those that engage in artisanal and small-scale gold mining (ASGM) and those that rely solely on agriculture. First, descriptive analysis is used to clarify the socioeconomic and livelihood characteristics of the sample, which lays the groundwork for subsequent econometric model estimation. A total of 600 rural households is included in this analysis. Among them, 370 households participate in ASGM, and 230 households are engaged only in agricultural production. The core characteristics of these two groups of households are all summarized in Table 5.1

Table 5.1: Selected Descriptive Statistics of Mining and Non-Mining Households

Variable	Non-ASGM (n =230)	ASGM (n = 370)
Agricultural labour productivity (GHS/labour day)	94.15	82.73
Family labour (days)	186.08	145.58
Land lost to mining (ha)	0.26	0.98
Annual household income (GHS)	22,707.92	36,035.07
Food-secure households	0.58	0.47
Household Food Insecurity Access Scale (HFIAS)	10.93	11.64
Household Dietary Diversity Score (HDDS)	7.36	6.98

Source: Household survey data (2026)

Table 5.1 presents the descriptive statistics comparing households that participated in artisanal and small-scale gold mining (ASGM) with those that relied primarily on agriculture. The results reveal clear differences in livelihood characteristics between the two groups. Households engaged in ASGM recorded a substantially higher average annual household income (GHS 36,035.07) than non-participating households (GHS 22,707.92), reflecting the additional income generated from mining activities.

Despite their higher incomes, ASGM-participating households devoted fewer family labour days to farming (145.58 days) than non-participating households (186.08 days). This pattern suggests that labour was reallocated from agriculture to mining, where expected short-term returns were relatively higher. Mining households also experienced considerably greater farmland loss, averaging 0.98 hectares compared with 0.26 hectares among non-mining households, indicating that mining activities reduced the availability of productive agricultural land.

These differences were reflected in agricultural performance. Households participating in ASGM recorded lower average agricultural labour productivity (GHS 82.73 per labour day) than households engaged solely in farming (GHS 94.15 per labour

day). Similarly, mining households were less likely to be food secure (47%) than non-mining households (58%). They also reported a higher average Household Food Insecurity Access Scale (HFIAS) score (11.64 versus 10.93) and a lower Household Dietary Diversity Score (HDDS) (6.98 versus 7.36), suggesting poorer food access and dietary quality.

Overall, the descriptive evidence highlights the livelihood trade-offs associated with ASGM participation. Although mining provides additional household income, it is also associated with reduced agricultural labour input, greater loss of productive farmland, lower agricultural labour productivity, and poorer household food security. These findings support the Sustainable Livelihoods Framework and the Agricultural Household Model, which suggest that households allocate labour and other resources to activities offering higher expected returns, often at the expense of agricultural production and long-term livelihood sustainability. However, these descriptive comparisons do not establish causality because they do not control differences in household, farm, institutional, and environmental characteristics. Consequently, the subsequent econometric analysis estimates the relationship between ASGM participation, agricultural labour productivity, and household food security while controlling for these factors.

4.2 Reliability Analysis of the Agricultural–Mining Coexistence Scale

Cronbach's alpha coefficient was utilized to assess the internal consistency of the agricultural–mining coexistence scale. Conducting a reliability analysis is a vital initial step, as it verifies whether the specific items measuring a latent construct possess the necessary consistency for use in further statistical evaluations.

Comprising six items, the coexistence scale was developed to assess household views on agricultural–mining coexistence, environmental stewardship, land-use management, institutional support, and community involvement. The evaluation yielded a Cronbach's alpha of 0.91, demonstrating exceptional internal consistency across the items. Because this result surpasses the standard 0.7.

4.3 Agricultural Labour Productivity Results

Agricultural labour productivity was analyzed using a multiple linear regression model estimated with robust standard errors to account for potential heteroskedasticity. The model examined the relationship between participation in artisanal and small-scale gold mining (ASGM) and agricultural labour productivity while controlling for household, farm, institutional, and environmental characteristics. Robust estimation was adopted to improve the reliability of the estimated coefficients and statistical inference.

The estimated model explained approximately 52.8% of the observed variation in agricultural labour productivity, indicating that the explanatory variables jointly account for a substantial proportion of productivity differences among sampled households. The overall model was statistically significant, suggesting that the selected explanatory variables provide a meaningful explanation of agricultural labour productivity in the study area.

Table 5.2. Multiple Linear Regression Estimates of Agricultural Labour Productivity

Variable	Coefficient	Robust Standard Error	p-value
ASGM participation	-10.256***	1.902	<0.001
Land lost to mining (ha)	-6.599***	1.518	<0.001
Education (years)	5.320***	0.319	<0.001

Farm size (ha)	0.107	0.583	0.855
Extension access	12.105***	1.514	<0.001
Credit access	7.475***	1.506	<0.001
Asset index	6.111***	0.740	<0.001
Rainfall shock	-2.993*	1.727	0.083
Household size	-0.146	0.341	0.669

Source: Household survey data (2026)

Note: Robust standard errors are reported. *** indicates statistical significance at the 1% level ($p < 0.01$), providing very strong evidence that the estimated coefficient differs from zero. ** indicates statistical significance at the 5% level ($p < 0.05$), while * indicates statistical significance at the 10% level ($p < 0.10$), suggesting weaker evidence that should be interpreted with caution. Coefficients without asterisks are not statistically significant ($p \geq 0.10$), indicating insufficient evidence of an association with agricultural labour productivity after controlling for other explanatory variables.

The regression results indicate that participation in artisanal and small-scale gold mining (ASGM) was negatively and statistically significantly associated with agricultural labour productivity ($\beta = -10.256$, $**p < 0.01$). Holding all other factors constant, households participating in ASGM recorded agricultural labour productivity that was approximately GHS 10.26 lower per labour day than comparable non-participating households. This finding suggests that engagement in mining reduces the efficiency with which labour is converted into agricultural output, likely because economically active household members divert labour from farming to mining activities, resulting in delays in land preparation, planting, weeding, and harvesting.

Mining-related farmland loss also had a negative and statistically significant effect on agricultural labour productivity ($\beta = -6.599$, $**p < 0.01$). Each additional hectare of farmland lost or degraded through mining was associated with a reduction of approximately GHS 6.60 per labour day in agricultural productivity. This result highlights the importance of productive land as a key component of agricultural output and demonstrates how land conversion and environmental degradation constrain farming efficiency.

Education exerted a positive and highly significant influence on agricultural labour productivity ($\beta = 5.320$, $**p < 0.01$). Each additional year of formal education increased agricultural labour productivity, suggesting that educated farmers are better able to adopt improved technologies, access agricultural information, and manage farm resources efficiently.

Institutional support variables also contributed positively to agricultural performance. Access to agricultural extension services showed the largest positive institutional effect ($\beta = 12.105$, $**p < 0.01$), indicating that farmers receiving extension support achieved significantly higher labour productivity through improved farm management and adoption of recommended agronomic practices. Likewise, access to production credit had a positive and statistically significant effect ($\beta = 7.475$, $**p < 0.01$), reflecting the role of credit in financing improved seed, fertiliser, mechanisation, and hired labour. Household asset ownership also exerted a positive and significant influence ($\beta = 6.111$, $**p < 0.01$), suggesting that wealthier households possess greater capacity to invest in productive agricultural technologies and withstand production risks.

Rainfall shock exhibited a negative but marginally significant relationship with agricultural labour productivity ($\beta = -2.993$, $p < 0.10$), indicating that adverse climatic conditions may reduce farm productivity by disrupting agricultural operations. In contrast, farm size (β

= 0.107, $p = 0.855$) and household size ($\beta = -0.146$, $p = 0.669$) were not statistically significant, implying that land area and household labour availability alone do not necessarily improve agricultural productivity without complementary investments in technology, skills, and institutional support.

Overall, the findings demonstrate that although ASGM provides important income-generating opportunities, it is associated with lower agricultural labour productivity through labour reallocation and farmland degradation. Conversely, education, extension services, access to credit, and household assets significantly enhance agricultural performance. These findings underscore the need for integrated policies that promote responsible mining, protect productive agricultural land, strengthen agricultural support services, and encourage investment in sustainable farming to improve rural livelihoods in mining communities.

4.4 Household Food Security Results

Household food security was examined using a binary logistic regression model to estimate the association between participation in artisanal and small-scale gold mining (ASGM) and the probability of a household being food secure. Because logistic regression coefficients are expressed in log-odds and are not directly interpretable in probability terms, the results are presented as odds ratios (ORs) together with average marginal effects (AMEs). The odds ratios indicate the relative likelihood of household food security associated with each explanatory variable, whereas the average marginal effects quantify the average change in the predicted probability of being food secure resulting from a one-unit change in each explanatory variable, holding all other factors constant. Presenting both measures provides a more intuitive and policy-relevant interpretation of the empirical findings.

Table 5.3. Binary Logistic Regression Estimates of Household Food Security

Variable	Odds Ratio	Average Marginal Effect	p-value
ASGM participation	0.660*	-0.097*	0.066
Land lost to mining (ha)	0.876	-0.031	0.505
Education (years)	1.105***	0.023***	0.008
Farm size (ha)	0.998	-0.000	0.981
Extension access	1.229	0.048	0.241
Credit access	1.235	0.049	0.236
Asset index	1.142	0.031	0.154
Rainfall shock	0.996	-0.001	0.984
Household size	0.852***	-0.037***	<0.001

Note: Odds ratios and average marginal effects are reported. Robust standard errors were used in estimation. *** denotes statistical significance at the 1% level ($p < 0.01$), ** denotes significance at the 5% level ($p < 0.05$), and * denotes significance at the 10% level ($p < 0.10$). Variables without asterisks are not statistically significant ($p \geq 0.10$).

The regression results indicate that participation in artisanal and small-scale gold mining (ASGM) was negatively associated with

household food security. The estimated odds ratio of 0.660 suggests that mining-participating households were less likely to be food secure than non-participating households after controlling for household, farm, institutional, and environmental characteristics. The corresponding average marginal effect (AME = -0.097) indicates that participation in ASGM reduced the predicted probability of household food security by approximately 9.7 percentage points. However, this relationship was statistically significant only at the 10% level ($p = 0.066$) and should therefore be interpreted as suggestive rather than conclusive.

The negative association suggests that higher income from mining does not necessarily translate into improved household food security. Although ASGM provides additional cash income, these gains may be offset by labour reallocation away from agriculture, loss of productive farmland, environmental degradation, and greater dependence on purchased food. Furthermore, mining income is often irregular, whereas household food needs remain continuous throughout the year.

Education has a positive and statistically significant effect on household food security. The odds ratio of 1.105 indicates that each additional year of formal education increased the likelihood of being food secure, while the average marginal effect (AME = 0.023) suggests an increase of approximately 2.3 percentage points in the probability of household food security. This finding implies that education enhances livelihood diversification, adoption of improved agricultural practices, financial management, and informed household nutrition decisions.

Household size was negatively associated with food security. The estimated odds ratio of 0.852 and the average marginal effect (AME = -0.037) indicate that each additional household member reduced the probability of being food secure by approximately 3.7 percentage points. Larger households place greater pressure on available food resources, particularly when agricultural production and household income do not increase proportionately.

Although access to agricultural extension, production credit, and household assets showed positive relationships with household food security, their effects were not statistically significant. Nevertheless, their positive coefficients are consistent with agricultural development theory, suggesting that institutional support, access to finance, and productive assets can strengthen household resilience, improve agricultural investment, and enhance long-term food security.

Similarly, farm size, land lost to mining, and rainfall shocks did not have statistically significant effects after controlling for other explanatory variables, indicating that household food security is influenced by a combination of socioeconomic, institutional, and environmental factors rather than by any single production-related characteristic.

Overall, the findings suggest that while ASGM offers important opportunities for livelihood diversification and income generation, its potential welfare benefits may be constrained by declining agricultural production and increased dependence on food markets. These results underscore the need for integrated policies that promote responsible mining, protect productive agricultural land, strengthen agricultural support services, and enhance household food security in mining communities.

4.5 Robustness Tests and Model Diagnostics

To evaluate the reliability and consistency of the estimated models, several diagnostic and robustness tests were performed. Diagnostic procedures are essential because they assess whether the assumptions underlying the econometric models are satisfied and whether the estimated coefficients provide reliable statistical inference.

Multicollinearity among the explanatory variables was examined using the Variance Inflation Factor (VIF). The results indicated that all VIF values were below the conventional threshold of 10, suggesting that multicollinearity was not a serious concern and that the estimated regression coefficients were stable.

Potential heteroskedasticity in the agricultural labour productivity model was addressed using robust standard errors, thereby improving the efficiency and validity of statistical inference. The robustness of the household food security results was further assessed by estimating alternative

specifications using the Household Food Insecurity Access Scale (HFIAS) and the Household Dietary Diversity Score (HDDS) as

complementary indicators of household food security. The direction and general magnitude of the estimated effects remained broadly consistent across the alternative specifications, indicating that the principal findings were not sensitive to the choice of food security indicator.

Model adequacy was also evaluated through appropriate goodness-of-fit and specification tests. These diagnostic procedures indicated that the estimated models provided an acceptable representation of the observed data and that no serious specification errors were detected. Collectively, the diagnostic and robustness assessments increase confidence in the consistency and reliability of the empirical findings reported in this chapter.

4.6 Discussion of Key Research Findings

The findings indicate that participation in artisanal and small-scale gold mining (ASGM) presents both economic benefits and livelihood challenges for rural households. While mining participation was associated with higher household income, it also corresponded with lower agricultural labour productivity and a reduced likelihood of household food security. This suggests that the financial gains from mining may be offset by labour reallocation, farmland loss, and environmental degradation.

The negative relationship between ASGM participation and agricultural labour productivity supports the Agricultural Household Model, which argues that households allocate labour to activities offering higher expected returns. As more labour shifts from farming to mining, agricultural production becomes less efficient. This finding is consistent with earlier studies that reported declining farm productivity in mining communities (Hilson & Garforth, 2013; Wongnaa et al., 2024).

Similarly, the negative association between mining participation and household food security is consistent with the Sustainable Livelihoods Framework, which emphasizes that improvements in financial capital alone may not compensate for the depletion of natural and human capital. Although mining generates additional income, declining agricultural production and increased dependence on purchased food may weaken household food security (Nunoo et al., 2023).

The positive effects of education, extension services, credit access, and household assets highlight the importance of institutional and human capital in improving agricultural productivity and strengthening household resilience. Overall, the findings underscore the need for integrated policies that promote responsible mining, protect agricultural land, strengthen agricultural support services, and improve institutional coordination to achieve sustainable rural livelihoods.

4.6.1 Policy Implications, Integrated Agricultural–Mining Coexistence Framework, Conclusions, And Recommendations

This chapter synthesizes the key findings of the study and discusses their implications for policy, practice, and future research. Drawing on the empirical evidence, it examines how participation in artisanal and small-scale gold mining (ASGM) influences agricultural labour productivity and household food security in the Ahafo Region of Ghana. The findings indicate that while ASGM provides important income-generating opportunities for rural households, it also contributes to labour reallocation, farmland degradation, and increased vulnerability to food insecurity. These results reinforce the need for integrated policy approaches that simultaneously promote responsible mining, sustainable agricultural production, and environmental protection (Hilson & Maconachie, 2020; World Bank, 2023).

The chapter first discusses the policy implications of the findings, focusing on integrated land-use planning, responsible mining practices, agricultural productivity enhancement, environmental restoration, food security, livelihood diversification, and institutional coordination. It then presents the Integrated Agricultural–Mining Coexistence Framework, which constitutes the principal conceptual contribution of this study. The framework provides a coordinated strategy for strengthening collaboration among key stakeholders, including the Ministry of Food and Agriculture, the Minerals Commission, the Environmental Protection Agency, district assemblies, traditional authorities, and local communities, to promote sustainable rural livelihoods (Arthur-Holmes & Busia, 2020; UNEP, 2023).

Finally, the chapter presents the study's conclusions, recommendations, limitations, and directions for future research. Collectively, these sections demonstrate that effective governance of mining communities requires integrated, evidence-based policies capable of balancing mineral extraction with agricultural sustainability, environmental conservation, household food security, and long-term rural development, while contributing to the achievement of Sustainable Development Goals (SDGs) 1, 2, 8, 12, and 15 (United Nations, 2015; FAO et al., 2023).

4.6.2 Policy Implications

The findings indicate that while artisanal and small-scale gold mining (ASGM) provides important income opportunities through livelihood diversification, it can also reduce agricultural labour productivity and weaken household food security through labour reallocation, farmland degradation, and environmental deterioration. These findings highlight the need for integrated rural development policies that recognise agriculture and mining as interconnected sectors rather than managing them independently (Hilson & Maconachie, 2020; World Bank, 2023).

Government agencies, including the Ministry of Food and Agriculture, the Minerals Commission, the Environmental Protection Agency, and district assemblies, should strengthen integrated land-use planning to protect productive agricultural land while regulating mining activities. Environmental governance should be enhanced through stricter monitoring, land reclamation, and the adoption of mercury-free mining technologies (UNEP, 2023). In addition, greater investment in agricultural extension, education, rural credit, and productive assets is needed to improve agricultural productivity and encourage households to invest mining income in sustainable agricultural enterprises. Strengthening institutional coordination and integrating food security into mining and agricultural policies will further promote resilient rural livelihoods (FAO et al., 2023).

4.6.3 Integrated Agricultural–Mining Coexistence Framework

This study proposes an integrated agricultural–mining coexistence framework that promotes sustainable rural livelihoods by recognizing agriculture and ASGM as complementary livelihood activities. The framework comprises six interrelated components:

1. Integrated land-use planning to protect agricultural land while regulating mining activities.
2. Sustainable agricultural development through extension services, mechanization, irrigation, climate-smart agriculture, and improved technologies.
3. Responsible mining is supported by stronger environmental regulation, mercury-free technologies, and land reclamation.
4. Livelihood diversification encourages productive investment of mining income into agriculture and rural enterprises.
5. Institutional collaboration and community participation involving government agencies, traditional authorities, farmers, miners, and civil society.
6. Continuous monitoring and evaluation of agricultural productivity, environmental quality, food security, and policy effectiveness.

Together, these components provide a practical framework for balancing economic development, environmental sustainability, and household food security while supporting the achievement of Sustainable Development Goals (SDGs) 1, 2, 8, 12, and 15.

5. Conclusion

This study evaluated the effects of artisanal and small-scale gold mining on agricultural labour productivity and household food security in the Ahafo Region of Ghana and developed an Integrated Agricultural–Mining Coexistence Framework to promote sustainable rural livelihoods. The findings demonstrate that although ASGM increases household income, it can also reduce agricultural productivity and weaken household food security through labour reallocation, farmland degradation, and environmental degradation.

The study further shows that education, agricultural extension, access to credit, and household assets significantly enhance agricultural productivity and strengthen household resilience. These findings suggest that sustainable rural development requires integrated policies that simultaneously promote responsible mining, agricultural development, environmental restoration, and institutional coordination. The proposed framework provides a practical policy guide for balancing mineral extraction with agricultural sustainability and improving rural livelihoods in Ghana and other mineral-producing regions.

6. Policy Recommendations

Based on the findings of this study, the following recommendations are proposed.

First, the Government of Ghana should strengthen integrated land-use planning by protecting productive agricultural land and designating approved mining zones to minimize land-use conflicts and promote sustainable agricultural development (World Bank, 2023).

Second, the Environmental Protection Agency, Minerals Commission, and other regulatory institutions should strengthen environmental monitoring, enforce land reclamation, promote mercury-free mining technologies, and regularly monitor heavy metal contamination in agricultural soils and water resources to protect environmental quality and food safety (United Nations Environment Programme [UNEP], 2023).

Third, the Ministry of Food and Agriculture should expand agricultural extension services and improve farmers' access to affordable credit, mechanization, irrigation, and climate-smart agricultural technologies to enhance agricultural productivity and resilience (Ministry of Food and Agriculture [MoFA], 2023; FAO et al., 2023).

Fourth, district assemblies, financial institutions, and development partners should promote livelihood diversification by encouraging households to invest mining income in agriculture, agro-processing, and other sustainable rural enterprises (Hilson & Maconachie, 2020).

Finally, government agencies, traditional authorities, farmers, miners, and civil society organizations should strengthen institutional collaboration through participatory land-use planning and community-based natural resource management to promote the sustainable coexistence of agriculture and mining (Oloya & Ouko, 2026).

7. Study Limitations

This study has several limitations. First, the cross-sectional research design limits the ability to establish causal relationships between ASGM participation and household welfare outcomes. Second, the household survey data may be subject to recall bias despite careful questionnaire design and data collection procedures. Third, environmental impacts were assessed primarily through household responses rather than detailed laboratory analyses or geospatial measurements. Finally, the successful implementation of the proposed Integrated Agricultural–Mining Coexistence Framework will depend on adequate institutional coordination, financial resources, and sustained policy commitment.

8. Future Research Directions

Future research should employ longitudinal or panel data to better examine the long-term effects of ASGM on agricultural

productivity and household food security. Advanced econometric approaches, together with Geographic Information Systems (GIS), remote sensing, soil analysis, water quality assessment, and heavy metal monitoring, would provide a more comprehensive assessment of environmental and food safety impacts.

Comparative studies across mining regions in Ghana and other Sub-Saharan African countries are also recommended to improve the generalizability of findings. Further research should examine gender, youth participation, and climate change and evaluate the effectiveness of the proposed Integrated Agricultural–Mining Coexistence Framework in promoting sustainable rural livelihoods and supporting the achievement of Sustainable Development Goals (SDGs) 1, 2, 8, 12, and 15 (United Nations, 2015).

Reference

- [1] Adjei, E. (2007). Impact of Mining on Livelihoods of Rural Households. A Case Study of Farmers in the Wassa Mining Region, Ghana [Vilnius University]. In *BIBSYS Brage (BIBSYS (Norway))*. <http://hdl.handle.net/11250/265203>
- [2] Adranyi, E., Stringer, L. C., & Altink, H. (2024b). Artisanal and small-scale gold mining governance and cross-sectoral policy coherence in Ghana. *Resources Policy*, 96, 105235–105235. <https://doi.org/10.1016/j.resourpol.2024.105235>
- [3] Adranyi, E., Stringer, L. C., & Altink, H. (2024b). Artisanal and small-scale gold mining governance and cross-sectoral policy coherence in Ghana. *Resources Policy*, 96, 105235–105235. <https://doi.org/10.1016/j.resourpol.2024.105235>
- [4] Agriculture, M. of F. and. (2023). *Agriculture in Ghana: Facts and figures (2022)*. Statistics, Research and Information Directorate.
- [5] Akafari, A. A., Abebe, G. K., Martiniello, G., Chaaban, J., & Chalak, A. (2021). Land appropriation, customary tenure and rural livelihoods: gold mining in Ghana. *Third World Quarterly*, 42(11), 2572–2592. <https://doi.org/10.1080/01436597.2021.1965871>
- [6] Akudugu, M. A., Millar, K. K.-N.-D., & Salifu, M. (2020). Crop Productivity and Implications for Food Security and Rural Livelihood Development in Africa. In *Preprints.org*. <https://doi.org/10.20944/preprints202001.0327.v1>
- [7] Arthur-Holmes, F., & Busia, K. A. (2020). Occupying the Fringes: The Struggles of Women in Artisanal and Small-Scale Gold Mining in Rural Ghana—Evidence from the Prestea–Huni Valley Municipality. *Gender Issues*, 38(2), 156–179. <https://doi.org/10.1007/s12147-020-09261-4>
- [8] Asante, B. O., Ma, W., Prah, S., & Temoso, O. (2024). Farmers' adoption of multiple climate-smart agricultural technologies in Ghana: determinants and impacts on maize yields and net farm income. *Mitigation and Adaptation Strategies for Global Change*, 29(2). <https://doi.org/10.1007/s11027-024-10114-8>
- [9] Batame, M. (2024). Unlocking gender dynamics in food and nutrition security in Ghana: assessing dietary diversity, food security, and crop diversification among cocoa household heads in the Juaboso-Bia cocoa landscape. *BMC Public Health*, 24(1), 985–985. <https://doi.org/10.1186/s12889-024-18204-7>
- [10] Breman, H., Schut, A. G. T., & Seligman, N. G. (2019). *From fed by the world to food security: Accelerating agricultural development in Africa*. <https://doi.org/10.18174/498300>
- [11] Cochran, W. G. (1977). Sampling Techniques. 3rd Edition. Zenodo (CERN European Organization for Nuclear Research). <https://doi.org/10.5281/zenodo.15338807>
- [12] Conteh, F. M., & Maconachie, R. (2021). Artisanal mining, mechanization and human (in) security in Sierra Leone. *The Extractive Industries and Society*, 8(4), 100983–100983. <https://doi.org/10.1016/j.exis.2021.100983>
- [13] Danso-Abbeam, G., Ehiakpor, D. S., & Aidoo, R. (2018). Agricultural extension and its effects on farm productivity and income:

insight from Northern Ghana. *Agriculture & Food Security*, 7(1). <https://doi.org/10.1186/s40066-018-0225-x>

- [14] Danso-Abbeam, G., Ogundeji, A. A., Ehiakpor, D. S., Korir, L., & Djokoto, J. G. (2025). Exploring the linkages between on-farm enterprise diversification and food security in Northern Ghana. *Discover Food*, 5(1). <https://doi.org/10.1007/s44187-025-00352-3>
- [15] Daum, T. (2023). Mechanization and sustainable agri-food system transformation in the Global South. A review. *Agronomy for Sustainable Development*, 43(1). <https://doi.org/10.1007/s13593-023-00868-x>
- [16] Genesquin, G. L. K., Kimseyinga, S., Genesquin, G. L. K., & Kimseyinga, S. (2023). Land tenure security and agricultural production in the rural areas of Burkina Faso. *African Journal of Agricultural Research*, 19(11), 1083–1099. <https://doi.org/10.5897/ajar2023.16520>
- [17] Hilson, G., & McQuilken, J. (2014). Four decades of support for artisanal and small-scale mining in sub-Saharan Africa: A critical review. *The Extractive Industries and Society*, 1(1), 104–118. <https://doi.org/10.1016/j.exis.2014.01.002>
- [18] Hirons, M. (2020). How the Sustainable Development Goals risk undermining efforts to address environmental and social issues in the small-scale mining sector. *Environmental Science & Policy*, 114, 321–328. <https://doi.org/10.1016/j.envsci.2020.08.022>
- [19] Iddrisu, A. M., Gafa, D. W. A., Emini, C. A., & Beaumais, O. (2020). Implications of the Fertilizer-Subsidy Programme on Income Growth, Productivity, and Employment in Ghana. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3601004>
- [20] Inderjit, S. (1986). *Agricultural household models extensions, applications, and policy*.
- [21] Issahaku, H., Mahama, I., & Addy-Morton, R. (2020). Agricultural labour productivity and credit constraints: implications for consumption in rural Ghana. *African Journal of Economic and Management Studies*, 11(2), 331–351. <https://doi.org/10.1108/ajems-03-2019-0124>
- [22] Janvry, A. de, & Sadoulet, É. (2020). Using agriculture for development: Supply- and demand-side approaches. *World Development*, 133, 105003–105003. <https://doi.org/10.1016/j.worlddev.2020.105003>
- [23] Kapari, M., Hlophe-Ginindza, S., Nhamo, L., & Mpandeli, S. (2023). Contribution of smallholder farmers to food security and opportunities for resilient farming systems. *Frontiers in Sustainable Food Systems*, 7. <https://doi.org/10.3389/fsufs.2023.1149854>
- [24] Karlan, D., Osei, R., Osei-Akoto, I., & Udry, C. (2014). Agricultural Decisions after Relaxing Credit and Risk Constraints *. *The Quarterly Journal of Economics*, 129(2), 597–652. <https://doi.org/10.1093/qje/qju002>
- [25] Kugbega, S. K., & Aboagye, P. Y. (2021). Farmer-herder conflicts, tenure insecurity and farmer's investment decisions in Agogo, Ghana. *Agricultural and Food Economics*, 9(1). <https://doi.org/10.1186/s40100-021-00186-4>
- [26] Kuwornu, J. K. M., Suleyman, D. M., & Amegashie, D. P. K. (2013). ANALYSIS OF FOOD SECURITY STATUS OF FARMING HOUSEHOLDS IN THE FOREST BELT OF THE
- [27] CENTRAL REGION OF GHANA. *Russian Journal of Agricultural and Socio-Economic Sciences*, 13(1), 26–42. <https://doi.org/10.18551/rjoas.2013-01.04>
- [28] Lahiri-Dutt, K. (2018). Between the Plough and the Pick: Informal, artisanal and small-scale mining in the contemporary world. In *ANU Press eBooks*. ANU Press. <https://doi.org/10.22459/bpp.03.2018>
- [29] Li, M., Li, J., Haq, S. ul, & Nadeem, M. (2024). Agriculture land use transformation: A threat to sustainable food production systems, rural food security, and farmer well-being? *PLoS ONE*,

- [30] 19(1). <https://doi.org/10.1371/journal.pone.0296332>
- [31] Mabe, F. N., Issifu, S., & Wongnaa, C. A. (2023). Farmers' coping strategies to artisanal small-scale mining activities: welfare improvement or deterioration in Asutifi North District of Ghana? *Journal of Economics and Development*, 26(1), 50–66. <https://doi.org/10.1108/jed-02-2023-0029>
- [32] Nordhagen, S., Fofana, M. L., Barry, A. O., Diallo, S., Songbono, J. L., Stokes-Walters, R., Zhang, L. X., Klemm, R., & Winch, P. J. (2021). Between the city and the farm: food environments in artisanal mining communities in Upper Guinea. *Public Health Nutrition*, 25(2), 1–13. <https://doi.org/10.1017/s1368980021002020>
- [33] Nti, T., Chen, Y., Quayson, B. P., & Agyei, F. Y. (2020). Illegal Mining and Sustainability Performance: Evidence from Ashanti Region, Ghana. *International Journal of Scientific Research and Management (IJSRM)*, 8(3), 1661–1676. <https://doi.org/10.18535/ijssrm/v8i03.em03>
- [34] Ofosu, G., Dittmann, A., Sarpong, D., & Botchie, D. (2020). Socio-economic and environmental implications of Artisanal and Small-scale Mining (ASM) on agriculture and livelihoods. *Environmental Science & Policy*, 106, 210–220. <https://doi.org/10.1016/j.envsci.2020.02.005>
- [35] Okoh, G., & Hilson, G. (2011). POVERTY AND LIVELIHOOD DIVERSIFICATION: EXPLORING THE LINKAGES BETWEEN SMALLHOLDER FARMING AND ARTISANAL MINING IN RURAL GHANA. *Journal of International Development*, 23(8), 1100–1114. <https://doi.org/10.1002/jid.1834>
- [36] Oloya, O. J. O., & Ouko, V. O. (2026). From Aid Dependency to Agricultural Resilience: Evaluating the Effectiveness of Extension Services, Cooperatives, and Policy Institutions in Post- Conflict South Sudan. *International Journal of Innovative Science and Research Technology (IJISRT)*, 3653–3653. <https://doi.org/10.38124/ijisrt/26jan1279>
- [37] Opoku, C. B. (2020). Vulnerability and Responses of Farm Households to Socio-economic Shocks: Evidence from Tarkwa-Nsueam Municipality of Ghana. *International Journal of Innovative Research and Development*, 9(4). <https://doi.org/10.24940/ijird/2020/v9/i4/apr20014>
- [38] Sabogu, A., Nassè, T. B., & Osumanu, I. K. (2020). LAND CONFLICTS AND FOOD SECURITY IN AFRICA: AN EVIDENCE FROM DORIMON IN GHANA. *International Journal of Management & Entrepreneurship Research*, 2(2), 74–96. <https://doi.org/10.51594/ijmer.v2i2.126>
- [39] Service, G. S. (2021). *2021 Population and Housing Census: General Report Volume 3A*. Ghana Statistical Service.
- [40] Setsoafia, E. D., Ma, W., & Renwick, A. (2022). Effects of sustainable agricultural practices on farm income and food security in northern Ghana. *Agricultural and Food Economics*, 10(1). <https://doi.org/10.1186/s40100-022-00216-9>
- [41] Tannor, S. J., Kelboro, G., Greve, K., Borgemeister, C., & Tischbein, B. (2022). Climate variability and extractivism exposures: Understanding household perspectives on livelihood resilience in rural Ghana. *The Extractive Industries and Society*, 12, 101164–101164. <https://doi.org/10.1016/j.exis.2022.101164>
- [42] The State of Food Security and Nutrition in the World 2023. (2023). In *FAO; IFAD; UNICEF; WFP; WHO; eBooks*. <https://doi.org/10.4060/cc3017en>
- [43] Thiombiano, B. A., & Le, Q. B. (2023). Agricultural livelihood systems typology for coping with diversity in smallholder farming system research: A demonstrative case in South-western Burkina Faso. *African Journal of Agricultural Research*, 19(1), 8–19. <https://doi.org/10.5897/ajar2022.16211>

- [47] Wongnaa, C. A., Tawiah, F. O., Ogunleye, A., Prah, S., Ampomah, M. A., Akweley, G. A., & Gyekye, A. (2026). Impact of adoption of integrated soil fertility management on household welfare: evidence from tomato farmers in Ghana. *Agricultural and Resource Economics Review*, 1–28. <https://doi.org/10.1017/age.2025.10014>
- [48] Yiridomoh, G. Y. (2021). “Illegal” Gold Mining Operations in Ghana: Implication for Climate-Smart Agriculture in Northwestern Ghana. *Frontiers in Sustainable Food Systems*, 5. <https://doi.org/10.3389/fsufs.2021.745317>