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The interface of environment and human wellbeing: Exploring the impacts of gold mining on food security in Ghana

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ABSTRACT

This paper explores the intricate connections between the environment and human wellbeing, focusing on the interplay between mining, agriculture, and food security. Despite a vast body of literature examining the impact of mining on agriculture and subsequent implications for food security, there remains a notable gap in comprehensive studies evaluating these effects across all dimensions of food security: availability, access, utilisation, and stability. Particularly lacking are assessments regarding the food diversity of women of reproductive age in mining areas. Drawing from a survey involving 460 participants, alongside 85 face-to-face interviews, the study extensively investigates the complex relationship between small-scale mining, smallholder farming, and food security. It elucidates both the positive and negative aspects of this nexus, emphasising its influence on economic activities, market dynamics, employment opportunities, and income generation. However, the study also sheds light on adverse consequences, such as land dispossession, water pollution, and increased competition for labour. Utilising the Food Insecurity Experience Scale (FIES) survey, the research reveals alarming levels of food insecurity, with 50.1% experiencing moderate food insecurity and 13.3% facing severe food insecurity, surpassing the national average. This highlights a significant portion of the population enduring at least a day without adequate food, particularly impacting women with low dietary diversity scores. These findings underscore the intricate linkages between mining, smallholder farming, and individual well-being, concluding that while mining may stimulate local economies, it substantially undermines food security across its fundamental dimensions. Consequently, mining emerges as a substantial contributor to food insecurity and compromises the well-being of numerous individuals, disproportionately affecting the most vulnerable groups, especially women.

1. Introduction

In sub-Saharan Africa, agriculture has long served as a fundamental pillar of numerous economies, persisting as a crucial contributor to food security, GDP, employment, and trade. Highlighted by Giller (2020) and the FAO; IFAD; UNICEF; WFP; WHO, this sector plays a pivotal role in meeting the sustainable development goals 1 – zero poverty and 2-zero hunger (UN DESA, 2016). Despite its decline as the primary employer, the agricultural sector remains vital for most impoverished and food-insecure populations residing in rural areas (Castañeda et al., 2018). However, efforts to bolster agricultural development have struggled to yield transformative policies directly supporting smallholder farmers (Giller, 2020), leading many to seek alternative livelihoods to supplement their incomes. Remarkably, scholars have observed a trend among smallholder farmers diversifying into small-scale mining, viewing it as a supplementary source of income (Hilson and Garforth, 2012, 2013; Bryceson et al., 2014; Hilson, 2016a, 2016b; Afriyie et al., 2016; Mkodzongi and Spiegel, 2019; Hilson and Maconachie, 2020). This shift has been prompted by contracting global markets for agricultural exports, triggering processes of de-agrarianisation, and prompting rural households to explore alternative revenue sources (Bryceson et al., 2014). Hilson and Garforth (2012) argued that despite the diversification of smallholder farmers, small-scale mining does not supplant smallholder farming entirely, contrary to the implications of the term 'de-agrarianisation.' Instead, it exists alongside subsistence farming practices.

Extensive literature has explored the interplay between small-scale mining and smallholder farming in sub-Saharan Africa, presenting

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varying perspectives. Some assert symbiotic relationships between these activities (Kamlongera, 2011; Maconachie, 2011; Okoh and Hilson, 2011; Hilson and Garforth, 2012, 2013; Hilson, 2016a; Chigumira, 2018; Mkodzongi and Spiegel, 2019),while others depict competitive dynamics, particularly in countries like Ghana (African Center for Economic Transformation, 2017; Snapir et al., 2017; Hausermann et al., 2018; Ferring and Hausermann, 2019; Obodai et al., 2023). These relationships are often linked to socio-economic and environmental impacts, with positive socio-economic effects considered complementary and environmental aspects associated with negative impacts (Ofosu et al., 2020; Obodai et al., 2023, 2024).

While small-scale mining can augment incomes and secure land tenure for farmers in various sub-Saharan African nations (Fisher et al., 2009; Hilson and Garforth, 2013; Hilson, 2016a, b; Chigumira, 2018; Pokorny et al., 2019; Mkodzongi and Spiegel, 2019; Baffour-Kyei et al., 2021; Huntington and Marple-Cantrell, 2022; Adranyi et al., 2023) concerns about environmental costs, such as mercury pollution affecting agricultural activities, have been raised (Amonoo-Neizer et al., 1996; Golow and Adzei, 2002; Golow and Mingle, 2003; Clifford, 2017; Gyamfi et al., 2021). Additionally, the degradation of agricultural lands due to mining activities and subsequent loss of food production have been documented (Snapir et al., 2017; Hausermann et al., 2018; Ferring and Hausermann, 2019; Obodai et al., 2019, 2024; Huntington and Marple-Cantrell, 2022).

Despite a wealth of literature exploring the relationship between mining and agriculture and its implications for food security,[1] a significant gap remains in comprehensive studies evaluating these effects across all dimensions of food security. Particularly, there's a lack of assessments concerning the food diversity of women of reproductive age in mining areas. Except for the recent study by Nunoo et al. (2023), a significant portion of the literature regarding the implications of the interplay between small-scale mining and agriculture on food security has been indirect, often focusing on singular aspects of food security, particularly the dimension of food availability, relying on secondary data. For instance, Danyo and Osei-Bonsu (2016) utilised secondary data on agricultural productivity, consumer price indices of food commodities, and national food import statistics. Their findings revealed that small-scale gold mining, causing land degradation, water contamination, air pollution, and a shift in labour from food crop farming to mining, significantly impacted low food production, escalated food prices, and heightened living costs, especially in illegal small-scale mining prone regions of Ghana. Huaserman et al. (2018) highlighted how mining operations substantially disrupted farming activities, leading to local food scarcity and acute food insecurity, largely attributed to land degradation or displacement resulting from small-scale mining. Adator et al. (2023) suggested that an increase in people opting for small-scale mining as a livelihood over agriculture could potentially cause food security challenges within affected communities. Similarly, Barenblitt et al. (2021) argued that land degradation and deforestation due to small-scale mining significantly impact food production in southeastern Ghana. Nunoo et al. (2023) conducted a recent study analysing the impact of using cocoa farmlands for small-scale mining on household-specific food security indicators, including access, utilisation, and stability. Their conclusions suggested that farmers who repurpose their farmlands for small-scale mining experience increased household food insecurity and dietary diversity in the short term, while losing their ability to effectively manage food insecurity.

To address the identified gap, this study aims to comprehensively evaluate the implications of the relationship between small-scale mining and agriculture on all four dimensions of food security. The study endeavours to provide a nuanced understanding by examining a representative sample of various occupational classes, including farmers and miners. It aims to explore the relationship between mining and agriculture in relation to food security and assess its implications on the four dimensions of food security. The subsequent sections will delve into an elaborate discussion of the concept of food security, the research context and methodology, followed by the presentation and discussion of results, concluding with a summary of the findings.

2. The concept of food security: current issues and theoretical perspectives

In global development discussions of the 1960s and 1970s, the term "food security" emerged as a multidimensional concept (Anderson and Cook, 1999; Braun et al., 1992; FAO, 2006). It denotes the state where all individuals possess both physical and economic access to sufficient, safe, and nutritious food that aligns with their dietary needs and preferences for maintaining an active and healthy lifestyle (World Food Summit, 1996). The Food and Agriculture Organisation (FAO, 2006) defines food security across four dimensions: food availability, access, utilisation, and stability. Availability pertains to the presence of adequate and suitable quality food, either produced domestically or acquired through imports (including food aid). Access encompasses the ability of an individual to obtain food that meets their dietary requirements through necessary resources or entitlements. Utilisation involves obtaining optimal nutrients from food, influenced by non-food factors like safe drinking water, sanitation, healthcare, feeding habits, food preparation, diet variety, and intra-household food distribution, contributing to an individual's nutritional status. Stability relates to the consistent access to food. Even if someone has an adequate diet today, if they frequently face food shortages, their nutritional status could be at risk, marking them as food insecure. Recently, the High-Level Panel of Experts (HLPE) on Food Security and Nutrition proposed incorporating agency and sustainability as additional dimensions into the existing model of food security (HLPE, 2020; Clapp et al., 2022). Agency signifies the capacity of individuals or groups to make decisions concerning food consumption, production, processing, distribution within food systems, and participation in shaping food system policies and governance. Sustainability refers to the long-term ability of food systems to provide food security and nutrition without compromising future generations' economic, social, and environmental foundations (HLPE, 2020).

Food security remains a pivotal concern in global development acknowledged by policymakers and experts. Among the seventeen Sustainable Development Goals (SDGs), Goal 2 is dedicated to eradicating hunger, ensuring food security, and promoting sustainable agriculture. Despite substantial national, regional, and global policies and initiatives, the target remains distant. The assessment on global food security by FAO; IFAD; UNICEF; WFP; WHO shows that the world is not progressing adequately towards achieving the Zero Hunger objective outlined in SDG 2.1 by 2030. Compounding this challenge are the repercussions of COVID-19 and the Ukraine conflict, amplifying global food insecurity (Akpaki et al., 2020; Loopstra, 2020; Niles et al., 2020; The Lancet Global Health, 2020; Dabone et al., 2021; Gundersen et al., 2021). The total count of hungry individuals is on the rise, with Africa considerably lagging in meeting the 2030 Zero Hunger target (FAO; IFAD; UNICEF; WFP; WHO). According to estimates, between 702 and 828 million people (8.9%–10.5% of the world's population) were afflicted by hunger in 2021, with Africa accounting for the largest share at 278 million (20.2%). Moreover, nearly all subregions in Africa are witnessing an uptick in food insecurity,[2] with severe food insecurity affecting 23.4% of the continent's populace, while almost 58%

[1] The concept of food security is elaborately discussed in the next section.

[2] *The Food Insecurity Experience Scale (FIES) is a survey that is used to identify severe food insecurity. The FIES survey consists of eight questions that have been carefully selected, tested, and shown to be successful at assessing the degree of respondents' food insecurity across a range of cultural, linguistic, and developmental contexts. The following sections of this chapter explore this measure of food security in detail, while Chapter 3 discusses its measurement.*

Table 1
Major Approaches and examples of indicators adopted in the assessment of food security at different levels.

Approaches	Dimension of food security	Assessment Indicators	Scale of measurement	Institution
Food availability /Malthusian Theory	Food Availability	Undernourishment - Average nutrition gap and the distribution gap - Global Hunger Index	Global & National	FAO, USDA IFPRI
Income Based	Food Availability	Household Income & Expenditure surveys	Global & National	FAO, USDA
Basic Needs/Food First	Food Access & Utilisation	- Household Dietary Diversity Score (HDDS) - Food Consumption Score (FCS)	Individual & Household	USAID WFP
Entitlement	Food Availability and Access	Multi-level indicators	Individual & Household	USAID, World Bank, UNICEF
Sustainable Livelihood	Availability, Access, Utilisation & Stability	Comprehensive Food Security & Vulnerability Analysis	Household	WFP
Capability	Availability, Access, Utilisation & Stability	Multi-level indicators	Household & Individual	
Experience-Based Food Insecurity Measurement Scale	Food Access	Food Insecurity Experience Scale (FIES) US Household Food Security Survey Module Hunger Scale Household Food Insecurity Access Scale Coping Strategy Index (CSI)	Household	FAO ERA, USDA FANTA, USAID FANTA, USAID CARE & WFP

Source: Authors' Construct with information from Hadley and Crooks 2012; Carletto et al., 2013; Burchi and De Muro 2016; FAO, 2017; Carfiero et al., 2018, Marta, 2013, Swindale and Bilinsky, 2006, Coates et al., 2007.

experience moderate or severe[3] food insecurity in 2021.

The concept of food security has been approached from various theoretical standpoints. Sen (1983) delineated two primary approaches, the 'nature-focused' and 'society-focused,' highlighting the divergent paths—one rooted in natural sciences and engineering, the other in social aspects like politics and economics. While Sen's findings weren't specific to food security, they have significantly influenced the array of methodologies employed in its assessment.

Table 1 presents the major approaches that have guided food security discussions over time, encompassing Malthusian views (food availability), income-based, basic needs, entitlement, sustainable livelihoods, human development and capability, place-based, and experience-based approaches. These methodologies have informed analyses of food security across temporal and investigative dimensions (Marta, 2013; Burchi and De Muro, 2016). Maxwell (1996) identified three fundamental paradigm shifts in food security thinking—moving from global to individual perspectives, transitioning from a food-centric to a livelihood perspective, and a shift from objective indicators to subjective perceptions. These alterations mirror the evolving theoretical viewpoints on food security and the evaluative criteria used. Consequently, this paper delves into food insecurity using experiential-based models, particularly the Food Insecurity Experience Scale (FIES), to underscore the agency aspect of food security (Clapp et al., 2022).

3. Materials and methods

3.1. Research context

Ghana, recognised as the largest gold producer in Africa and the sixth globally, was chosen as a focal point for this case study (Reuters, 2023; World Gold Council, 2023).The nation's gold mining industry, one of the oldest on the African continent, mirrors the operations of other significant global gold producers. Over the past two decades, the small-scale gold mining sector in Ghana has experienced substantial growth, largely influenced by global market dynamics, including increased gold prices (Hausermann et al., 2018; Barenblitt et al., 2021). The case study for this research focused on the former Amansie West District (AWD), which was subsequently divided into Amansie West and South in 2018. AWD stands out as a predominantly agrarian region that concurrently experiences significant small-scale gold mining activity (Ghana Statistical Service, 2014). This district was specifically chosen due to its prevalence of small-scale mining operations and its proximity to natural resources such as forest reserves and river systems. Geographically, the AWD is situated between Longitude 6.05° and 6.35° West and Latitude 1.40° and 2.05° North, covering a land area of 1230km2, constituting 5% of the Ashanti Region's total land area. The district falls within a wet semi-arid climate exhibiting a double maxima rainfall pattern, occurring from March to July as the major season and from September to November as the minor season. Its vegetation predominantly comprises rain forest with wet semi-deciduous features, creating highly fertile grounds that sustain agriculture as the primary means of subsistence across the district. The AWD experiences annual rainfall averaging between 855 mm and 1500 mm. During December to March, it commonly encounters dry weather characterised by high temperatures and early morning fog or moisture coupled with cold conditions. The area sustains consistently elevated temperatures, averaging approximately 27 °C every month. While humidity levels reach their peak during the rainy season, there is a significant drop from December to February (MoFA Ghana, 2024). The district encompasses four significant forest reserves: Oda River, Apanprama, Jemira, and Gyeni River. As of 2020, the district's population was estimated at 174,218, displaying an average growth rate of 2.6.

3.2. Research Ethics

The study received a favourable opinion by Human Research Ethics Committee (HREC) of the Open University (Ref: HREC/3390/XXXX. Study participants provided written or oral informed consent to participate in the study.

3.3. Datasets

3.3.1. The survey

The data collection for this study took place in rural Ghana between March and November 2020. Employing a multi-stage mixed method sampling approach (Tashakkori and Teddlie, 2003), survey participants were recruited. Initially, households were identified as the primary sampling unit, forming enumeration zones. The five councils within the Amansie South district were grouped into clusters, forming the basis for selecting locations and participants. This was primarily due to the prevalence of small-scale mining activities within the district. A

[3] *Severe food insecurity entails a drop in food consumption to the point of hunger. Moderate food insecurity is defined as an inability to obtain healthy and sufficient food on a consistent basis, even if this does not always result in hunger.*

stratified sampling method was used to randomly pick one community from each stratum. Employing a probability technique for each mining community ensured comprehensive coverage of the sub-district population, enhancing statistical accuracy. Mem, notable for its absence of small-scale mining operations during the study, was among the selected localities. Hence, six communities were designated as enumeration areas (EAs). Individuals aged 18 and above from randomly chosen households within each community constituted the units of analysis for the survey. A total sample size (n) of 460 study participants was evenly distributed across the sampled locations. The minimum sample size was calculated using SurveyMonkey Online's sample size calculator, applying the mathematical formula described in equation (1).

$$n = \frac{\frac{z^2 \times p\ (1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)} \quad \text{(Equation 1)}$$

where n is the sample size, N is the population size, e is the margin of error, 'p' is the sample proportion and 'z' is the z-score (number of standard deviations a given proportion is away from the mean).

In 2020, a population of 81,512 required a minimum representative sample size of 385 individuals with a 5% margin of error. However, to account for a potential non-response rate of 20% or less, a total sample size of 460 participants was utilised. This sample was proportionally allocated across various localities based on their estimated population projections.

The survey was conducted using the SurveySolutions application developed by the World Bank (The World Bank, 2018). The questionnaire was designed using the Questionnaire Designer, an online tool. A thorough assessment of the questionnaire was conducted online to identify and address any potential issues. Subsequently, the questionnaire was uploaded to a cloud-based server[4] and distributed to four proficient interviewers. Each interviewer was provided with randomly generated usernames and passwords, accessing the questionnaire through the Survey Solutions Interviewer program version 20.07.2 on their Android tablets. One of the interviewers acted as the field supervisor, while the lead researcher served as the data controller. The role of the supervisor involved managing the workload of interviewers and ensuring the quality of collected interviews. A hierarchical three-tier authority structure was implemented to allocate, review, and approve the collected data, ensuring its high quality. Initially, the lead researcher distributed questionnaires to the supervisor, who then disseminated them to the interviewers. At the end of each day's data collection, interviewers synchronised their datasets, which underwent thorough cross-checking and either approval or revision as necessary. Upon the approval of the supervisor, the data was forwarded to the lead researcher for further inspection and final approval, facilitated by the SurveySolutions application, ensuring the acquisition of secure and high-quality datasets. Additionally, following the daily data synchronisation, opportunities were provided for sharing observations or addressing any encountered challenges. Post-fieldwork, the lead researcher exported the approved datasets in user-friendly formats such as SPSS and CSV, storing them securely on Open University Servers for subsequent data analysis.

3.3.2. Interviews

As a complement to the survey, interviews with key informants were conducted by the research team. The selection of interview participants was a deliberate process, employing purposive and referral/snowball sampling techniques (Bryman, 2016). A total of 85 individuals involved in various capacities were engaged for this investigative phase. Selection criteria at both local and national levels centred on participants' hands-on experience, comprehensive understanding, and direct or indirect involvement in mining or agricultural activities. At the national level, meticulous consideration was given to recruiting key informants from governmental bodies such as the Ministry of Food and Agriculture, the Ministry of Land and Natural Resources, and other regulatory organisations possessing relevant expertise. Additionally, district officials well-versed in mining and farming operations were specifically enlisted to corroborate findings garnered from the survey at the local level. This cohort included District Assembly officials and members representing agricultural and mining associations. Moreover, individuals actively engaged in mining and smallholder farming were purposefully included

Table 2
The food insecurity experience scale survey Module by FAO.

No	Label	Questions in English	Twi Translated Questions	Response	
1	WORRIED	During the last 12 Months, was there a time when you were worried you would not have enough food to eat because of a lack of money or other resources?	Enam se wonni sika ne akadee bi nti no, na wodwene ho paa se wonnya aduane dodoo a wope nni	No	Yes
2	HEALTHY	Still thinking about the last 12 Months, was there a time when you were unable to eat healthy and nutritious food because of a lack of money or other resources?	Wo koso dwini bosome dumienu yi ntam yi a, mmere bi si ye a woandidi yiye efiri se na sika anaa mmoaye foforo bi nni ho?	No	Yes
3	FEWFOODS	Was there a time when you ate only a few kinds of foods because of a lack of money or other resources?	Enam se wonni sika ne akadee bi nti no, na aduane potee, kakra bi ena na wodie	No	Yes
4	SKIPPED	Was there a time when you had to skip a meal because there was not enough money or other resources to get food?	Enam se wonni sika ne akadee bi nti no, na wonntumi nnidi bere ano-bere ano	No	Yes
5	ATELESS	Still thinking about the last 12 Months, was there a time when you ate less than you thought you should because of a lack of money or other resources?	Wo koso dwini bosome dumienu yi ntam yi a, mmere bi si ye a wodidi kitiwa bi efiri se na sika anaa mmoaye foforo bi nni ho?	No	Yes
6	RANOUT	Was there a time when your household ran out of food because of a lack of money or other resources?	Enam se wonni sika ne akadee bi nti no, eto da a aduane a wone wo fiefoo benya adie no tumi sa	No	Yes
7	HUNGRY	Was there a time when you were hungry but did not eat because there was not enough money or other resources for food?	Enam se wonni sika ne akadee bi nti no, eto da a ekom de wo dee, nanse wonnidi	No	Yes
8	WHOLEDAY	During the last 12 months, was there a time when you went without eating for a whole day because of a lack of money or other resources?	Wo bosome ahorow dumienu yi etam yi no, mmere be wo hos a Enam se wonni sika ne akadee bi nti no, eto da a, wobuada?	No	Yes

[4] *The World Bank provided independent access to its cloud-based server during the time of the investigation. Later, this offer was limited to studies conducted by the World Bank or affiliated organisations. As a result, it came in handy because I didn't have to set up my own cloud-based server.*

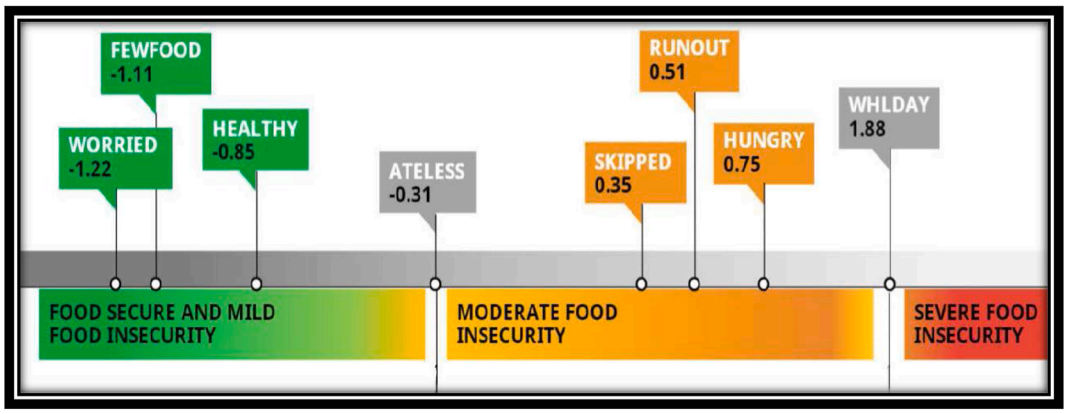


Fig. 1. Global standard threshold.
Source: FAO (2018).

to address the research questions. This diverse selection facilitated a multi-faceted reconstruction of knowledge and fostered a collaborative comprehension of the subject matter.

3.4. Indicators for measuring food insecurity

The study examined the four core dimensions of food security: food availability, accessibility, utilisation, and stability. To assess food availability, the study scrutinised local-level data on food crop output obtained from the Ministry of Food and Agriculture (MoFA) of Ghana via the Statistics, Research, and Information Directorate (SRID) within the ministry. Additionally, national-level statistics regarding food crop output sourced from FAOSTAT, a data platform by the FAO, were incorporated into the analysis. Preceding the analysis, the researchers ensured the reliability and comprehensiveness of the datasets, reformatting them into user-friendly structures using Microsoft Excel. These datasets were examined alongside interview transcripts derived from selected key stakeholders, as elaborated in the preceding section.

In assessing food access, the study utilised the Food Insecurity Experiential Scale (FIES) due to its ease of administration, rapidity, cost-effectiveness, and established theoretical foundations supported by extensive research (Leroy et al., 2015; Cafiero et al., 2018). Comprising eight specific questions with affirmative or negative response options (refer to Table 2), the FIES reliably assess the prevalence of food insecurity by focusing on the access dimension of food security (Cafiero et al., 2018). To adapt the scale for the study participants, predominantly *Akan* and *Twi*[5] speakers, the translated Twi version of the scale (See Table 2), previously validated and aligned with local contexts was used. This measurement tool is rooted in subjective beliefs and experiences of individuals regarding food security. It shares comparability with other personal-experience-based food security measures, such as the Household Food Insecurity Access Scale (HFIAS) employed in various countries like the United States, Brazil, Canada, and Mexico (Coates et al., 2007; Maxwell and Caldwell, 2008; Maxwell et al., 2013). The selection of the FIES as the primary measure for determining the prevalence of moderate or severe food insecurity stemmed from thorough consultations with diverse stakeholders.

Aligned with the SDG Indicator Framework for Target 2.1 of the Sustainable Development Goal, specifically indicator [2.2.1], the FIES emerged as one of the two crucial indicators to globally monitor food security progress (Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) 2017; Cafiero et al., 2018). Each item in the FIES scale delineates degrees of food insecurity, spanning from mild to severe (questions 1 to 8), with a 12-month reference period used to capture seasonal fluctuations in food security, in line with SDG monitoring practices. The FIES employs two thresholds to classify food insecurity severity (Fig. 1). The first threshold, indicated by the severity level of the FIES item 'ATELESS' (eating "less than you should"), distinguishes between 'food secure or mildly food insecure' and 'moderately food insecure' categories. The second criterion, marked by the severity level of the FIES item 'WHLDAY' ("went an entire day without eating"), separates the 'moderately food insecure' from the 'severely food insecure' categories (Cafiero et al., 2018; FAO, 2018).

Several studies have highlighted a positive correlation between an individual's dietary diversity and the sufficiency of micronutrients, an

Table 3
Food groups.

No.	Food Categories	Description/Examples
1	Food made from grains	Porridge, bread, rice, pasta/noodles, or other foods made from grains. Eg. Banku,
2	White roots, tubers, and plantains	White potatoes, white yam, white cassava, or cocoyam, other foods made from roots, tubers, or plantain
3	Pulses (beans, peas, and lentils)	Mature beans or peas (fresh or dried seed), lentils or bean/pea products, including hummus, tofu, and tempeh
4	Nuts and seeds	Any tree nut, groundnut/peanut or certain seeds, or nut/seed "butters" or pastes
5	Milk and milk products	Milk, cheese, yoghurt, or other milk products but NOT including butter, ice cream, cream, or sour cream
6	Organ meat	Liver, kidney, heart or other organ meats or blood-based foods
7	Meat and Poultry	Beef, pork, lamb, goat, rabbit, game, chicken, duck, or other birds
8	Fish and seafood	Fresh or dried fish, shellfish, or seafood
9	Eggs	Eggs from poultry e.g., chicken, duck, guinea fowl or any other egg
10	Dark green leafy vegetables	Dark green leafy vegetables, including kontomire, Alefu, gboma, bitter leaf, cassava leaf, Ayoyo etc
11	Vitamin A rich vegetables, roots, and tubers	Carrots, sweet potatoes
12	Vitamin A rich fruits	Ripe mango, ripe papaya, dried peach
13	Other vegetables	Other vegetables e.g., tomato, onion, eggplant
14	Other fruits	Other fruits
14	Oils and fats	Oil, fats, or butter added to food or used for cooking
15	Sweets	Sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies, and cakes
16	Spices, condiments, beverages	Spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages
17	Did you eat anything (meal or snack) OUTSIDE the home yesterday?	

[5] Akan and Twi are local Ghanaian languages.

Table 4
Aggregation of food groups from the questionnaire to create MDD-W Indicator.

Food Group	Aggregated 10 food groups
Foods made from grains + White roots and tubers and plantains	Grains, Roots, and Tubers
Pulses (beans, peas, and lentils)	Pulses
Nuts and seeds	Nuts and Seeds
Milk and milk products	Diary
Organ meat + Meat and poultry + Fish and seafood	Meat, Poultry and Fish
Eggs	Eggs
Dark green leafy vegetables	Dark green leafy vegetables
Vitamin A-rich vegetables, roots, and tubers + Vitamin A-rich fruits	Other Vitamin A-rich fruits and vegetables
Other Vegetables	Other Vegetables
Other Fruits	Other Fruits

Source: Adapted from (FAO and FHI, 2016).

essential element in assessing diet quality (Kennedy et al., 2007, 2010; Arimond et al., 2010; Mallard et al., 2016; Zhao et al., 2017). Consequently, in evaluating the utilisation aspect of food security, the study focused on dietary diversity (DD) as an indicator of the nutritional adequacy of individual diets (Kennedy et al., 2010). The research employed the qualitative open 24-h recall technique to assess DD, involving the recollection of all food and beverages consumed in the preceding day and night, including inquiries about essential ingredients in mixed dishes (FAO and FHI, 2016). This method was chosen due to its user-friendly nature for both enumerators and respondents, structured probing capabilities, and its potential for enhanced food categorisation, among other benefits (FAO and FHI, 2016). Additionally, the use of a 24-h recall aligns with prior research on dietary diversity (refer to (Arimond et al., 2010; Koppmair et al., 2017; Caswell et al., 2018), aiding participants in recalling details accurately and reducing the likelihood of errors (FAO, 2010). Throughout the data collection process, responses to inquiries about dietary diversity were documented in a tabulated grid format, contributing to the creation of a predefined food category table (See Table 3) based on the confirmation or negation of each food group's consumption.

Dietary diversity assessments among women of reproductive age (WRA) hold significance due to their heightened nutritional needs and sensitivity to micronutrients. Addressing the higher prevalence of food insecurity among women compared to men, the Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) serves as an indicator to comprehend their dietary diversity. This binary indicator, derived from the consumption of at least five out of ten designated food categories by women aged 15–49 the preceding day or night, is indicative of their micronutrient adequacy (Martin-Prevel et al., 2015). The study, in line with MDD-W criteria, grouped the collected food categories from the survey into ten distinct food groups, as outlined in Table 4. Subsequently, the mean dietary diversity score was calculated within a theoretical range of 0–10. Following this, the study determined the dichotomised classification of adequate and inadequate dietary diversity. In this classification, dietary diversity was deemed inadequate if fewer than five food groups were consumed by participants on the previous day.

3.5. Data analysis and presentation

3.5.1. Statistical analysis

Food access was evaluated through the FIES-SM analytical approach, employing Item Response Theory (IRT) as the analytical framework. The Rasch model, a one-parameter logistic measurement model, was used to quantify the prevalence of food insecurity. This model assumes the alignment of respondent and item positions on a one-dimensional scale and postulates that the log-odds of a respondent affirming an item is a linear function of the disparity between the severity of the food insecurity experienced by the respondent and the item's severity

Table 5
Personal and Socio-economic characteristics of the sample.

Variables		Total number of respondents	% Or Mean (SD)
Age (years)		460	36 ± 15.7
Gender	Men	227	49.4
	Women	233	50.6
Marital Status	Unmarried	115	24.9
	Married	345	75.1
Migration Status	Natives	324	70.5
	Migrants	136	29.5
Employment Status	Employed	389	84.6
	Unemployed	71	15.4
Level of schooling	Primary/ none	348	75.6
	Secondary	96	20.8
	Higher	17	3.6
Average total monthly income ($)		387	97 ± 68

((Engelhard, 2013; Cafiero et al., 2018). The data analysis adhered to the three processes recommended by FAO (2017): parameter estimation, statistical validation, and estimation of food insecurity prevalence. Parameter estimation and statistical validation were carried out using RStudio[6] version 1.4.1. Specifically, the RM. weights package, developed by the Voices of the Hungry project to facilitate Rasch analysis of FIES data, was employed in this study (FAO, 2017). The study achieved an acceptable Rasch reliability of 84%, indicating a substantial amount of data variability explained by the Rasch model. Furthermore, the relationship between food insecurity (access dimension) and socioeconomic characteristics was illustrated using multiple linear regressions. Two linear regression models were utilised: Model 1 examined the basic association between each socioeconomic indicator and food security, while Model 2 incorporated all relevant parameters associated with food security. Additionally, a sensitivity analysis was performed using binary logit regression. These analytical procedures were executed using IBM SPSS Statistics version 27.

3.5.2. Thematic analysis

The audiotapes from the interviews underwent cataloguing and indexing, receiving unique serial numbers for convenient referencing. This system facilitated the revisit to specific data points during the analysis phase (Denscombe, 2017). Post-indexing, transcription of the audiotapes took place, revealing initial patterns and themes pertinent to the study questions. The team iteratively collected, read, and cross-checked the transcriptions with field notes for coherence and reliability. These transcriptions were saved as Microsoft Word document before their integration into NVivo Plus 12 for coding, categorisation, and analysis, organised into labelled folders for easy retrieval. The transcripts underwent thematic analysis, following Braun and Clarke's (2006) six-stage process. This involved multiple readings of transcripts for familiarity and identification of patterns, followed by the creation of initial codes in NVivo Plus. The subsequent steps included meticulous coding aligned with research questions, sorting emergent codes into potential themes, refining sub-themes for consistency, and finally, labelling and using these for analysis and report writing. The subsequent section of the article discusses the survey and interview results.

4. Results and discussions

4.1. Descriptive analyses

Table 5 presents descriptive statistics about the survey respondents. The mean age was 36 years (SD = ±15), which matches and validates

[6] *RStudio is an integrated development environment for R, an open-source programming language for statistical computing and graphics.*

the relatively young demographic of the research district. The youthful age population poses both an opportunity and a risk to food security outcomes. To begin, a youthful population provides a huge pool of labour for the mining and agriculture sector. Additionally, the youthful population creates an increasing market for agricultural products. Despite this, the youthful population has the potential to place a pressure on both the current and future food systems, as well as the natural ecosystem. To begin, the dietary requirements of a youthful population are greater than those of an older population, implying that there would be an increase in food demand. Second, with average life expectancy in Ghana at birth being 64 years in 2019 (The World Bank, 2021), this indicates that many of the study participants will have nearly half (28 years) more years to live, holding all factors constant. These sustained high food demands will place a strain on both the current and future local food systems, as well as the natural ecosystem. The age of the study participants influences their livelihood assets and the livelihood strategies they use to achieve food security (Chambers and Conway, 1992). Additionally, various age groups respond differently to the vulnerabilities associated with food security.

Also, gender has a significant impact on the capability for achieving food security objectives. Access to land and labour capabilities were gendered, with women disproportionately exploited in terms of labour wages (Obodai et al., 2023). Despite their role as food stewards and cooks, women have limited access to resources, making them more vulnerable to rising food insecurity. Food insecurity is heavily gendered, with women experiencing it at a higher rate than males (FAO et. al. 2022). A recent study conducted in Sub-Saharan Africa discovered that proximity near mine sites increases the risk of food insecurity for women (Wegenast and Beck, 2020). The participants of the survey were 51% female, the majority (75%) of whom were married. Given the large household size of 4.5 in the district, many of these married women may be responsible for supplying food not only for themselves but also for these huge families.

Moreover, many study participants (71%) were native[7] and had low levels of education (76 %). These personal attributes may influence their capability to access food. For example, the migration status of an individual has a significant impact on their access to natural resources such as land for farming or mining. Migrant farmers with smaller land interests were among the most affected by land dispossession(Obodai et al., 2023). Additionally, given the rural nature of the case study, a low level of education is expected, which has a significant impact on the livelihood choices they can employ and their food security outcome. It is worth noting that the low level of education means that most research participants are ineligible for jobs in large-scale mining companies that require highly skilled labour. The difficulties of many youngsters to obtain employment in large-scale mining firms is cited as a reason in their engagement in small-scale mining, both legally and illegally (Afriyie et al., 2016). Further, as highlighted by a key informant, small scale miners took advantage of certain farmers' low education and lack of information when it came to land negotiations and appropriation for mining (ORH_02_DT). It was alleged that some small-scale miners produced forged documents purportedly obtained from the Minerals Commission to take over farms for mining purposes. Due to these farmers' poor levels of knowledge, they are unable to verify the authenticity of documents and hence succumb to such pretences as selling their farmlands for pitiful income compensations out of fear of losing the land without compensation. Finally, a substantial proportion of study participants (80 % of total) were employed. This, of course, will influence their food security outcomes. However, the critical question is whether the earnings and income generated by various livelihoods are sufficient to cover the rising cost of living in the district. After adjusting for outliers, the average monthly income was $97.[8] This indicates that, even though a few people benefit from farming or mining, many people live in poverty. In the next section, the issue of food availability is discussed.

Table 6
Benefits and adverse relationships between mining and smallholder farming in relation to food security.

Beneficial relationships	Adverse relationships
A ready market for cash crops for sale to miners and other related employees	Land/farm dispossession for mining activities
Employment opportunities	Destruction and pollution of natural water resources
Income generation to meet household needs	Reduction and loss of farm labour
	Limited local food availability and access

4.2. The correlation between mining activities and smallholder farming in relation to food security outcomes

Scholars have debated whether the relationship between mining and smallholder farming is one of mutual benefit or competition (Okoh and Hilson, 2011; Hilson and Garforth, 2012, 2013; Kitula, 2006; Boadi et al., 2016; Hilson and Laing, 2017; Ofosu et al., 2020; Poignant, 2023; Siaw et al., 2023). This relationship is however heavily influenced by asymmetric power dynamics and the involvement of diverse stakeholders across various scales (Obodai et al., 2023). In this section, the connections between mining and smallholder farming concerning food security are analysed. Table 6 presents a summary of the benefits and adverse effects of the relationships.

From the standpoint of food security, a pivotal correlation emerges between mining activities and smallholder farming, chiefly through the provision of a readily accessible market for food crops. The expanding populace involved in mining activities, whether directly or indirectly, contrasts starkly with the diminishing count of farmers, consequently generating substantial demand for food crops. This establishes a readily available market for farmers and traders dealing in food crops. However, land dispossession due to mining activities (Nunoo et al., 2023; Obodai et al., 2023) as well water and labour-related challenges limit the capacity of farmers to meet the high demand for food crops. The economic attractiveness of small-scale mining in comparison to farming, particularly regarding higher daily wages for miners, compels casual workers to opt for mining over farming, thereby affecting the availability of farming labour. This has led some farmers, particularly the younger generation, to forsake farming for quick earnings through small-scale mining, as mining offers immediate profits unlike agriculture, which demands patience for returns. This competition between mining and farming for labour has significantly escalated labour costs for farmers, making it challenging to hire workers. The preference for mining due to higher wages has resulted in severe difficulties for farmers in hiring casual laborers for agricultural activities. The economic advantage of mining in terms of better compensation for labour has led to the scarcity of farm labour and increased reliance on agrochemicals, posing risks to both farmers and the environment. The preference for mining due to higher wages has resulted in severe difficulties for farmers in hiring casual labourers for agricultural activities. The following are direct quotes from various farmers concerning the issue of accessing labour:

> "Because of galamsey activities, it is difficult to get labourers to work on the farm. Everyone prefers to work in galamsey sites than to work in farming as the farmers pay less compared to mining". (SSI_AD003_M_FM).

> "Now it is very difficult getting labourers to work by day on your farms because of galamsey. But for the agrochemical we use, it would

[7] *Natives are individuals with either of their parents coming from the study communities or born in the study communities.*

[8] *The currency exchange rate was $1 to ¢5.7 as of February 2021 (XE.com Inc).*

Fig. 2. (a) The polluted Oda River at Watreso (b) the polluted Offin River at Keniago

have been difficult weeding our farms. This is because the labourers will prefer to work in galamsey sites because of the high daily wages". (SSI_D003_M_FM).

"It is very difficult to get labourers to assist with farm work here. Those who are available for farm work on a day are those who do not get employed for galamsey activities on that day. … we had this caretaker. He however mostly went to work on galamsey sites. He only visits the farm when he is unable to get a galamsey offer". (SSI_W02_M_FM).

The economic advantage of mining in terms of better compensation for labour leads to the scarcity of farm labour and increased reliance on agrochemicals, posing risks to both farmers and the environment. This labour competition underscores the economic edge of small-scale mining over smallholder farming and its ramifications for food security. This labour imbalance affects farm sizes and production, potentially exacerbating the gap between impoverished farmers and wealthy miners. To address this, some farmers have adjusted their practices, reserving days traditionally dedicated to mining for agricultural work, like the harvesting of cocoa pods. This shift reflects their adaptive response to the labour shortage caused by the dominance of small-scale mining. A farmer articulated this new approach as follows:

"It is a problem [difficulty in getting labourers for farming]. Breaking the cocoa pods after harvesting is a great challenge now because of the galamsey activities as you won't get labourers to assist. Tuesdays are taboo days here so there are no galamsey activities. So, what we do now is to wait for Tuesdays to get people to assist with that. This was never the case previously". (SSI_W09_M_FM).

Moreover, the extensive water requisites in surface mining, undertaken by both large-scale corporations and individuals engaged in small-scale mining (both legally and illegally), pose a significant constraint on the ability farmers to meet the growing demand for food crops. This situation represents an adverse consequence of the correlation between mining activities and smallholder farming concerning food security. The withdrawals encompass a range of actions, such as diverting surface water or interrupting it to process mineral ores or de-water mining sites for safe operations. Illicit small-scale mining, in particular, frequently encroaches directly upon surface water sources, impacting their quality and quantity. Findings from the study indicate a gradual decline in river water quality and the near-complete disappearance of minor water bodies like streams and ponds, which traditionally served as sources of drinking water and fulfilled other domestic functions. Participants in the study unanimously reported that major rivers and streams in their communities had been contaminated due to small-scale mining activities, rendering them unsuitable for either drinking or agricultural purposes (refer to Fig. 2). Also, water resources once utilised for year-round vegetable cultivation have become unsuitable due to pollution or destruction caused by small-scale mining activities. Through a focus group discussion with vegetable farmers, it was revealed that due to the destruction of small streams utilised for watering vegetables, some farmers have resorted to gathering and using water from mine pits (FGD_OD001_VFM). Despite being aware of its unsuitability for human use, these farmers were compelled to employ it. This practice may introduce dissolved contaminants from polluted water into the food chain, underscoring the potential health risks associated with inadequate access to clean water resources.

Besides, the symbiotic relationship between mining and smallholder farming presents promising employment and income prospects stemming from mining activities. Scholars have highlighted these benefits as a key rationale for formalising the mining sector ((Maconachie and Hilson, 2011; Hilson et al., 2017, 2019). In countries like Ghana (Hilson and Garforth, 2013), Zimbabwe (Chigumira, 2018), Sierra Leone (Cartier and Burge, 2011; Maconachie, 2011), Burkina Faso (Werthmann, 2009), and Malawi (Kamlongera, 2011), mining, especially at the artisanal and small scale, offers an alternate means of livelihood for select farmers. However, existing research overlooks the specific demographics of farmers who can capitalise on these opportunities. Not all farmers can access the potential livelihood and income streams mining offers. Factors like age and limited resources (land and finances) hinder many from benefiting (ORH_04_AD). The demanding nature of small-scale mining often leads to the use of narcotics like marijuana and tramadol among miners (KII_008_M_LS). Consequently, mining as an alternative livelihood primarily benefits younger, physically capable farmers. This contributes to the dominance of elderly individuals in smallholder farming, as mining becomes feasible mainly for those who can either provide land or financial support. Notably, some farmers own extensive cocoa farms and possess family lands for engaging in illicit small-scale mining. An example is Nana,[9] a 10-ha cocoa farmer, an assembly member, and a small-scale miner employing approximately 20 laborers in mining activities. The ensuing sections will explore the ramifications of the interconnectedness between mining and smallholder farming on the four dimensions of food security: food

[9] *Pseudonym name.*

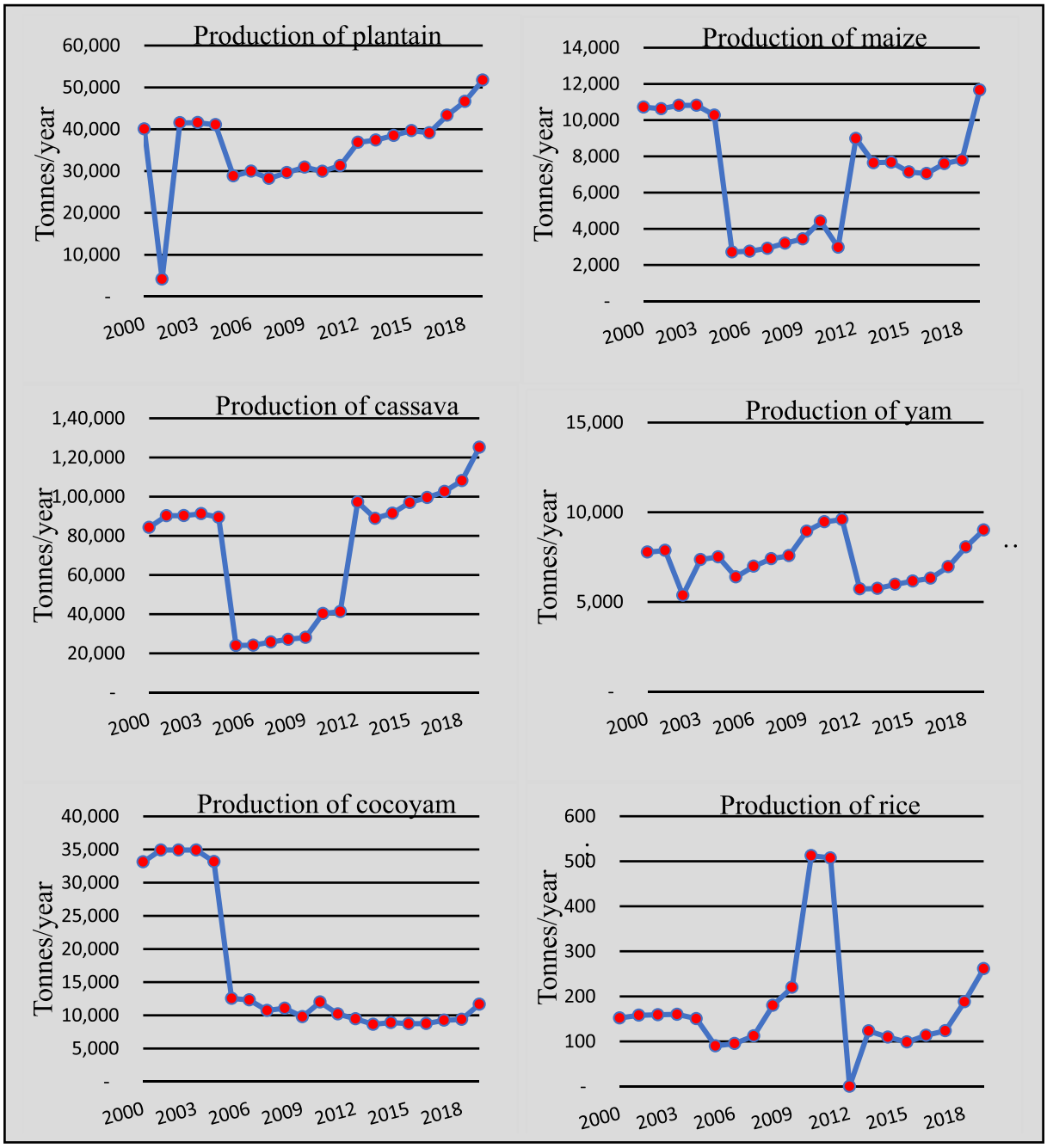


Fig. 3. Production of major food crops.
Source: Statistical Research and Information Directorate SRID of MoFA Ghana, 2020.

availability, access, utilisation, and stability.

4.3. *Food availability: balancing production, trade and increases in prices*

One key factor that determines food availability is food production and trade, which constitutes the supply side of food security (FAO, 2008). Food availability is primarily through domestic food production complemented with trade. To assess food availability, historical data on major food staples produced domestically for the last 19 years (2000–2019) were analysed.

Surprisingly, the data revealed that the production of all major staple foods began to fall sharply in 2004 with some food crops having sporadic variations until 2016 and 2018 (Fig. 3). For instance, maize (*Zea mays*) output, a major staple crop that is needed in the preparation of various Ghanaian cuisines, remained low in comparison to pre-2004 levels until 2019. Moreover, cocoyam (*Colocasia esculenta)* production did not exceed pre-2004 levels from 2004 to the time of the study. These periods of precipitous drops in the production quantities of the primary staple foods correspond to the increase activities in small-scale mining activities and their associated environmental footprint (Obodai et al., 2024). Therefore, a negative association between mining and food crop yields can be determined. A District Director of the Ministry of Food and Agriculture (MoFA) confirmed this drop in main food crops due to mining activities (KII _001_M_LS). Active small-scale mining leads to the encroachment of farms and arable lands, especially those located in wetland areas suitable for the cultivation of maize and other food crops and vegetables. A Chief Farmer/Leader of the District Farmers' Association, as well as an Assembly Member at the District, confirmed the

following implications of mining on food availability:

> The areas that previously supported food and cash crop production have been used for mining activities. Now, only a side of the community is used for food, and there are food challenges (KII_008_M_LS).

> Previously, people used to sell foodstuff on their head or arrange them on small tables in front of their houses, but now, this does not often occur. Such foodstuffs, including plantain and cassava, must be purchased from Kumasi. The areas that used to be the food basket of the community have all been taken over by the main mining company in the community. (ORH_04_AD).

The comments provided offer a stark portrayal of the challenges faced by mining communities in maintaining domestic food crop yields, which is in line with previous studies by (Wegenast and Beck, 2020) in Sub-Saharan Africa and in Ghana (Danyo and Osei-Bonsu, 2016). The impact of both large and small-scale mining operations on diminishing food availability is clearly attributed in the quotations, underscoring the significant role of mining in affecting food supply. In addition to the decline in domestic food production, the absence of an organised district market and inadequate road infrastructure pose additional threats to food availability. Without an organised market, local food supplies are reduced, resulting in traders and families having to travel long distances to Kumasi, the regional capital, to obtain necessary supplies. Moreover, the considerable distance between Kumasi and the district capital, coupled with poor road conditions, increases transportation costs and ultimately, food prices in the area. Furthermore, the district's dense population, because of immigration for mining activities, exacerbates the already precarious food availability issue. Despite limited food supply and other essential requirements, demand remains high due to the burgeoning population. This, in turn, leads to local food shortages and a surge in food prices, as the increased demand for scarce resources drives up prices. Expressing the frustration of many, a Chief Farmer/Leader of District Farmers' Association and a farmer bemoaned the difficulty in obtaining food supplies and the accompanying skyrocketing prices, further emphasising the dire consequences of the food availability crisis as follows:

> "The traders travel to Kumasi to get foodstuff like yam [*Dioscorea]* and cassava [*Manihot esculenta]*. Even plantain [*Musa paradisiaca],* there are times it is exceedingly difficult to get here in this community and when you finally even get some, the prices are remarkably high. You can buy a bunch of plantain for thrice the cost it is sold in Kumasi. This is because of large areas been used for galamsey activities with only a few areas been used for food crop production" (KII_008_M_LS).

> "It [small-scale mining] has led to hunger in this community. All those who are not able to engage in galamsey activities lack money and the prices of food are expensive here thus they are unable to buy" (SSI_AD003_M_FM).

The current analysis highlights the severity of the challenge posed by mining activities on food availability, which is further compounded by infrastructural constraints. Of particular interest are the implications of the quoted observations. First, it is noteworthy that food prices in the rural farming district with a high proportion of low-income households are higher than those in the regional capital, which is characterised by minimal farming operations. This situation has the potential to adversely affect the welfare of many individuals, especially the poor rural households, for whom food constitutes a significant portion of their income. Therefore, many of these households may lack the financial resources to meet other essential needs such as education, health, and entertainment. This represents a serious condition, given that most of the research participants (68%) rely on food purchases, while only a minority (28%) produce their food. Second, the analysis reveals that the impacts of food availability are disproportionately felt by certain groups.

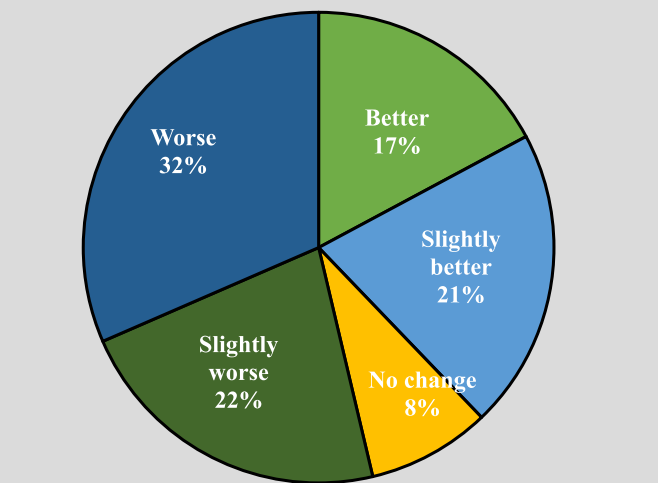


Fig. 4. Perception of current access to food compared to 10 years ago.

Mining, which pays higher daily or weekly wages than smallholder farming, provides miners with regular disposable income to meet their food demands. Conversely, smallholder farmers must manage their cash earnings during the harvest season, most of which is spent on debt before the next harvest. In addition, miners can afford to pay for the rising food prices due to their higher wages. Moreover, most miners are men, while women who work in mining earn less than their male counterparts. Despite evidence that women spend a significant proportion of their income on food (Meinzen-Dick et al., 2012), they have limited opportunities to pursue income-generating activities due to housekeeping and care tasks, as well as restricted access to productive resources, as noted by various studies (Moser 2012(Johnson et al.; Doss et al., 2017; Kang et al., 2019). Consequently, the impacts of food availability will likely be experienced differently by individuals, with women bearing the brunt, as found by Wegenast and Beck (2020) in Sub-Saharan Africa. In the next section, access to food is described.

4.4. Food accessibility: perceptions and prevalence of food insecurity

The perceptions of individuals of their current food access are compared to those from ten years earlier, when small-scale mining activity was not at its pinnacle. This is followed by a quantitative assessment of the prevalence[10] of food insecurity, a measure of the access dimension of food security.

As illustrated in Fig. 4, more than half (54 %) of study participants believe that their present access to food is either worse or slightly worse. Only a small proportion (8%) reported no change in their food access. From this, it can be deduced that there are challenges with food access. Thus, to properly comprehend the current level of food access, the Food Insecurity Experience Scale (FIES) as explained earlier, was applied. To reiterate, the FIES employs two thresholds to categorise the degree/severity of food insecurity (Refer to Fig. 1). The first threshold is established at the severity level of the FIES item ATELESS (i.e., eating "less than you should"), and it distinguishes between the categories of 'food secure or mildly food insecure' and 'moderately food insecure'. The second criterion is set at the severity level of the FIES item WHLDAY ("gone a whole day without eating"), which distinguishes the 'moderately food insecure' from the 'severely food insecure' categories (Cafiero et al., 2018; FAO, 2018). Based on these thresholds, 32% of study participants are food secure or mildly food insecure, with an exceptionally low probability of experiencing moderate and severe food insecurity

[10] *'Prevalence', as used here refers to the percentage of people in the total population who are affected by food insecurity at different levels of severity.*

Table 7
Food Insecurity parameters.

Raw score	Weighted cases	% of individuals	Prob (moderate)	Prob (severe)	Prevalence rate (moderate)	Prevalence rate (severe)
0	149	32.4	0.00	0.00	**50.1%**	**13.3%**
1	62	13.4	0.02	0.00		
2	10	2.2	0.10	0.00		
3	7	1.5	0.40	0.00		
4	10	2.2	0.71	0.00		
5	47	10.1	0.94	0.00		
6	19	4.1	0.99	0.01		
7	87	18.9	1.00	0.25		
8	70	15.2	1.00	0.56		

Table 8
Associations between socio-economic variables and food insecurity: Multivariate pooled linear analysis.

Variable	Model 1		Model 2	
	β	**(SE)**	**β**	**(SE)**
Gender (ref: men)	0.801	(0.304) *	0.769	(0.324) *
Age (in years)	0.450	(0.010) *	0.030	(0.013) *
Migration status (ref: native)	−0.364	(0.335)		
Marital status (ref: married)	−0.936	(0.351) *	−0.479	(0.400)
Employment status (ref: employed)	0.474	(0.423)		
Employment type (ref: others)				
Farming	1.524	(0.332) *	0.812	(0.413) *
Small-scale mining	0.463	(0.231) *	0.793	(0.235) *
Level of education (ref: basic/no education				
Secondary	−0.369	(0.187) *	0.087	(0.192)
Higher	−0.872	(0.271) *	−0.608	(0.314) *
Income (¢)	0.001	(0.001) *	−0.001	(0.001) *
Adjusted R Square			0.125	

*$p < 0.05$.

(See Table 7).

Additionally, a sizable proportion (50.3 %) were moderately food insecure, comparable to the average prevalence rate of 51.1% in the total population of Ghana for the last three years (2017–2019) (FAOSTAT, 2021). This statistic indicates that around half of the total population of the district experiences anxiety over food and has run out of food at least once in the last 12 months due to a lack of money and resources. This forced them to develop survival strategies such as consuming fewer foods than recommended, forgoing healthier foods, skipping meals, or eating little food. As a result, their access to consistent and nutritious meals is jeopardised. This has a detrimental impact on their diet quality, putting them at risk of a variety of forms of malnutrition and poor wellbeing. Alarming is the 13.3% of the study population who suffered severe food insecurity more than the national average of 8.4% over the last three years (2017–2019) (FAOSTAT, 2021). This reveals that less than two in ten individuals went to bed at least once in the preceding 12 months without eating for the full day due to a lack of money and resources. This demonstrates their level of hunger.

4.5. associations between socio-economic variables and food insecurity

Food security relates to several socioeconomic parameters, including gender, age, employment position, educational attainment, and income level. Thus, two linear regression models were constructed to account for these variables of food security (See Table 8 for results). Model 1 was a crude analysis that examined the association between each socio-economic variable and food security. Model 2 accounted for each of the variables that were found to be significantly associated with food security. Sensitivity analysis using binary logit regression found that the direction and magnitude were identical.

The linear regression results (Model 2) indicate that gender, age, occupation type, level of education, and income are all independent predictors of food security, even after controlling for confounding variables. While marital status was found to be an independent predictor of food security, it was not found to be significantly associated with food security after adjusting for confounding variables. Expanding on this, the results (Model 2) indicate that age is positively associated with food security ($\beta = 0.030$, SE = 0.013), $p = 0.063$). This means, the older people get, the more likely they are to experience food insecurity. Additionally, small-scale miners ($\beta = 0.793$, SE = 0.235, $p = 0.001$) and farmers ($\beta = 0.812$, SE = 0.413, $p = 0.050$) are more likely to experience food insecurity than other occupational categories. However, farmers (standardised $\beta = 0.018$) are more likely to face food insecurity than miners (standardised $\beta = 0.170$). Additionally, those with a higher level of education ($\beta = -0.608$, SE = 0.314, $p = 0.054$) were less likely to experience food insecurity in reference to obtaining a basic education. Finally, women ($\beta = 0.769$, SE = 0.324), $p = 0.018$) are more probable to experience food insecurity than men. In other words, more women than men face food insecurity. This has multiple ramifications for the nutritional wellbeing of women. The bivariate analysis of gender and food security, which employs the two previously described thresholds, reveals these distinctions considerably more clearly, as illustrated in Fig. 5. Food insecurity was most severe for women in small-scale mining geographies. This finding is consistent with one by Wegenast and Beck (2020), who found that industrial mining decreases food security outcomes for women, with women living near mining operations having less access to food.

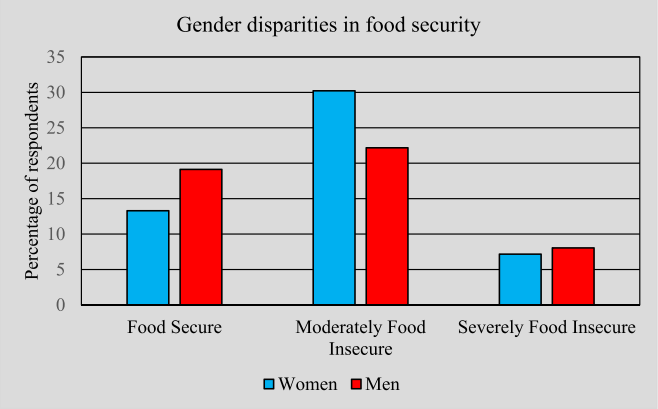


Fig. 5. Bivariate Analysis of the relationship between gender and food security.

Dietary diversity, which is a qualitative measure of food consumption, is often used as a proxy for nutrient adequacy in individuals' diets (Kennedy et al., 2010). Given the higher micronutrient requirements of women and the earlier established prevalence of a larger proportion of women encountering food insecurity compared to men, the next section, assess the dietary diversity specifically among women.

4.6. Food utilisation: exploring dietary diversity for women of reproductive age

To measure dietary diversity in women, the Minimum Dietary

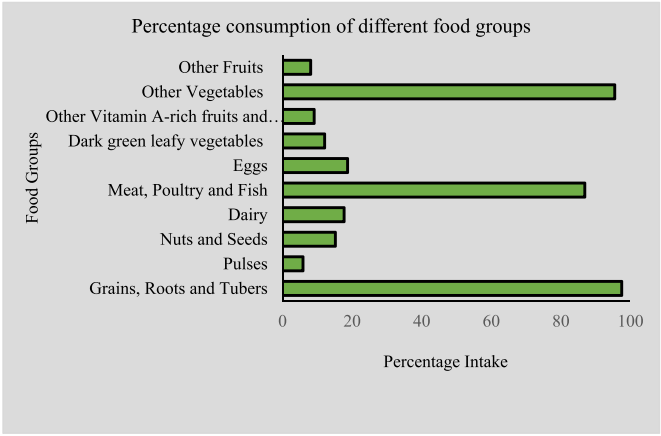


Fig. 6. Proportions of study participants consuming different food groups during the previous day of the survey.

Table 9
Minimum Dietary Diversity of women of reproductive age.

Variable	Mean ± SD	Total (%)
MDD-W Categories	3.67 ± 1.1	
Inadequate		157 (79.3)
Adequate		41 (20.7)

Diversity for Women of Reproductive Age (MDD-W) indicator was used. This indicator assesses the consumption of 11 essential micronutrients by measuring whether women aged 15–49 have consumed at least five of ten defined food groups the preceding day or night (Martin-Prevel et al., 2015) The MDD-W is a binary indicator, making it a useful tool for identifying women who are not consuming an adequate variety of nutrient-rich foods.

Fig. 6 reveals that grains, roots, and tubers (98%), meat, poultry, and fish (87%), and other vegetables (96%) are the dominant food groups consumed on the day preceding the survey, a finding that is consistent with the research conducted by (Ayensu et al., 2020). The high prevalence of these food groups is unsurprising given that they are the primary ingredients used in traditional meals in Ghana and other African regions. However, it is noteworthy and encouraging that a substantial proportion of women (87%) consumed meat, poultry, and fish the day or night before the study, especially in contrast to the low rates observed in the study conducted by (Ayamba, 2018) in the Upper East region of Ghana, where meat and poultry are abundant. This increase in meat, poultry, and fish consumption among women is likely attributable to the influx of imported animal products, particularly chicken, which is sold at a lower price than domestically produced poultry. On the other hand, less than two out of ten research participants consumed dark green leafy vegetables (12%), eggs (19%), dairy (18%), nuts and seeds (15%), and less than one in ten ingested other vitamin A-rich fruits and vegetables (9%), other fruits (8%), and pulses (9%). These findings raise questions about the effectiveness of current nutrition interventions and highlight the need to focus on improving the availability and accessibility of nutrient-rich foods to promote optimal dietary intake among the population.

Moreover, the study revealed a mean dietary diversity score (DDS) of 3.67 ± 1.1, falling below the recommended score of 5 as proposed by the Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) based on 10 aggregated food groups. This score was lower than the mean scores of 4.40 from pregnant women of all ages in the 2017 Ghana Micronutrient Survey (University of Ghana, 2017) and 4.00 from pregnant women and adolescent girls in two recent studies conducted in the Ashanti region of Ghana by (Ayensu et al., 2020; Gyimah et al., 2021), respectively. In comparison, (Ayamba, 2018) reported a slightly higher mean DDS of 3.97 ± 1.15 in one of the poorest regions of Ghana, the Upper East region (Ghana Statistical Service, 2018). These findings indicate that women's dietary diversity is low, attributable to a diminished local food supply and increasing food prices associated with mining, as mentioned earlier. Remarkably, 79% of women failed to attain the minimum dietary diversity threshold, which requires ingestion of at least five food groups the previous day (See Table 9), raising concerns about the adequacy of their diets.

Table 10
Relationship between dietary diversity and socio-demographic characteristics.

Variable	Dietary Diversity		Pearson Chi-Square	P-value
	Inadequate	**Adequate**		
Age				
>19	9 (4.5)	1 (0.5)	0.735	0.391
20–49	148 (74.7)	40 (20.2)		
Migration Status				
Natives	103 (52.0)	29 (14.6)	0.384	0.535
Migrants	54 (27.3)	12 (6.1)		
Educational Status				
No education	36 (18.2)	8 (4.0)	1.373	0.503
Basic education	95 (48.0)	23 (11.6)		
Higher education	26 (13.1)	10 (5.1)		
Marital Status				
Never married	23 (11.6)	5 (2.5)	2.049	0.562
Married	80 (40.4)	20 (10.1)		
Cohabiting	39 (19.7)	14 (7.1)		
Widow/Divorced/ Separated	15 (7.6)	2 (1.0)		
Employment Status				
Employed	130 (65.7)	34 (17.2)	0.001	0.985
Unemployed	27 (13.6)	7 (3.5)		
Type of employment				
Farming	34 (20.7)	10(6.1)	1.388	0.846
Mining	13 (7.9)	4 (2.4)		
Trading	51 (31.1)	14 (8.5)		
Civil/Public Service	2 (1.2)	1 (0.6)		
Artisans	30 (18.3)	5 (3.0		
Monthly Income[a]				
No income	1 (0.6)	0 (0.0)	3.129	0.372
Below 100	8 (4.4)	0 (0)		
100 to 500	77 (42.5)	21 (11.6)		
Above 500	55 (30.4)	19 (10.5)		

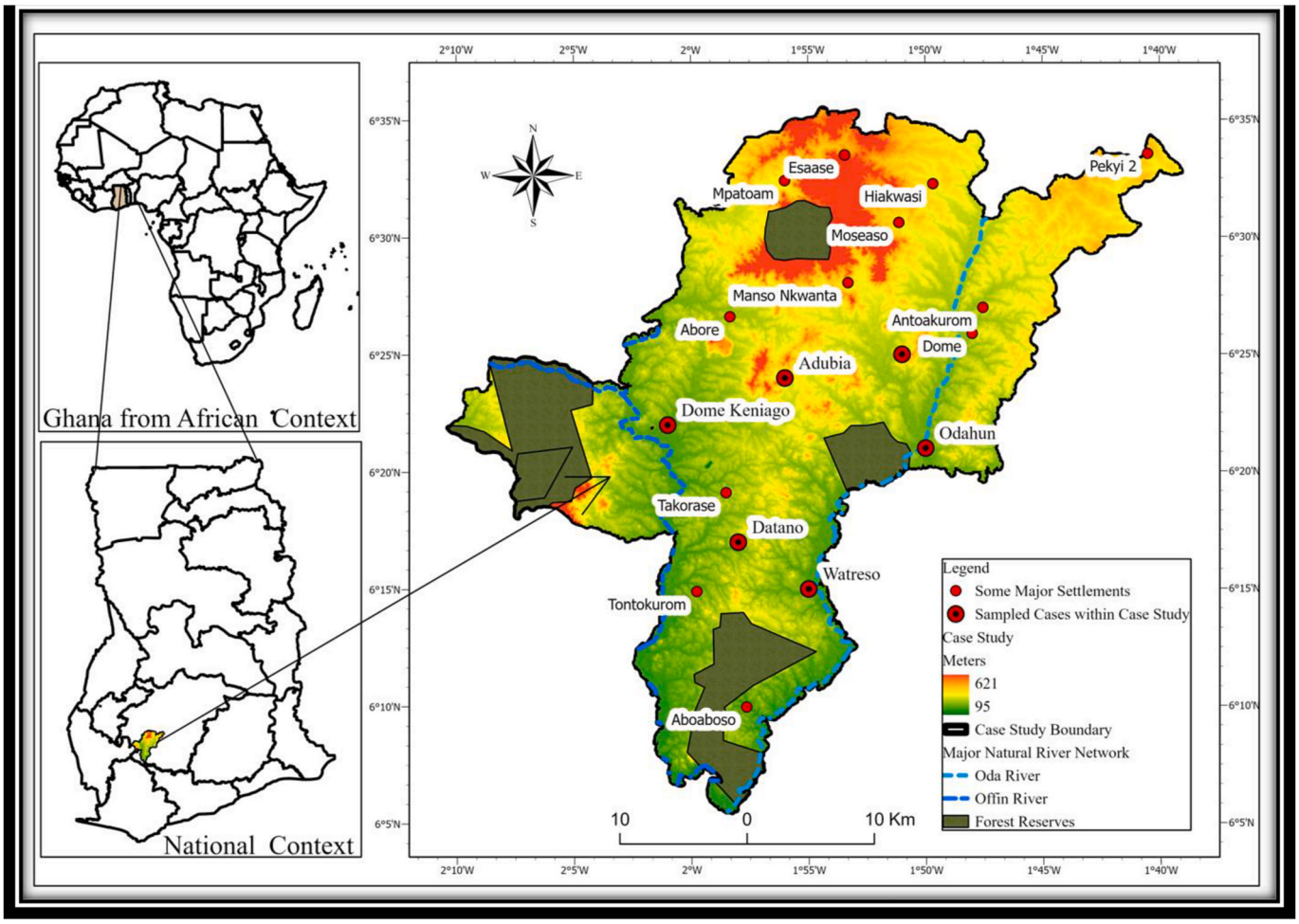
[a] Income is measured in Ghana Cedi (¢). ¢1 is equivalent of $0.17 as of July 2, 2021.

Exploring the possible relationship between sociodemographic attributes and the dietary diversity of women is important. To this end, a cross-tabulation analysis was carried out, and the findings are summarised in Table 10. The results of this analysis suggest that there are no statistically significant correlations between the sociodemographic characteristics of women and their dietary diversity at a significance level of 0.05. This outcome indicates that factors such as age, migration status, marital status, employment position, degree of education, and income have little to no impact on the adequacy or inadequacy of dietary diversity among women. Interestingly, these findings are consistent with a recent study by (Gyimah et al., 2021), which also reported no significant correlations between dietary diversity and sociodemographic variables, except for education and community type (rural). Specifically, all the study communities in our investigation were rural. These results further validate a concern expressed by a miner (SSI_025_M) regarding the unavailability of desired food variety and quality, even when individuals have the financial means to purchase them.

The following section will discuss the perspectives of study participants regarding food stability and their coping mechanisms.

4.7. Food stability

Access to adequate food is a fundamental necessity for individuals to attain food security. This hinges upon the consistent and reliable availability of food supplies. Achieving food stability necessitates the



Map. 1. Map of selected 'cases within Ghana'
Source: Obodai et. al. (2023)

absence of sudden shocks or recurring events that endanger ability of individuals to meet their nutritional needs (FAO, 2006). Ongoing discussions have highlighted concerns regarding mining activities, particularly small-scale mining, posing a threat to the steady availability and accessibility of food. These activities have led to local food shortages and increased prices due to diminished crop output over time, exacerbating food insecurity among many. Consequently, individuals have resorted to various coping strategies, such as reducing food intake, opting for less nutritious meals, skipping meals, or consuming smaller portions. Consequently, a significant proportion of individuals now face moderate to severe food insecurity. This situation has prompted serious apprehension and worry about the future stability of food, as expressed by a Chief Farmer at Odaho as follows:

> "The galamsey can lead to hunger because it has destroyed all our arable lands. In the future, we may not have any food crops and will have to buy everything [food crops]. We cannot live on only rice (Oryza sativa), we need plantain (Musa paradisiaca), cassava (Manihot esculenta), cocoyam (Colocasia esculenta), and other traditional food crops which in the future we will not be able to get due to the galamsey activities" (KII_010_M_LS).

This comment reflects widespread concerns among both miners and farmers regarding the future stability of food sources. It also underscores people's steadfast attachment to their customary staple foods, despite the presence of rice (Oryza sativa) in the market. Rice, prominently available due to importation, is highlighted here. However, in this context, rice dishes, especially among the elderly, do not hold the same level of importance or distinction as their traditional dishes like 'fufu,' 'banku,' and other local diets. Consequently, the declining availability of key ingredients for these local cuisines, coupled with their escalating prices over time, poses a substantial shock and setback to their food security outcomes.(see Map. 1)

5. Summary and conclusions

This article extensively explores the intricate connection between mining and smallholder farming concerning food security and the profound implications of this interrelation on the four key dimensions of food security: access, availability, utilisation, and stability. It explores the positive and negative aspects of this nexus, highlighting how it influences economic activities, market provisions, employment, and income generation, particularly benefiting the youth. Conversely, it sheds light on the adverse effects such as land dispossession, water pollution, and labour competition. While the positive impacts tend to be more individually oriented, benefiting immediate family members, the negative effects can affect both individuals and communities, extending beyond immediate jurisdiction and significantly impacting entire communities. These dynamics exert considerable influence on the four dimensions of food security.

Using the FIES survey, the study uncovered a concerning prevalence of moderate food insecurity at 50.1%, indicating widespread concerns about food access. Even more alarming was the rate of severe food insecurity at 13.3%, significantly higher than the national average. This points to a substantial portion of the population experiencing at least a

day without food. Particularly troubling was the disproportionately higher vulnerability among women, as evidenced by low dietary diversity scores, suggesting inadequate micronutrient intake, thereby jeopardising their health and that of their offspring.

This study differs significantly from previous research by providing a comprehensive examination of the impact of mining on all four dimensions of food security, encompassing a representative sample of various occupational classes, including farmers and miners. It underscores the intricate linkages between mining and smallholder farming and their ramifications on individual well-being, concluding that while mining stimulates local economies, it substantially undermines food security across its four crucial dimensions. Thus, mining emerges as a significant contributor to food insecurity and the compromised well-being of many individuals, disproportionately impacting the most vulnerable, particularly women and the elderly.

CRediT authorship contribution statement

Jacob Obodai: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Shonil Bhagwat:** Project administration, Resources, Supervision, Writing – review & editing. **Giles Mohan:** Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Jacob Obodai reports financial support and travel were provided by The Open University Faculty of Arts and Social Sciences. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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