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Full Length Research Paper

Predicting Livelihood Dimensions of Agrarian Households in Small-Scale Mining Communities of Ghana using Structural Equation Modeling

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The contribution of agriculture to rural livelihoods in many parts of Ghana has declined due to increasing small-scale mining activities. This trend may continue in the foreseeable future if rural livelihoods, which are basically agrarian, are not streamlined to coexist with small-scale mining. The study was conducted in four regions of Ghana (Ashanti, Eastern, Western and Central Regions) covering six out of the seven zones in Ghana exclusively blocked for small-scale mining by Minerals Commission of Ghana. The six blocked-out areas for small-scale mining covered in the study are Assin Fosu, Asankrangwa, Bibiani, Dunkwa, Tarkwa and Akim Oda. A three-stage sampling technique was used to randomly select 432 agrarian households from six small-scale mining communities in each of the six zones. The characteristics of respondents were summarized using descriptive statistics including arithmetic mean, standard deviation, minimum, maximum, frequencies and percentages. Carefully constructed statements were rated on a five-point Likert-scale to examine households' perception on the implementation of the institutional framework for small-scale mining in the country. Household Livelihood Vulnerability (HLV) Index, Household Livelihood Security (HLS) Index and Household Livelihood Diversity (HLD) Index were computed based on primary data from the field. The determinants of these three interrelated household livelihood parameters were estimated simultaneously in a system of structural equations using the three-stage least squares approach. This was done to account for cross-correlation among household livelihood vulnerability, security and diversity and bridge the gap of research inefficiency of using single-regression equation models in separately predicting the dimensions which are interrelated. The study provides results that are relevant to livelihood development in small-scale-mining communities which are also consistent with findings from other studies. Livelihood assets describing the socioeconomic characteristics of agrarian households in the form of human, social, natural, physical and financial capital were poorly developed. Agrarian households have negative perception about the implementation of the institutional framework for small-scale mining in rural communities in Ghana. Livelihoods and assets of agrarian households are vulnerable to small-scale mining. Characterized with moderately low livelihood security and diversity, agrarian households do not diversify livelihood portfolios to supplement income from on-farm activities. Through the system of structural equations, the study identified a number of socio-economic and institutional factors that can interact to simultaneously improve the three dimensions of livelihoods in small-scale mining communities. Based on the empirical results, the study provides practical recommendations to improve livelihoods of agrarian households in rural communities affected by small-scale mining.

Keywords: Livelihood vulnerability index, livelihood security index, livelihood diversity index, small-scale mining, system of structural equations, three-stage least square

INTRODUCTION

Rural livelihoods in Ghana are basically agrarian since agriculture remains a dominant economic activity for rural households in the country; for instance, 87%-89% of rural households are engaged in crop production (Diao, 2010). While some households get their source of livelihood from on-farm activities, others engage themselves in the processing and marketing of farm produce. Supply and distribution of agricultural inputs also provide a source of livelihood. Studies of rural income portfolios by Ellis and Freeman (2007) generally establish that, 50 percent of rural household incomes in low income countries are generated from engagement in on-farm activities. Any other economic activity that competes with agriculture for rural resources may ruin the livelihoods of rural households and render them vulnerable to livelihood insecurity, if not properly integrated.

Small-scale mining is one activity which, in recent times, has attracted rural household labour, agricultural land and rendered rural environment less conducive for agricultural production (Weber-Fahr *et al.,* 2002). Small-scale mining could be formal or informal operations with predominantly simplified forms of exploration, extraction, processing and transportation. It is normally low capital intensive but manual and very labour-intensive, using only picks, shovels and basins or somewhat mechanized, using heavy machinery on a small scale (Extractive Hub, 2017; Mining Facts, 2012).

Mining is an important subsector in the Ghanaian economy. It generates employment, foreign exchange and tax revenue for the socio-economic development of Ghana in general, and the development of rural communities in particular (Weber-Fahr *et al.,* 2002). When managed well, the net foreign exchange and tax revenue generated from mining can be used by governments to propel overall economic growth and fund poverty reduction programs (Weber-Fahr *et al.,* 2002). Contribution of mining to Ghana's export earnings increased by 16% to US$6.678 billion in 2019 from US$5.760 billion in 2018 representing an average of 42% of Ghana's total export. The contribution of mining to Ghana's tax revenue increased from 14.62% in 2015 to 18.38% in 2019 with that of GDP increasing from 9.8% in 2018 to 10.3% in 2019. While large-scale mining employs 148,000 people, small-scale sector provides jobs for 500,000 people in Ghana. Small-scale mining accounts for over 70% of the total employment created from mining sub-sector in Ghana (Ghana Chamber of Mines, 2015, 2019a&b; Baah-Boateng, 2018).

In spite of its positive contribution to the economy, small-scale mining has become pervasive in rural Ghana (Akabzaa & Darimani, 2001; Ghana Statistical Service, GSS, 2000), taking up large tracts of land from farmers, and impacting negatively on their livelihoods (Diao, 2010; Ellis and Freeman, 2007). Rural environment is threatened since institutional framework for mining is not fully implemented to protect the environment and livelihoods of rural households. The regulatory agencies have failed to efficiently regulate the activities of small-scale mining in Ghana due to inadequate capacity at both the district and the zonal levels (Eshun and Okyere, 2017; Osei-Kojo *et al.,* 2016). Food security and livelihoods are adversely affected by mining-related factors such as loss of agricultural land; water pollution; water supply; noise; dust; and land disturbance often associated with mining activities (Hilson, 2002a&b; Maconachie and Binns, 2007). Small scale mining competes seriously with rural households for agricultural lands, labor and other resources which form the bases of their livelihoods. Whilst small-scale mining draws resources from agriculture which is the main source of rural livelihoods (Diao, 2010), it has a relatively limited capacity to generate enough jobs to match the total number of people it lays off from agriculture (Aryee *et al.,* 2003; GSS, 2000). Scarcity of agricultural labour in mining communities has increased wage rate and the cost of other agricultural inputs making them less affordable to rural farmers (Mishra and Pujari, 2008). This phenomenon leads to high production cost, low net farm income and impoverished livelihoods. The contribution of agriculture in providing the most important income and livelihood sources for rural households is declining due to increasing mining activities. The proportion of farm households who primarily depend on farming in mining communities of Ghana consistently declined from 56% in 2006 to less than 33% in 2013 (Diao, 2010; Diao and Hezell, 2019).

Each of these threatens livelihood security and diversity of agrarian households and makes livelihoods vulnerable to small-scale mining in Ghana. The contribution of agriculture to livelihood security and diversity may continue to decline and livelihoods may deteriorate, if livelihoods of agrarian households, which are basically agrarian, are not streamlined to coexist with small-scale mining.

The purpose of the study was to empirically examine the major dimensions of livelihoods of agrarian households in small-scale mining communities in Ghana to inform the direction of harmonizing the coexistence between small-scale mining and agriculture. It aims at providing findings on the determinants of livelihood vulnerability to mining, livelihood security and diversity, and thus holistically describing livelihoods of agrarian households in small-scale mining communities in Ghana. Such findings may contribute to promoting livelihood development in mining communities whilst sustaining mining for the development of the national economy.

Review of Conceptual literature on Livelihood Dimensions

The concept of livelihood originated from the work of Chambers and Conway (1992). They established that a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living. Assets are resources of different types which people use by either owning or directly controlling them (that is, have decision making power about how they are used) or having access to resources that do not belong to them. The DFID (1999) livelihood framework breaks assets into five types of capital namely: Human, social, natural, physical and financial capital. Livelihood approaches provide the bases for analysing the factors affecting livelihoods. These factors include access to livelihood assets and ability to put these to productive use (i.e. livelihood security), the different strategies they adopt (livelihood diversification), the context in which they live, and susceptibility to shocks and stresses (vulnerability), the policies, institutions and processes that shape their access to assets and opportunities, (FAO, 2004). Livelihood approaches highlight three key dimensions of livelihoods namely: livelihood security, livelihood diversification and livelihood vulnerability to shocks and stresses.

Household Livelihood Security has been conceptualized as adequate and sustainable access to income and resources to meet basic needs, including adequate access to food, potable water, health facilities, educational opportunities, housing, and time for community participation and social integration (Frankenberger 1996). In its simplest form, livelihood security is the ability of a household to meet its basic needs (or realize its basic rights). These needs include adequate food, health, shelter, minimal levels of income, basic education and community participation. If any of these basic needs is not met, that household is considered to be living in absolute poverty (Frankenberger *et al*. (2000). All households need sources of livelihood that give them sufficient purchasing power to buy the food that they need but cannot or do not produce for their own consumption (FAO, 2008). Food security has, therefore, become but one sub-set of objectives of poor households (Maxwell and Smith 1992) and for that matter food is only one of a whole range of factors which determined why the household takes decisions and spread its risk. Hence the concept of food security has led to the development of the concept of household livelihood security. The household livelihood security model places particular emphasis on household actions, perceptions and choices, with food security as only one of the priorities followed to pursue the desired outcome. The household livelihood security model has evolved, according to Frankenberger *et al*. (2000), to embody three fundamental attributes: 1) the possession of human capabilities (e.g. education, skills, health, psychological orientation); 2) access to other tangible and intangible assets (social, natural, and economic capital); and 3) the existence of economic activities). These attributes have been described by, Akter and Rahman (2012), Lindenberg (2002), Frankenberger *et al*. (2000) to cover five major household livelihood security domains, namely economic security; food security; health security; educational security; and empowerment security.

How well a household can make use of its assets to pursue its diverse livelihood activities depends on its vulnerability context. Vulnerability refers to People's exposure to risks, the sensitivity of their livelihood systems to these risks, and the extent of the assets available to cope with risks and adapt to them (FAO, 2004). Vulnerability is the household's susceptibility to shocks and stresses that affect the household's ability to generate sufficient income to earn a livelihood and achieve a threshold level of nutritional requirements for a healthy life both now and in the future. Stresses are long-term trends or recurring events that put ongoing pressure on the household's livelihood and food security. Shocks, on the other hands, are unanticipated adverse events that undermine the household's livelihood and food security. Stresses and shocks emanate from a variety of sources in the economic, natural, health, political, and social environments. Vulnerability is neither the opposite of security nor the same thing as poverty since poverty describes a state of material well-being with respect to an absolute or relative poverty line. Vulnerability refers to susceptibility to a sudden or gradual decline in a household's ability to secure its livelihood and food security. Both poor and non-poor people may be vulnerable and vice versa *(*USAID, 1992). Vulnerability is a function of the risk's exposure, sensitivity to risks, and adaptive capacity (Heltberg and Bonch-Osmolovskiy, 2010). E*xposure* is the chance that assets and livelihoods will be impacted by an event, and *sensitivity* is the susceptibility of assets and livelihoods to the risk emanating from the event. *Adaptive capacity* is the ability to use social risk management strategies to reduce risk and human vulnerability associated with a risky event (Heltberg, Siegel, and Jorgensen, 2009) and is influenced by socio-economic status of individuals or households (Ribot, 2010).

A household with well-diversified assets and livelihood activities can cope better with shocks and stresses than one with a more limited asset base and few livelihood sources. Livelihood diversification is the process of constructing a diverse portfolio of livelihood

activities and social support capabilities for survival in order to improve standard of living. Households that have the capacity to construct alternative livelihood portfolios are well able to diversify into other activities and minimize their vulnerability to risks (Hart, 1994; Saleth, 1997). Fabusoro *et al.* (2010) explain livelihood diversification, in a broader context, as the attempts by individuals and households to identify new ways to raise incomes and reduce environmental risks. Ellis (1998) considers livelihood diversification as the process by which farm families construct a diverse portfolio of activities and social support capabilities in their struggle for survival in order to improve their living standards. According to him, diversification is a household survival strategy for risk reduction, overcoming income instability caused by seasonality and improving food security. According to Khatun and Roy (2012), livelihood diversification can take place through both agricultural livelihood diversification and non-agricultural livelihood diversification. Livelihood diversification in this study refers to the attempts by individuals and households to find new ways to raise incomes and reduce vulnerability to the risk of small-scale mining activities.

METHODOLOGY OF THE STUDY

The study was conducted in four regions of Ghana namely, Ashanti, Eastern, Western and Central Regions where small-scale mining competes seriously with agriculture, which is the main source of rural livelihoods. The regions are endowed with mineral deposits, vegetation, productive soil conditions, and copious and bimodal rainfall pattern vital for both agricultural production and mining of minerals. Six (6) out of seven (7) blocked-out areas designated exclusively for small-scale mining are located in the four regions (Minerals Commission of Ghana 2007).

Sample Size, Sampling Technique and Data Collection

A cross-sectional/primary data were used for the study. A three-stage sampling technique was used to sample 432 agrarian households in the study area, approximated from a statistically determined sample size of 407 households using *Equation 1* developed by Cochran (1963) to yield a representative sample for populations that are large, greater than 50,000.

At first, six (6) of the blocked-out areas designated for small-scale mining in Ghana were purposively selected to confine the study in Ashanti, Eastern, Western and Central Regions and to identify the inter relationship between agricultural livelihoods and small-scale mining. The blocked-out areas selected were Assin Fosu, Asankrangwa, Bibiani, Dunkwa, Tarkwa and Akim Oda areas (Minerals Commission, 2007). Each blocked-out area is made up of a list of communities in which mining activities are undertaken. Communities in each area were screened by taking out those that have overlapping and spill over effects from large-scale mining. This was done to ensure that communities that are exclusively exposed to the activities of small-scale mining were used for the study. At the second stage of sampling, six (6) of the screened communities in each of the six (6) blocked-out areas were systematically sampled by selecting every other community from the list to obtain 36 small-scale mining communities for the study. The third and the last stage of sampling involved systematically sampling 12 agrarian households from each of the 36 communities to obtain a total sample size of 432 agrarian households. In selecting the households, each community was divided into 4 quadrants. In each quadrant, a household from every 5th or 7th house along a transient was enumerated depending on the size of the community. The sample size distribution is shown in Table 1. Data collection was carried out from 7th August to 22nd September, 2017 by the researcher and his team using a well structured and pretested questionnaire to interview households. During the interview, information was solicited from household heads. In situations where the head was not available, any member of the household who prove to have the needed information was interviewed.

$$n = \frac{Z^2 pq}{e^2} \qquad (1)$$

Where n is the sample size, Z is the statistic for the desired confidence level (in this study 99% which is 2.58 in the statistical table), e is the desired level of precision (confidence interval expressed as decimal, in this study, $e = 0.064$ (i.e. +/-6.4% margin of error meaning the study accommodated 6.4% error), *p* is the estimated proportion of an attribute that is present in the population (in this study, households that are agrarian and influenced by mining activities) which may be known from prior research or other sources. If *p* is unknown the variability of the attribute in the proportion is not known we then equate *p = 0.5* which assumes maximum heterogeneity or variability (i.e. a 50:50 split), then q is given as q=1-p ((Daniel, 1999).

Table 1: Sample size distribution

	Blocked out area for Small Scale and Artisanal Mining in Ghana	Mining Communities selected for the study	Provincial District of selected communities	Region of selected communities	Number of households
1	Assin Fosu Area	1. Assin Asaman	Assin North	Central Region	12
		2. Assin Awusam	Assin North	Central Region	12
		3. Assin Nyadowam	Assin North	Central Region	12
		4. Twifo Mokwaa	Twifo/Hemang	Central Region	12
		5. Akwaboso	Upper Denkyira West	Central Region	12
		6. Tentekrom	Upper Denkyira West	Central Region	12
2	Asankrangwa Area	7. Mmoseaso	Wasa Amenfi Central	Western Region	12
		8. Bremang	Wasa Amenfi Central	Western Region	12
		9. Amoamang	Wasa Amenfi Central	Western Region	12
		10. Odaa Anhweam	Wasa Amenfi Central	Western Region	12
		11. Odaa Kuroforom	Wasa Amenfi Central	Western Region	12
		12. Nkakaa	Wasa Amenfi Central	Western Region	12
3	Bibiani Area	13. Nkatieso	Bibiani/Anhwiaso/ Bekwae	Western Region	12
		14. Asawinso Ketuam	Bibiani/Anhwiaso/ Bekwae	Western Region	12
		15. Ntakam	Bibiani/Anhwiaso/ Bekwae	Western Region	12
		16. Abrokofe	Juaboso	Western Region	12
		17. Kwaokrom	Juaboso	Western Region	12
		18. Abono	Juaboso	Western Region	12
4	Dunkwa Area	19. Fiankoma	Amansie Central	Ashanti Region	12
		20. Akutuase	Amansie Central	Ashanti Region	12
		21. Afraso	Amansie West	Ashanti Region	12
		22. Tontokrom	Amansie West	Ashanti Region	12
		23. Bonsaaso	Amansie West	Ashanti Region	12
		24. Yawkasa	Amansie West	Ashanti Region	12
5	Tarkwa Area	25. Wasa Afranse	Wasa Amenfi East	Western Region	12
		26. Wasa Mammieso	Wasa Amenfi East	Western Region	12
		27. Wasa Nkyiase	Wasa Amenfi East	Western Region	12
		28. Wasa Saaman	Wasa Amenfi East	Western Region	12
		29. Wasa Tieku	Wasa Amenfi East	Western Region	12
		30. Wasa Adanse	Wasa Amenfi East	Western Region	12
6	Akim Oda Area	31. Akrofufu	Atiwa	Eastern Region	12
		32. Akwabuoso	Atiwa	Eastern Region	12
		33. Abommosu	Atiwa	Eastern Region	12
		34. Apapam	Abuakwa	Eastern Region	12
		35. Afiesa	Abuakwa	Eastern Region	12
		36. Adadientam	Abuakwa	Eastern Region	12
Total sample size					432

Measuring Household Perception on the implementation of institutional framework for mining

To examine the effect of institutional framework for mining on livelihoods, households were made to score its implementation using a Likert Scale. The summative method introduced by Likert (1932) to measure attitudes, known in research as Likert Scale, is now widely used as a tool in survey research (Weng and Cheng, 2000). It is an essential tool for collecting and analyzing data on attitudes in psychology and social surveys (Dittrich *et al*, 2007). The study examined household perception of the implementation of institutional framework for mining using sets of Likert-scale items measured on a five-point scale of strongly disagree to strongly agree. The summation of Likert-scale scores was taken to compute the perception score for the implementation of the institutional framework (Murray, 2013). The perception score was then used as a regressor in an econometric analysis following Norman's (2010) recommendation. He indicates that parametric tests such as Pearson correlation and regression analysis can be used with Likert-scale data if the sum or mean of scores for a category of items are used to describe the stance for a phenomenon.

Measuring Household Livelihood Vulnerability (HLV) to Small-Scale Mining

Household livelihood vulnerability (HLV) index measures household susceptibility to the risk of mining. This study used indicators in the three major domains of livelihood vulnerability namely: exposure of the risk of mining on household assets and livelihoods, sensitivity to the risk of mining, and adaptive capacity to reduce the risk of mining on household assets and livelihoods, to measure household susceptibility to the stress of mining (Heltberg and Bonch-Osmolovskiy, 2010 and Islam *et al.,* 2014). Seven sub-components of Livelihood vulnerability indicators were grouped under the three major vulnerability domains following Hahn *et al*. (2009). Indicators for exposure domain were selected from the risk of mining on household assets and livelihoods. Indicators for sensitivity domain were selected from households' health, food and water factors that make them susceptible to the risk of mining. Indicators for adaptive capacity domain were selected from socio-economic profile, livelihood strategies and social networks, of households that contribute to reducing the risk of mining on assets and livelihoods. Vulnerability indicators selected under the three domains are listed in Table 2.

Because each of the indicators was measured on a different scale, it was necessary to standardize each as an index by adopting the UNDP (2016a) Human Development Index. Standardized livelihood vulnerability indicator for the *ith* household of the *ith* domain ($zind_i$) was obtained from *Equation 2* as the ratio of the difference of the survey value of the indicator for the *ith* household (ind_i) and the minimum value of that indicator in the survey of households (ind_{min}) to the range of maximum value (ind_{max}) and minimum value (ind_{min}), of the indicator in the survey of households. For indicators that measure percentages, maximum and minimum values were set at 0 (Zero) and 100 (One Hundred) respectively (Hahn *et al., 2009)*. Maximum and minimum values (goalposts) are set in order to transform the indicators into indices between 0 and 1 (UNDP, 2016a, 2016b).

$$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}} \qquad (2)$$

After each of the *j* number of indicators for the *nth* domain was standardized, they were averaged using *Equation 3* to calculate the livelihood vulnerability index for the *ith* household in the *nth* domain.

$$HLV_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J} \qquad (3)$$

Once HLV is constructed in each of the (*n=3)* domains of livelihood vulnerability, the composite overall household livelihood vulnerability index (HLV_{ci}) for the *ith* household is constructed using *Equation 4* by applying a balanced weighted average approach (Sullivan *et al*., 2002).

$$HLV_{ci} = \frac{\sum_{n=1}^{5} w_n HLS_{ni}}{\sum_{n=1}^{5} w_n} \qquad (4)$$

The weight of each of the ($n = 3$) domains (*w*) is determined by the number of indicators that make up the domain and is included to ensure that all indicators contribute equally to the overall household vulnerability index. The household vulnerability index is scaled from 0 (least vulnerable) to 1 (most vulnerable).

Table 2: Indicators under the three domains of livelihood vulnerability

SUB-COMPONENTS OF VULNERABILITY DOMAINS	Indicators of Livelihood Vulnerability	Definition of indicator/index	Standardization/Index for the *ith* household
	EXPOSURE		
Risk of mining on household assets and livelihoods	Percentage of household farming land taken by mining	*Household farming land taken up by mining* / *Household farming land before mining*	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
	Percentage of household agriculture Labour force drifted to mining	*Household adult members drifted to mining who were hitherto engaged in on-farm and off-farm activities* / *Members currently engaged in on-farm and off-farm activities + members who are drifted to mining*	
	Number of on-farm enterprises lost as a result of mining	Number of on-farm income sources lost as a result of mining	
	Number of off-farm enterprises lost as a result of mining	Number of off-farm/processing income sources lost as a result of mining	
	Household access to forest	0=Access to forest for collection of fruits, honey, snail, mushroom, medicinal herbs, weaving materials, wood for carving, etc.: 1=No access to forest	
	Household access to sand and clay deposit for use. 1=No, 0=Yes	0=Household access to sand and clay deposit for use: 1=No access to forest	
	drop-out from JHS resulting from mining	Number of household members under 15 years dropped out from school to engaged in mining	
	drop-out from SHS resulting from mining	Number of household members between15and 18 years dropped out from school to engaged in mining	
	Number of household natural water source polluted by mining	Number of household natural water source polluted by mining	
	Exposure Index	Exposure of the risk of mining on household assets and livelihoods measured on a scale of 0 to 1	$HLV_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$

Table 2 Cont'd: Indicators under the three domains of livelihood vulnerability

SUB-COMPONENTS OF VULNERABILITY DOMAINS	Indicators of Livelihood Vulnerability	Definition of indicator/index	Standardization/Index for the *ith* household
	SENSITIVITY		
Health factors that make household susceptible to the risk of mining	Distance to get to nearest Hospital	Distance to get to nearest Hospital (km)	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
	Percentage of household members with chronic illness	$\frac{\text{Household members with chronic illness}}{\text{Household size}}$	
	Total Number of days where household members had to miss school or work due to illness	Total Number of days in the past six months where household members had to miss school or work due to illness	
	Percentage of household members that do not sleep under mosquito nets	$\frac{\text{Household members that do not sleep under mosquito nets}}{\text{Household size}}$	
	Community is periodically sprayed against mosquitoes	0=community of household is periodically sprayed against mosquitoes 1=Community of household is not sprayed	
Food factors that make household susceptible to the risk of mining	Percentage of household annual food supply from household farm	$\frac{\text{Household annual food requirement from farm}}{\text{Total annual household food requirement}}$	
	Availability of food stock for use in difficult times	0=Household has annual food stock for use in difficult times 1=No food stock	
	Inverse of number of food crops grown by household	$\frac{1}{\text{number of food crops grown by household}}$	
Water factors that make household susceptible to the risk of mining	Access to water resources (streams, rivers, dams, etc.)	0=Household has access to water resources for fishing or farming. 1=Household has no access to water resources	
	Typical time used to fetch water	Minutes used by household in a round trip to fetch water	
	Wholesomeness of rain water in community	0=Rain water is wholesome for domestic purposes by household 1=Rain water is unwholesome	
	Number of water conflict within the last six months	Number of water conflicts emanating from water shortage within the last six months	
	Number of months in year with scarce water sources	Number of months in year where water is scarce	
	Sensitivity index	Susceptibility of household assets and livelihood to the risk of mining measured on a scale of 0 to 1	$HLV_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$

Table 2 Cont'd: Indicators under the three domains of livelihood vulnerability

SUB-COMPONENTS OF VULNERABILITY DOMAINS	Indicators of Livelihood Vulnerability	Definition of indicator/index	Standardization/Index for the *ith* household
	ADAPTIVE CAPACITY		
Household Socio-economic profile contributing to reducing the risk of mining on household assets and livelihoods	Sex of household head	0=Head is male; 1=Head is female	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
	dependency ratio of household	*18 years and above not working + < 18 years* / *18 years and above who are working*	
	Inverse of average number of years spent in school by household adult members	*1* / *average number of years spent in school by household adult members18 years and above*	
	Farming technology mainly practiced by household	0= Modern farming technology practiced 1=Traditional farming technology practiced	
	Inverse of household total livelihood activities	*1* / *Number of household livelihood activities*	
Household livelihood strategies contributing to reducing the risk of mining on household assets and livelihoods	Percentage of household working members mainly engaged in on-farm activities (farming)	*Members mainly engaged in on-farm activities* / *Household working members*	
	Household engagement in off-farm activities	0= engagement in off-farm activities 1=No engagement in off-farm activities	
	Household engagement in non-farm local activities (artisanship and local services)	0= engagement in non-farm activities 1=No engagement in non-farm activities	
	Household engagement in local trade and commerce	0= engagement in local trade & commerce 1=No engagement in local trade & commerce	
	Household engagement in formal employment (salaried work excluding mining)	0= engagement in formal employment 1=No engagement in formal employment	
	Rearing of farm animals by household	0= Farm animals kept by household 1=Farm animals not kept by household	
	Engagement in alternative livelihoods	0= engagement in alternative livelihoods 1=No engagement in alternative livelihoods	
Household Social network contributing to reducing the risk of mining on household assets and livelihoods	Ratio of household annual borrowings to annual savings	*Household annual investment borrowings* / *Household annual savings*	
	Receive per give in the past 12 months	*Number of assistance received by household* / *Number of assistance given by household*	
	Number of living assistance obtained	Number of living assistance obtained by household from others in the last 12 month	
	Adaptive Capacity Index	Household ability to use strategies to reduce risk of mining on household assets and livelihoods measured on a scale of 0 to 1	$HLV_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$
	Household livelihood vulnerability index	**Household susceptibility to the risk of mining measured on a scale of 0 to 1**	$\boldsymbol{HLV_{ci} = \frac{\sum_{n=1}^{5} w_n HLS_{ni}}{\sum_{n=1}^{5} w_n}}$

Source: Authors' construct

Measuring Household Livelihood Security (HLS)

Household Livelihood Security index measures household's access to income and resources to meet its basic needs (Frankenberger 1996; Frankenberger *et al.* (2000). The livelihood security index uses a balanced weighted average approach (Sullivan *et al*., 2002) where each of the security indicators grouped in various domains contributes equally to the overall composite livelihood security index even though each security domain is comprised of a different number of indicators. To ensure that each security domain contributes equally to the overall composite livelihood security index, each domain is weighted by the number of indicators used to construct the index for the domain.

In this study, cross-sectional data on livelihood security indicators were collected from the selected households in the study area, as in Akter and Rahman, 2012; Rahman and Akter, 2010 and broadly grouped under the five livelihood security domains: economic security, food security, health security, education security and empowerment. These indicators listed under the five domains in Table 3 would improve household access to livelihood sources amidst mining activities. Household livelihood security index in each of the five domains were then constructed following the approach used by Akter and Rahman, 2012; Rahman and Akter, 2010.

Since each of the indicators is measured on a different scale, they are standardized by adapting the method used in the Human Development Index approach (UNDP, 2016a). Standardized livelihood security indicator for the *ith* household in the *nth* domain ($zind_i$) was obtained from *Equation 5* as the ratio of the difference of the survey value of the indicator for the ith household (ind_i) and the minimum value of that indicator in the survey of households (ind_{min}) conceived of as a subsistence value (UNDP, 2013) to the range of maximum value (ind_{max}) and minimum value (ind_{min}), of the indicator in the survey of households. For indicators that measure percentages, minimum and maximum values were set at 0 (Zero) and 100 (One Hundred) respectively (Hahn *et al., 2009)*. Minimum and maximum values (goalposts) are set in order to transform the indicators into index between 0 and 1. Increasing values of a livelihood security indicator make the household more secure and vice versa (UNDP, 2016a, and 2016b).

$$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}} \qquad (5)$$

After each of the *j* number of indicators in the *nth* domain of the *ith* household was standardized, they were averaged using *Equation 6* to calculate the household livelihood security (HLS_{ni}) index of the *ith* household in each of the (n=5) domains of livelihood security namely: economic security; food security; health security; education security; and empowerment security (Akter and Rahman, 2012; Lindenberg 2002; Frankenberger *et al*. 2000).

$$HLS_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J} \qquad (6)$$

Once HLS index is constructed in each of the (*n=5*) number of domains of livelihood security, the composite household livelihood security (HLS_{ci}) index for each household is constructed using *Equation 7* by applying a balanced weighted average approach (Sullivan et al., 2002). The balanced weighted average approach makes it possible for each indicator in a domain to contribute equally to the overall index even though each domain is comprised of a different number of indicators.

$$HLS_{ci} = \frac{\sum_{n=1}^{5} w_n HLS_{ni}}{\sum_{n=1}^{5} w_n} \qquad (7)$$

The weight of *nth* domain (w_n) represents the number of indicators in that domain and is included to ensure that all indicators contribute equally to the overall household security index. Both the Human Development Index and the Water Poverty Index are examples of composite indices calculated using weighted averages of individual indicators. The HLS index ranges between 0 and 1; the closer is it to 1 the more secure the household's livelihood is.

Table 3: Indicators under the five domains of household livelihood security

Indicators of Livelihood Security	Definition of indicator/index	Standardization/Index for the *ith* households
Economic		
Per person total annual income of household	$\frac{\text{Total annual livelihood income + Total annual remittance}}{\text{Household size}}$	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
Household agricultural land-man ratio	$\frac{\text{Household farm land}}{\text{Household farming members}}$	
Number of on-farm income enterprises	Number of income enterprises from on-farm activities	
Household Agricultural labour force	*Household members, 18 years and above, engaged in either on-farm or off-farm livelihood activities or both*	
Per person current value of household livestock (Cedis)	$\frac{\text{Market value of livestock + Market value of poultry}}{\text{Household size}}$	
Per person current value of household productive assets (Cedis)	$\frac{\text{Present value of household productive asset}}{\text{Household size}}$	
Per person current value of household basic living asset (Cedis)	$\frac{\text{Present value of household basic living asset}}{\text{Household size}}$	
Percentage of household active population per household size	$\frac{\text{Number of household members between 18 \& 60years}}{\text{Household size}}$	
Percentage of household active population (18-60 yrs) in employment	$\frac{\text{Number of household active members who are working}}{\text{Number of household active members}}$	
Average Household monthly income earned by women (Cedis per person)	$\frac{\text{Monthly livelihood \& remittance income earned by women}}{\text{Number of household women between 18 and 60 years}}$	
Per person current household annual investment loan (Cedis)	$\frac{\text{Total household annual investment borrowing}}{\text{Household size}}$	
Per person current household annual savings (cedis)	$\frac{\text{Total household annual savings}}{\text{Household size}}$	
Household Economic Security Index	Household economic security measured on a scale of 0 to 1	$HLS_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$
HEALTH		
Percentage of household members not suffered from diarrhoea within last 30 days	$\frac{\text{Household members not suffered from diarrhea}}{\text{Household size}}$	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
Percentage of household members not suffered from malaria within last 3 weeks	$\frac{\text{Household members not suffered from malaria}}{\text{Household size}}$	
Percentage of household members not suffered from other sickness within last 30 days	$\frac{\text{Household members not suffered from other sickness}}{\text{Household size}}$	
Household access to approved refuse dump	1= Access to approved refuse dump 0=No access to approved refuse dump	
Household access to improved and hygienic latrines	1= Access to improved and hygienic latrines 0=No access to improved and hygienic latrines	
Household access to Hand-dug wells or improved water systems	1= Access to hand-dug wells/improved water systems 0=No access to hand-dug wells/improved water systems	
Household access to clinics within 5km radius	1= Access to clinics within 5km radius 0=No access to clinics within 5km radius	
No. of health education programmes received by household per Year	No. of health education programmes received by household per Year	
Household Health Security Index	Household health security measured on a scale of 0 to 1	$HLS_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$

Table 3 Cont'd: Indicators under the five domains of household livelihood security

Indicators of Livelihood Security	Definition of indicator/index	Standardization/Index for the *ith* households
FOOD		
Dietary diversity	How many of the following food groups consumed per day by household: Meat/egg; Fish; Beans; Fruits; Vegetables; Fats & Oils; Plantain/Root & Tuber/Cereals?	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
Food frequency of household	Number of meals +snacks per day in household	
Average value of household annual food stock (Cedis per person)	$\frac{\text{Market value of household annual food stock}}{\text{Household size}}$	
Household staple food sufficiency	Number of months of household annual staple food supply from household farm in a year	
Food frequency of women	Number of main meals taken by women in household per day	
Household Food Security Index	Household Food Security measured on a scale of 0 to 1	$HLS_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$
EDUCATION		
Educational level of household head	Years in education attained by household head	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
Percentage Primary school enrolment	$\frac{\text{6-12 years members enrolled in Primary School}}{\text{6-12 years members of household}}$	
Percentage Jnr. High School enrolment	$\frac{\text{13-15 years members enrolled in Jnr. High School}}{\text{13-15 years members of household}}$	
Percentage Snr. High School enrolment	$\frac{\text{16-18 years members enrolled in Snr. High School}}{\text{16-18 years members of household}}$	
Percentage of adult with at least basic education	$\frac{\text{18 years or more who have at least 9 years in education}}{\text{Household members who are 18 years or more}}$	
Percentage of adult literacy	$\frac{\text{18 years or more who can read and write}}{\text{Household members who are 18 years or more}}$	
Household access to school within 5km radius	1=Access to school within 5km radius 0=No access to school within 5km radius	
Average years spent in school by adult household members	$\frac{\text{Total years spent in school by members 18 years or more}}{\text{Total household members who are 18 years or more}}$	
Household Education Security Index	Household Education Security measured on a scale of 0 - 1	$HLS_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$
EMPOWERMENT		
No. of social amenities in community	Number of social amenities such as market, electricity, community centre etc. in mining community	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
Household access to social amenities/services in community	1=Access to social amenities 0=No access to social amenities	
Number of forums/durbars on mining per year	Number of forums/durbars held to discuss mining issues in the community	
Household participation in planning community developmental projects	1=Household participates in planning projects 0=No participation by households	
Presence of community liaison committees for mining activities	1= Presence of liaison committees on mining 0=No liaison committees on mining	
Household empowerment security Index	Household empowerment security measured on a scale of 0 to 1	$HLS_{ni} = \frac{\sum_{J=1}^{J} zind_{ni}}{J}$
Household livelihood security Index	**Household Livelihood Security measuring household's access to income and resources to meet its basic needs on a scale of 0 to 1**	$\boldsymbol{HLS_{ci} = \frac{\sum_{n=1}^{5} w_n HLS_{ni}}{\sum_{n=1}^{5} w_n}}$

Source: Authors' construct

Measuring Household Livelihood Diversity (HLD)

Though several indices have been constructed to measure livelihood diversification, including Simpson index, Herfindahl index, Ogive index, Entropy index, Modified Entropy index, Composite Entropy index (Shiyani and Pandya, 1998), Simpson Index of Diversification (SID) has been adopted for this study to generate the extent of income and livelihood diversification among households, because of its computational simplicity, robustness and wider applicability (Sujithkumar, 2007; Fabusoro *et al.,*2010; Saha and Bahal, 2011; Khatun and Roy, 2012). The Simpson index is a dominance index because it gives more weight to common or dominant income sources. In this case a few rare income sources, with only a few incomes, does not affect the diversity. It takes into account both the strength of income sources, and an evenness of income distribution among the income sources. The original diversity equation derived by Simpson (1949) as in *Equation 8* has been modified and applied by several authors as the inverse (1/D) or the difference from 1 (1-D). This study used the difference from 1 approach (Fabusoro *et al*., 2010) as indicated in *Equation 9* to measure livelihood security (HLD). The index provides clear dispersion of income generated from livelihood activities and ranges between zero and one. The index moves towards 1 when complete diversification is achieved. The value of HLD is a proportion of household's involvement in other income generating activities on a scale of 0 to 1.

$$D = \frac{\sum_{i=1}^{s} n_i(n_i-1)}{N(N-1)} \qquad (8)$$

$$HLD_i = 1 - \frac{\sum_{j=1}^{s} n_{ij}\,(n_{ij}-1)}{N_i(N_i-1)} \qquad (9)$$

Where:
HLD_i = Household Livelihood Diversity Index for the *ith* household.
S = number of livelihood portfolios (income sources) for the *ith* household
n_i = annual household income generated from the *jth* income source of the *ith* household
N_i = Total annual household livelihood income generated from all livelihood portfolios (income sources) of the *ith* household outlined in Table 4.

A complete enumeration of livelihood portfolios (income sources) for the selected households was classified into 8 categories (income-generating sources) and fitted into the livelihood diversity index as in Table 4.

Analytical Framework

The data set was analyzed using descriptive and inferential statistics. The characteristics of respondents were summarized using descriptive statistics including arithmetic mean, standard deviation, minimum, maximum, frequencies and percentages. Determinants of household livelihood vulnerability to the risk of mining, household livelihood security and diversity were estimated simultaneously in a system of structural equations using the three-stage least squares approach.

Estimating the parameters of livelihood equations using Three-Stage Least Squares Approach

Current research on household livelihoods is characterized by the use of single-regression equation models to estimate the determinants of household livelihood vulnerability (HLV), household livelihood security (HLS) and household livelihood diversity (HLD) separately using ordinary least squares (OLS) in independent equations. From a statistical point of view, the use of single independent equation approach of estimating predictors of individual dimensions of livelihood that correlate with each other is inefficient (Judge *et al*., 198 8). Zellner and Theil (1962) recommend the use of a system of simultaneous equation model to estimate predictors of a system characterized by a series of regression equations which influence one another.

This study uses the simultaneous equation estimation approach to bridge the gap of research inefficiency of using single-regression equation models in separately predicting the key dimensions of livelihoods which are interrelated. This approach allows for an examination of the whole system of rural livelihoods with more than one multiple regression equation (Zellner and Theil, 1962; Prozzi and Hong, 2008; Anastasopoulos *et al.,* 2012).

One of the most important methods of analyzing systems estimation models is the three-stage least squares (3SLS) approach which is an appropriate estimation method when disturbances in the simultaneous equations are contemporaneously correlated (Waidler *et* al, 2014). The 3SLS approach was chosen against other simultaneous estimation approaches such as seemingly unrelated regression (SURE), two-stage least squares (2SLS) and multivariate regression (MVR) since it has the best predictive power and generate most efficient parameter estimates (Washington *et al*, 2011; Waidler *et* al., 2014). The 3SLS is an extension of the 2SLS method. The 2SLS approach consists of two steps, namely; the

Table 4: Livelihood portfolio/diversity of agrarian households

Household Livelihood Portfolio/Diversity	Definition of portfolio	Component of Simpson Index of diversity
Annual household income generated from (on-farm) crop production	Production of arable crops, vegetables and tree crops	$(n_{j=1})$
Annual household income generated from (on-farm) livestock production	Production of livestock, poultry and fish	$n_{j=2}$
Annual household income generated from alternative livelihood in non-traditional agriculture	Engagement in non-traditional agricultural production such as mushroom production, honey production, grasscutter rearing, snail production etc.	$n_{j=3}$
Annual household income generated from off-farm/processing activities	Engagement in processing (cassava, oil palm); Farm labor; Hunting; collecting (honey, wild fruits, firewood, medicinal herbs); Milling (rice); grinding (pepper); brewing; baking; processing food for sale	$n_{j=4}$
Annual household income generated from non-farm local activities (artisanship and local services)	Engagement in Transportation, Carpentry/furniture, Tailoring, Mechanic, Welding, construction, brick making, metalworking, Traditional medicine, Shoe making, Rentals, Barbaring, Blacksmith, Clergy work, Islamic teaching, Vulcanizing, Butchery, weaving, sewing, craftwork, carving, tapping and distillation of palm wine	$(n_{j=5})$
Annual household income generated from local trade and commerce	Engagement in Sale of processed agricultural products, Sale of used cloths, Food vending, Water trading	$n_{j=6}$
Annual household income generated from formal employment (salaried work) excluding mining	Engagement in Unskilled manual jobs, skilled manual jobs other than mining	$n_{j=7}$
Annual household income generated from mining	Skilled and unskilled salaried jobs in mining and mining related jobs	$n_{j=8}$
Number of household livelihood portfolio	Total number of livelihood portfolio	S
Total household annual income from all livelihood portfolios	Total household annual income generated from all livelihood portfolios	N
Household Livelihood Diversity (HLD) Index	LDI is a measure of the proportion of household's involvement in other income generating activities on a scale of 0 to 1	$HLD_i = 1 - \frac{\sum_{j=1}^{s} n_{ij}\ (n_{ij} - 1)}{N_i(N_i - 1)}$

Source: Authors' construct

estimation of the moment matrix of the reduced form of the simultaneous equations, and the estimation of the coefficients of one single structural equation after its reduction. Models estimated by MVR tend to have better significant parameters and predictive power than that of 3SLS for small sample sizes (n ≤ 60). On the

other hand, the 3SLS performs better if the sample size is considerably large (n ≥ 60), in this case the parameters of the 3SLS become more significant than that of MVR (Udoumoh *et al*, 2016).

Predictors of livelihood vulnerability, security and diversity, which are the three key interrelated livelihood dimensions, were estimated using the structural equations specified in equations 10, 11 and 12.

$$HLS_{ci} = \alpha_{1i} + \lambda_1 HLD_i + \beta_1 X_i + \varepsilon_{1i} \quad (10)$$

$$HLV_{ci} = \alpha_{2i} + \Upsilon_1 HLS_{ci} + \lambda_2 HLD_i + \beta_2 X_i + \varepsilon_{2i} \quad (11)$$

$$HLD_i = \alpha_{3i} + \Upsilon_2 HLS_{ci} + \beta_3 X_i + \varepsilon_{3i} \quad (12)$$

Where HLD_i, HLS_{ci}, used also as endogenous explanatory variables, and HLV_{ci} are the dependent variables representing household livelihood diversity index, household livelihood security index and household livelihood vulnerability index respectively, X is a vector of exogenous variables representing household socio-economic and institutional characteristics. The $\varepsilon_{1,}\ \varepsilon_{2,}\ \varepsilon_3$ represent the disturbance terms which are assumed to be correlated in the system of simultaneous equations, while $\alpha, \Upsilon, \lambda \text{ and } \beta$ are vectors of parameters to be estimated. The estimation technique was a built-up upon the OLS model used by Hahn, 2009; Rahman and Akter, 2010; Fabusoro *et al.* 2010; Akter and Rahman, 2012; Khatun and Roy 2012) to estimate the determinants of livelihood security, vulnerability and diversity.

In the first stage of the 3SLS approach, regression estimates were obtained using OLS, by regressing each endogenous dependent variable on all exogenous variables, and by using the regression-predicted values as instruments to estimate the 2SLS parameters. In the second stage, the contemporaneous (cross-equation) variance-covariance matrix of disturbances (the relationship between $\varepsilon_{1,}\ \varepsilon_{2,}\ \varepsilon_3$) was determined by using the 2SLS parameter estimates to compute residuals. In the third and last stage, generalized least-squares (GLS) technique was applied to estimate the 3SLS model parameters by using the contemporaneous variance-covariance matrix of the disturbances (error term) to obtain the transformation of the original variables for the application of the generalized least-squares (GLS) (Washington *et al*, 2011Udoumoh *et al*, 2016).

The order condition that makes the equations to be identified under the systems estimation method was satisfied by excluding from each equation a total number of all variables which is equal to or greater than the number of endogenous variables in the equation system minus one.

RESULTS AND DISCUSSION

The study has been conducted to predict the key dimensions of livelihoods of agrarian households in small-scale mining communities to provide information for policy direction on ways of streamlining rural livelihoods. This may harmonize the coexistence between small-scale mining and rural livelihoods to promote livelihood development for agrarian households whilst sustaining mining for the development of the national economy. The ensuing sections discuss the results of the study.

Socioeconomic Characteristics of Agrarian Households

The socio-economic background of agrarian households in small-scale mining communities are summarized in Tables 5a and 5b under the five major groups of household livelihood assets categorized by Fabusoro *et al*. (2010) and DFID (1999). Agrarian households in the small-scale mining communities had poor human capital characterised by aging farming household members with increasing farming experience and poor agricultural extension contact. The average farming experience for a household was 18.68 years. As indicated in Table 5b, 56.9% of the households did not receive any extension service. Agrarian households never participated in planning community interventions in the small-scale mining communities as 74% of them were not given such opportunity. They, however, were able to establish direct linkages with mining authorities to improve on their social capital needed to address problems emanating from mining. Majority of them, representing 69%, had direct linkages with mining authorities to present their grievances on mining activities. Majority of agrarian households, representing 63% and 84% respectively, had access to forest and community arable land bank which provided natural capital to facilitate livelihood activities. They had poor access to physical capital needed to pursue livelihood activities. Households had to travel, on average, up to a distance of 11.02km to access major roads, markets, Agricultural Extension Offices and agricultural input shops. Community radio was, however, available to majority (93%) of the households. Majority of them, representing 84.4%, pursued farming as their major source of income with an average household farm size

Table 5a: Quantitative Statistical Summary of Household Socio-economic Characteristics

Household Assets	Statistics (N=432)			
	Min	Max	Mean	Std. Dev.
Human Capital of Household				
Age of Household Head	23.0	85.0	48.73	13.039
Average farming experience (in years) of farming members	1.0	60.0	18.68	11.028
Physical Capital of Household				
Household distance to major road in km	0.2	30.0	6.69	6.782
Household distance to nearest market in km	0.2	65.0	11.02	15.346
Household distance to nearest Agricultural Extension Office (km)	0.5	48.0	9.72	8.106
Household distance to nearest Agricultural input Shop in km	0.2	18.0	3.6	3.870
Financial Capital of Household				
Total Farm size in acres	0.5	40.0	8.74	6.870
Average farm size of household farming members in acres	0.5	20.0	4.68	3.714

Source: Computed from survey data, 2017

Table 5b: Qualitative Statistical Summary of Household Socio-economic Characteristics

Household Assets	Category	Statistics (N=432)	
		Freq.	%
Household Human Capital			
Sex of household head	Male	347	80.3
	Female	85	19.7
	Total	432	100
Household agricultural extension contact	Contact	186	43.1
	No contact	246	56.9
	Total	432	100
Household Social Capital			
Household participation in planning community interventions	Participation	111	25.7
	No participation	321	74.3
	Total	432	100.0
Household linkages to mining authorities	Linkage	298	69.0
	No linkage	134	31.0
	Total	432	100.0
Household Natural Capital			
Household access to forest for collection of fruits, honey, snail, mushroom, medicinal herbs, weaving materials, wood for carving etc.	Access	273	63.2
	No access	159	36.8
	Total	432	100
Household access to community arable land bank for producing household staple food	Access	364	84.3
	No access	68	15.7
	Total	432	100
Household Physical Capital			
Household access to Community Radio/Information Center	Access	402	93.1
	No access	30	6.9
	Total	432	100
Household Financial Capital			
Major livelihood portfolio pursued by households	Mining and mining related activities	67	15.5
	Farming	365	84.4
	Total	432	100

Source: Survey data, 2017

of 4.6 acres. Only 15% of the household pursued small-scale mining and its related activities as their major source of livelihood.

Household Perception on the Implementation of Institutional Framework for Mining

Institutional framework constrains human activities in accordance with social rules (Mehta *et al*. 1999). The study assesses household perception on the implementation of the institutional framework for mining on a five-point Likert Scale ranging from 1 to 5. The scale measures strongly disagree, disagree, neutral, agree and strongly agree respectively and summarizes the results in Tables 6. Agrarian households in small-scale mining communities had negative perception on the implementation of the institutional framework for mining which comprises regulatory framework and livelihood interventions. Six major categories of livelihood interventions namely: agricultural livelihood interventions, livelihood restoration interventions, economic development and poverty reduction interventions, educational interventions, health interventions and water and sanitation interventions, as part of the social rules that structure mining activities, were poorly implemented.

Table 6: Summary of mean perception scores for the implementation of institutional framework of mining

Institutional Framework of Mining	Household mean Perception Scores: Strongly Disagree (1) to Strongly Agree (5) N=432			
	Min	**Max**	**Mean**	**Std. Dev.**
Mean perception Score for regulatory framework of mining	1.9	3.3	2.20	0.375
Mean perception score for agricultural livelihood interventions	1.0	3.0	1.10	0.258
Mean perception score for livelihood restoration interventions	1.0	3.0	1.67	0.342
Mean perception score for economic development and poverty reduction interventions	1.0	4.5	1.76	0.649
Mean perception score for education interventions	1.0	4.3	2.13	0.437
Mean perception score for health interventions	1.0	3.0	1.87	0.741
Mean perception score for water and sanitation intervention	1.0	3.0	1.87	0.246
Overall mean perception Score for implementation of institutional framework of mining	**1.1**	**2.8**	**1.80**	**0.224**

Source: Computed from Survey Data, 2017

Indices of Livelihood dimensions

Three key dimensions of household livelihoods were measured and examined in the small-scale mining communities using livelihood indices. Livelihood vulnerability index, livelihood security index, and livelihood diversity index were used to measure household livelihood vulnerability to small-scale mining, household livelihood security, and diversity respectively.

Livelihood Vulnerability Index and vulnerability to small-scale mining

Livelihood vulnerability Index measures household susceptibility to stresses emanating from natural disasters or human economic activities (Hahn *et al.* 2009). Livelihood vulnerability index ranges between 0 and 1 such that the closer it is to 1 the more vulnerable the household's livelihood is to the risk (Islam *et al,* 2014). Following the categorization of vulnerability by Heltberg and Bonch-Osmolovskiy (2010), household vulnerability to the stress of small-scale mining was examined in this study under three major domains: exposure of the risk of mining to household; household sensitivity to the risk of mining; and adaptive capacity of household to reduce the risk of mining by adapting the UNDP Human Development Index (UNDP, 2016a&b).

Indicators that measure households' susceptibility to the stress of mining were examined under the three major domains and used to work out household vulnerability index for each household. Summary statistics of the indicators are exhibited in Table 7. Indicators under exposure domain measured the exposure of the risk of mining on household assets

Table 7: Summary of indicators under the domains of livelihood Vulnerability

Sub-components of vulnerability domains	Indicators of household livelihood Vulnerability	Statistics N=432			
		Min	Max	Mean	Std. Dev.
	Exposure domain				
Risk of mining on household assets and livelihoods	Percentage of household total farming land taken by mining	0.00	100.00	4.43	11.152
	Percentage of household agricultural Labour force drifted to mining	0.00	66.67	8.95	11.152
	Number of on-farm enterprises (income sources) lost as a result of mining	0.00	10.00	0.51	1.265
	Number of off-farm/processing income enterprises (sources) lost as a result of mining	0.00	1.00	0=01	0.083
	Household access to forest for collection of fruits, honey, snail, mushroom, medicinal herbs, weaving materials, wood for carving, etc. 1=No, 0=Yes	0.00	1.00	0.37	0.483
	Household access to sand and clay deposit for use. 1=No, 0=Yes	0.00	1.00	0.22	0.416
	Number of household members under 15 years actively engaged in mining (drop-out from JHS)	0.00	2.00	0.01	0.128
	Number of household members between 15 and 18 years actively engaged in mining (drop-out from SHS)	0.00	1.00	0.02	0.124
	Household natural water source is polluted by mining. 1=Yes, 0= No	0.00	1.00	0.95	0.225
	Sensitivity domain				
Health factors that make household susceptible to the risk of mining	distance to get to nearest Hospital (km)	0.15	18.00	2.21	3.07
	Percentage of household members with chronic illness	0.00	90.00	1.99	8.779
	Total Number of days in the past six months where household members had to miss school or work due to illness	0.00	180.00	13.36	28.485
	Percentage of household members that do not sleep under mosquito nets	0.00	100.00	49.36	45.303
	Community is periodically sprayed against mosquitoes. 1=No, 0=Yes	0.00	100.00	0.98	0.143
Food factors that make household susceptible to the risk of mining	Number of months of household annual food not from household farm	0.00	12.00	0.48	2.494
	Household farm as major source of household staple food 1=Yes, 0=No	0.00	1.00	0.83	0.373
	Availability of food stock for use in difficult times: 1=No, 0=yes	0.00	1.00	0.16	0.371
	Inverse of number of food crops grown by household	0.10	1.0	0.28	0.190
	Typical time (minutes) used to fetch water	1.00	90.00	17.38	14.31
	River/Stream is wholesome for domestic purposes. 1=No, 0=Yes	1.00	0.00	0.99	0.083
	Rain water is wholesome for domestic purposes. 1=No, 0=Yes	1.00	0.00	0.08	0.273
	Number of water conflict within the last six months	0.00	90.00	1.19	5.346
	Number of months in year with scarce water sources	0.00	10.00	0.53	1.304

Table 7 Cont'd: Summary of indicators under the domains of livelihood vulnerability

Sub-components of vulnerability domains	Indicators of household livelihood Vulnerability	Statistics N=432			
		Min	Max	Mean	Std. Dev.
	Adaptive Capacity domain				
Household Socio-economic profile contributing to reducing the risk of mining on household assets and livelihoods	Sex of household head: 1=female, 0=male	0.00	1.00	0.17	0.380
	dependency ratio of household	0.00	9.00	1.78	1.254
	Percentage of active members (18 years and above) who are unemployed	0.00	87.00	18.03	22.825
	percentage of household livelihood income from farming (crop, livestock, fish)	0.002	100.00	61.04	31.986
	Inverse of average number of years spent in school by household adult members 18 years and above	0.06	10.00	0.60	2.027
	Farming technology mainly practiced by household: 1=Traditional, 0=modern	0.00	1.00	0.98	0.143
	Inverse of household total agricultural livelihood portfolios	0.33	1.0	0.62	0.231
Household livelihood strategies contributing to reducing the risk of mining on household assets and livelihoods	Percentage of household working members engaged in on-farm activities (farming)	33.33	100.00	89.39	19.80
	Household engagement in off-farm activities: 1=No, 0=Yes	0.00	1.00	0.86	0.344
	Household engagement in non-farm local activities (artisanship and local services):1= No, 0=Yes	0.00	1.00	0.74	0.441
	Household engagement in local trade and commerce: 1= No, 0=Yes	0.00	1.00	0.54	0.500
	Household engagement in formal employment (salaried work excluding mining): 1= No, 0=Yes	0.00	1.00	0.93	0.262
	Rearing of farm animals by household: 1=no animals kept, 0=animals are kept	0.00	1.00	0.29	0.455
	Engagement in alternative livelihood in non-traditional agriculture: 1=No, 0=Yes	0.00	1.00	0.99	0.048
Household Social network contributing to reducing the risk of mining on household assets and livelihoods	Ratio of household annual borrowings to annual savings	0.00	50.00	1.25	6.409
	Receive per give in the past 12 months (in terms of number)	0.00	20.00	1.24	2.081
	Number of living assistance obtained from mining organization in 12 month	0.00	0.00	0.00	0.000

Source: Computed from survey data, 2017

and livelihoods. Indicators under sensitivity domain are health, food and water factors that measured household susceptibility to the risk of mining. Indicators under adaptive capacity domain are household socio-economic profile, household livelihood strategies, and household social network that measured household capacity to reduce the risk of mining on household assets and livelihoods. Indicators with higher values contributed to building a higher livelihood vulnerability index and made households more vulnerable. Standardized values of these indicators were used to work out livelihood vulnerability index under each domain of vulnerability

and the composite household livelihood vulnerability (HLV_c) index for each household.

The exposure of the risk of small-scale mining on household assets and livelihoods, measured by the mean exposure index shown in Table 8, was as low as 0.2301 on a scale of 0 to 1. Households' sensitivity to the risk of mining, measured by the mean sensitivity index of 0.3270 and adaptive capacity, measured by a mean value of 0.4560 contributed greatly to making households vulnerable to small-scale mining. The net effect of the three sub-vulnerability indices gave rise to a mean composite household livelihood vulnerability (HLV_c) index of 0.3636 with a maximum value of 0.549. The adaptive capacity and the sensitivity indices were the major contributors to the composite livelihood vulnerability index making households more vulnerable to the risk of mining. Though the mean HLV_c suggests that households were generally less vulnerable to the risk of mining, the maximum value implies that some households were moderately vulnerable and can only cope with the risk of small-scale mining after receiving livelihood interventions (Thabane, 2015).

Households were sensitive to the risk of small-scale mining due to poor health, food and water factors that made them susceptible to the risk of mining. Weak socio-economic profile, poor livelihood strategies and social network of households weakened their adaptive capacity to reduce the risk of mining on household assets and livelihoods.

Table 8: Household Livelihood Vulnerability (HLV) Indices

Household Livelihood Vulnerability Domain	Household Livelihood Vulnerability (HLV) Index N=432			
	Min	**Max**	**Mean**	**Std. Dev.**
Exposure Index	0.000	0.625	0.2301	0.10445
Sensitivity Index	0.169	0.523	0.3270	0.07253
Adaptive Capacity Index	0.210	0.792	0.4560	0.97134
Composite Livelihood Vulnerability (HLV_c) Index	0.226	0.549	0.3636	0.06170

Source: Computed from Survey Data, 2017 *Low vulnerability = $HLV_c < 0.43$: coping or resilient household; Moderate vulnerability = $0.43 \leq HLV_c \leq 0.75$: household can cope after receiving assistance; High vulnerability $HLV_c > 0.75$: household requires special intervention to attain livelihood security (Thabane, 2015)*

Livelihood Security Index and livelihood security of agrarian households

Household livelihood security (HLS) index is a measure of household livelihood security status of a household and ranges between 0 and 1 such that the closer it is to 1 the more secure the household's livelihood is (Akter and Rahman (2012), Rahman and Akter (2010). Following Akter and Rahman (2012); Lindenberg (2002); Frankenberger *et al*. (2000), five major household livelihood security domains: economic security; food security; health security; educational security; and empowerment security were used to construct the livelihood security index for agrarian households affected by small-scale mining activities by adapting the UNDP Human Development Index (UNDP, 2013, 2016a&b). Livelihood security indicators outlined in Table 9 were used to measure livelihood security status of agrarian households in small-scale mining communities. Indicators with higher values contributed to building a higher livelihood security index and vice-versa. Standardized values of these indicators were used to work out livelihood security index for each household.

The summary statistics of the five sub-livelihood security indices and the composite index is highlighted in Table 10. The mean and the minimum values of household economic security indicators, as seen in Table 9, indicate low economic status of agrarian households in small-scale mining communities. This observation resulted in poor average household economic security index of 0.1688 exhibited in Table 10. Economic security was the weakest of the five sub-livelihood security indices resulting probably from the combined effect of perceived poor implementation of agricultural livelihood, economic development, poverty reduction and livelihood restoration interventions in Table 6 designed to improve the economic status and

Table 9: Summary of indicators under the five major domains of livelihood security

Indicators of household livelihood security	Statistics N=432			
	Min	Max	Mean	Std. Dev.
Economic Domain				
Per person total annual income of household in Cedis	28.75	52883.33	3603.67	5711.993
Household agricultural land-man ratio	0.00	28.00	4.97	4.164
Number of on-farm income enterprises	3.0	7.0	4.98	0.987
Household agricultural labour force	1.00	5.00	2.76	0.513
Per person current value of household livestock and poultry (Cedis)	0.00	3125.00	175.41	337.064
Per person current value of household productive assets (Cedis)	5.83	45500.00	6300.65	6922488
Per person current value of household basic living asset (Cedis)	0.143	3087.50	192.504	319.911
Percentage of household active population (18-60 years) per household size	13.33	100.00	54.92	22.126
Percentage of household active population (18-60 years) in employment	12.50	100.00	81.97	22.825
Average Household monthly income earned by women (Cedis per person)	0.00	6000.00	244.16	450.471
Per person current household investment loan (Cedis)	0.00	10000.00	135.28	764.922
Per person current household savings (cedis)	0.00	26666.67	469.59	1930.827
Health Domain				
Percentage of household members not suffered from diarrhoea within last 30 days	0.00	100.00	87.27	22.020
Percentage of household members not suffered from malaria within last 3 weeks	0.00	100.00	72.27	27.863
Percentage of household members not suffered from other sickness within last 30 days	0.00	100.00	81.46	31.983
Household access to approved refuse dump:1= Access, 0=No access	0.00	1.00	0.89	0.311
Household access to improved and hygienic latrines: 1= Access, 0=No access	0.00	1.00	0.59	0.491
Household access to Hand-dug wells or improved water systems:1=Access, 0=No	0.00	1.00	0.98	0.126
Household access to clinics within 5km radius:1=Access,0=No access	0.00	1.00	0.84	0.370
No. of health education received by household per Year	0.00	6.00	0.58	1.082
Food Domain				
Dietary diversity: number of food groups consumed per day: (i.e Meat/egg, Fish, Beans, Fruits, Vegetables, Fats & Oils, Plantain/Root & Tuber/Cereals)	3.0	7.0	4.98	0.987
Food frequency (number of meals and snacks per day)	1.00	5.00	2.80	0.473
Average value of household annual food stock (Cedis per person)	0.00	20333.33	324.73	1472.571
Number of months of household annual staple food supply from household farm in a year	0.00	12.00	9.477	2.516
Number of main meals taken by women in household per day	1.00	5.00	2.76	0.513
Education Domain				
Percentage of 6-12 years children enrolled in Primary School	0.00	100.00	94.18	19.632
Percentage of 13-15 years children enrolled in Junior High School (JHS)	0.00	100.00	80.11	39.214
Percentage of 16-18 years children enrolled in Senior High School (SHS)	0.00	100.00	40.17	47.844
% of adult members 18 years or more who have 9 years or more of education	0.00	100.00	58.09	36.438
Percentage of adult members 18 years or more who can read and write (literacy)	0.00	100.00	46.04	37.891
Access to school within 5km radius: 1=Access, 0=No access	0.00	100.00	0.99	0.960
Empowerment Domain				
No. of community Developmental amenities obtained from mining	0.00	4.00	0.63	0.868
Household access to developmental amenities or services obtained from mining:1=Access, 0.5= No access, 0= No amenity	0.00	1.00	0.40	0.91
Number of forums/durbars with mining company per year	0.00	4.00	0.19	0.606
Household participation in planning community developmental projects: 1=Participation, 0=No participation	0.00	1.00	0.26	0.437
Presence of community liaison committees for mining activities: 1=Yes, 0=No	0.00	1.00	0.83	0.375

Source: Computed from survey data, 2017

Table 10: Household Livelihood Security (HLS) Indices

Household Livelihood Security Domain	Household Livelihood Security (HLS) Index N=432			
	Min	Max	Mean	Std. Dev.
Economic Security Index	0.065	0.587	0.1688	0.56923
Health Security Index	0.250	1.000	0.7269	0.14556
Food Security Index	0.150	0.751	0.4382	0.09630
Education Security Index	0.196	0.992	0.6212	0.18570
Empowerment Security Index	0.000	1.000	0.3093	0.22412
Composite Household Livelihood Security (HLS_c) index	0.247	0.659	0.4356	0.06749

Source: Computed from Survey Data, 2017

Low security = HLS <0.259; moderate security = 0.259 ≤ HLS≤0.420; High security = HLS >0.420 (Barela et al. 2018)

enhance livelihood of households (Robinson, 2011). The major contributors to HLS in small-scale mining communities were health, education and food securities with mean indices of 0.7269, 0.6212 and 0.4382 respectively. The mean composite household livelihood security (HLS_c) index, which shows the combined effect of all the five sub-security indices exhibited in Table 10, is 0.4356 with a minimum value of 0.247. The mean value suggests that though livelihoods of agrarian households in small-scale mining communities were moderately secure, the minimum value is an indication that some households had low livelihood security (Barela *et al*. 2018).

Livelihood portfolio, diversification and Diversity Index of agrarian households

Household Livelihood Diversity (HLD) index adapted from Simpson Index of Diversification (SID) is a measure of household ability to broaden livelihood portfolio and to diversify income sources (Khatun and Roy, 2012). It provides an index of household livelihood portfolio which, according to Cinner and Bodin (2010), is frequently viewed as a critical component of household economies in developing countries. HLD index ranges between 0 and 1with values close to 0 implying that the household relies mainly on one source of income while 1 means that income of such household is perfectly diversified (Sujithkumar, 2007; Fabusoro *et al.,* 2010; Saha and Bahal, 2011).

A complete enumeration of livelihood activities in the small-scale mining communities was classified into 8 categories of income sources in the study following Fabusoro *et al. (*2010); Saha and Bahal (2011). These income sources characterizing the livelihood portfolios of the enumerated households have been summarized in Table 11. The mean annual income from each income source as well as mean total income from all livelihood sources are shown in the table. It is observable from the table that on-farm activities involving crop production emerged the major livelihood income source for households in small-scale mining communities. This observation is consistent with Diao (2010) who established that agriculture, particularly crop production, remains a dominant economic activity for rural households in Ghana. Data on household livelihood incomes was used to measure Household Livelihood Diversity (HLD) index for each household. The mean HLD index of 0.3357 shown in Table 11 puts households under medium level of diversification while maximum HLD index of 0.734 put some households under high level of diversification. The minimum HLD index of 0.000 put some households under no diversification while no household was found under very high diversification. While some households diversified their income sources, indicated by the mean and maximum values, others lived on one income source, basically on-farm activities in crop production, as suggested by the minimum value of 0.00. The trend establishes that agrarian households in small-scale mining communities could not generally diversify livelihoods by constructing enough portfolios to supplement on-farm activities that were exposed to the devastating effect of mining.

Table 11: Household livelihood income (in '000 of Cedis) and Household HLD Index

Household Livelihood Income Sources	Household Livelihood Income and Diversity (HLD) Index N=432			
	Min	**Max**	**Mean**	**Std. Dev.**
Annual household income generated from on-farm; crop production (arable crops, vegetables and tree crops) **(n_1)**	0.05	133.25	8.753	13.3705
Annual household income generated from on-farm; livestock, poultry and fish production **(n_2)**	0.00	2.50	0.189	0.3939
Annual household income generated from alternative livelihood in non-traditional agriculture **(n_3)**	0.00	7.40	0.017	0.3561
Annual household income generated from off-farm/processing activities **(n_4)**	0.00	24.00	0.299	1.4590
Annual household income generated from non-farm local activities (artisanship and local services) **(n_5)**	0.00	84.00	1.146	4.8886
Annual household income generated from commerce **(n_6)**	0.00	72.00	1.893	4.8074
Annual household income generated from formal employment (salaried work) excluding mining **(n_7)**	0.00	31.20	0.707	3.0957
Annual household income generated from mining **(n_8)**	0.00	150.00	5.162	19.3362
Number of household livelihood income sources **(*S*)**	1.00	5.00	2.868	0.9482
Total annual household annual income generated from all livelihood income sources **(*N*)**	0.10	232.03	18.165	25.9895
Household Livelihood Diversity Index (HLD)	0.000	0.734	0.3357	0.21827

Source: Computed from Survey Data, 2017; $HLD = 1 - \frac{\sum_{i=1}^{s} n_i(n_i-1)}{N(N-1)}$ ***S*** *=8= number of livelihood income sources for a household;* ***N*** *= Total annual household income generated from all livelihood activities (livelihood income sources) of a household;* ***n*** *= annual household income generated from the ith (each) livelihood income source of a household. No diversification=HLD < 0.01, Low level of diversification=0.01 ≤ HLD ≤ 0.25, Medium level of diversification= (0.26 ≤ HLD ≤ 0.50), High level of diversification = 0.51 ≤ HLD ≤ 0.75), Very high level of diversification = HLD > 0.75* (Ahmed *et al.*, 2018)

Determinants of Livelihood Dimensions among Agrarian Households in Small-Scale Mining Communities

Although past research has provided numerous important insights on household livelihoods, the cross-correlation of the key dimensions of household livelihood has not been fully addressed. This study identified a significant correlation among the three dimensions of livelihoods, HLV, HLS and HLD, as indicated in Table 12. This observation indicates the presence of cross-correlation among the dimensions of livelihoods. Multi-equation system was then used to examine the dimensions. This was done to bridge the gap of research inefficiency in using single-regression equation models in livelihood studies by adopting the simultaneous equation estimation approach that accounts for the cross-correlation among livelihood vulnerability, security and diversity.

Determinants of household livelihood vulnerability to small-scale mining, livelihood security and diversity were examined simultaneously using the Three-Stage Least Square (3SLS) model. The fitness and estimates of the model are exhibited in Table 13. The fitness of the 3SLS model is confirmed by the correlation among the residuals of the system of equations explaining the three key dimensions of livelihoods. The Chi-Square test of independence rejected the null hypothesis of independence and confirmed a dependency among the residuals of the equations. The explanatory power of the model was 87%, 72% and 59% respectively for household livelihood vulnerability, security and diversity.

Table 12: Correlation matrix for HLV, HLS and HLD

	HLV	HLS	HLD
HLV	1.00		
HLS	0.4129* (0.000)	1.00	
HLD	-0.4842* (0.000)	0.1130**(0.0188)	1.00

Source: Estimated from Survey Data, 2017 ** Significant at 1% ** Significant at 5%*

Socio-Economic Factors influencing Household Livelihood Vulnerability to Small-Scale Mining, Household livelihood Security and Diversity

Household characteristics that could reduce their vulnerability to the devastating effect of small-scale mining, improves livelihood security and livelihood diversity were estimated with the 3SLS in Table 13. Fourteen (14) socio-economic factors were simultaneously examined under the three key livelihood dimensions. Eight (8) of these factors, as indicated in Table 13, significantly and concurrently influenced the dimensions of household livelihood.

Household farming experience

Farming experience, measured by number of years in farming, is expected to improve the human capital of household and facilitate the process of constructing a diverse portfolio of livelihood activities to reduce susceptibility to the effect of mining. Average farming experience of agrarian households, as shown in Table 13, significantly and negatively influenced household livelihood diversity index. It was established that households with high average number of years in farming had low livelihood diversity index. This observation contradicts the findings of Dinku (2018) who identified a positive relationship between livelihood diversification and farming experience. It followed that households with aging farmers are less capable of constructing diverse livelihood portfolios. This observation is attributable to the fact that experienced farmers are more conversant with on-farm activities and may not have the appropriate skills needed to pursue alternative livelihood activities.

Agricultural extension contact

Agricultural extension service providers train households to be more productive in both on-farm and off-farm activities to obtain the best outcome. While agricultural extension contact was found to significantly and negatively influence household livelihood vulnerability to the impact of small-scale-mining, it significantly and positively influenced household livelihood security and diversity. This observation is consistent with the findings of Qaisrani *et al.* (2018), Dinku (2018) and Thabane (2015). As is shown in Table 13, agrarian households that benefited from agricultural extension services were likely to reduce their vulnerability to the risk of mining by 3% making them less vulnerable than their counterparts who had no agricultural extension contact. Such households could improve their livelihood security by 2.7% and involvement in constructing diverse livelihood activities to supplement on-farm livelihood portfolio by 8.5%. Technical knowledge obtained from agricultural extension services improves the human capital of households and positions them to improve their adaptive capacity to reduce the risk of mining and to effectively utilize available household natural assets for on-farm and off-farm activities to increase household income. Provision of agricultural extension services exhibited a high potential in improving livelihoods of agrarian households in the face of small-scale mining.

Linkage to mining authorities

Linkages to mining authorities enable households to get their grievances on mining addressed to minimize the effect of mining and enable households pursue their livelihood activities effectively. The study identified a significant and negative relationship between direct linkages to mining authorities and household livelihood vulnerability. Direct linkages to mining authorities made agrarian households less vulnerable to small-scale mining than their counterparts without such linkages. Agrarian households with direct linkages to mining authorities could reduce vulnerability by 4% as is evident in Table 13. Such linkages provided households with social capital which served as an effective tool for streamlining mining activities to improve livelihood development among agrarian households.

Table 13: Three-Stage Least-Square estimates for determinants of livelihood dimensions in small-scale Mining communities (025. Abankwah *et al*.)

Household Socio-Economic and Institutional Characteristics	Household Livelihood Vulnerability (HLV)				Household Livelihood Security (HLS)				Household Livelihood Diversity (HLD)			
	Coefficient	**Std. Err.**	**t-stat**	**P>|t|**	**Coefficient**	**Std. Err.**	**t-stat**	**P>|t|**	**Coefficient**	**Std. Err.**	**t-stat**	**P>|t|**
SOCIO-ECONOMIC CHARACTERISTICS OF AGRARIAN HOUSEHOLDS												
Human Capital of Households												
Average household farming experience (years)	-0.0010	0.0007	-1.44	0.151	-0.0016	0.0011	-1.46	0.145	-0.0049*	0.0013	-3.78	0.000
Sex of household head (1=Male, 0=otherwise)	-	-	-	-	-0.0128	0.0191	-0.67	0.502	0.0380	0.0421	0.90	0.367
Agricultural Extension contact(1=contact, 0=otherwise)	-0.0261**	0.0125	-2.09	0.036	0.0266**	0.0126	2.10	0.036	0.0849**	0.0405	2.09	0.036
Social Capital of Households												
Household linkages to mining authorities (1=linkage, 0=Otherwise)	-0.0397*	0.0149	-2.66	0.008	-	-	-	-	0.0124	0.0502	0.25	0.804
Participation in planning community interventions (1=Participate, 0=Otherwise)	0.0204	0.0140	1.46	0.144	-	-	-	-	0.0116	0.0376	0.31	0.758
Natural Capital of Households												
Access to forest for living (1=Access,0=Otherwise)	-	-	-	-	0.0387*	0.0151	2.56	0.010	0.1199*	0.0448	2.68	0.007
Access to community arable land bank (1=Access, 0=Otherwise)	0.0099	0.0236	0.42	0.675	0.0450	0.0338	1.33	0.183	0.1675*	0.0463	3.62	0.000
Physical Capital of Households												
Household distance to major road in km	-0.0011	0.0008	-1.28	0.202	-0.0009	0.0009	-0.98	0.325	-0.0031	0.0023	-1.34	0.181
Distance to nearest agro-input shop km	0.0036*	0.0013	2.68	0.007	-0.0020	0.0014	-1.45	0.146	0.0060	0.0043	1.42	0.157
Access to community radio/information center (1=Available, 0=Otherwise)	-0.0571**	0.0241	-2.37	0.018	0.0450	0.0338	1.33	0.183	0.1464**	0.0690	2.12	0.034
Financial Capital of Households												
Average household farm size	0.0037	0.0027	1.38	0.169	-3.18e-5	0.0036	-0.01	0.993	-	-	-	-
Major livelihood portfolio of households (1=Mining, 0=Otherwise)	-0.0085	0.0247	-0.35	0.729	-0.0006	0.0412	-0.01	0.989	-	-	-	-
Livelihood security index of households	-1.5190*	0.3002	-5.06	0.000	-	-	-	-	3.1360*	1.0955	2.86	0.004
Livelihood diversity index of households	-0.2329	0.2403	-0.97	0.332	-0.3192	0.4354	-0.73	0.464	-	-	-	-
INSTITUTIONAL FRAMEWORK OF MINING												
Household perception of the implementation of institutional framework of mining	-0.1005*	0.0362	-2.78	0.005	0.1063**	0.0538	1.98	0.048	0.3264*	0.0812	4.02	0.000
Constant	0.8140*	0.0798	10.19	0.000	0.2464*	0.0525	4.69	0.000	0.7727*	0.2553	3.03	0.002
	Number of Obs. = 432 R-Squared = 0.8680 Chi^2 = 111.42 (P = 0.000)				Number of Obs. = 432 R-Squared = 0.7160 Chi^2 = 127.79 (P = 0.000)				Number of Obs. = 432 R-Squared = 0.5895 Chi^2 = 359.77 (P = 0.000)			

Source: Estimated from Survey Data, 2017 ** Significant at 1%* *** Significant at 5%* *The 3SLS Model accounts for endogeneity by using the regression estimates from regression of each endogenous dependent variable on all exogenous variables in the first stage (OLS) to obtain regression-predicted values as instruments to* estimate the 2SLS parameters *and that represents the 1st stage of the 3SLS model*

Forest reserves

Forest reserves provide for the collection of fruits, honey, snail, mushroom, medicinal herbs, weaving materials, wood for carving etc. Household access to forest reserves was found to positively and significantly influence household livelihood security and diversity. Agrarian households that benefited from forests were likely to improve on livelihood security by 3.7% more than their counterparts without such access. This finding corroborates with Meekaew and Ayuwat (2019) who identified natural resources as positively influencing livelihood security. As indicated in Table 13 such agrarian households supplemented on-farm income by improving the proportion of their involvement in other livelihood activities by 12%. Forests contributed to broadening natural capital, facilitated their access to other livelihood assets (Pereira *et al*., 2006) needed for the construction of diverse livelihood portfolios and made them more secure.

Community arable land bank for producing household staple food

Arable land improves the natural capital of households which they use to pursue household livelihood activities. Communities that have land banks made them available for households that had the need to grow and supplement household supply of staple food. In some communities such land banks were made available by allowing households to farm arable crops under forest without cutting trees. The study examined the effect of such practice on household livelihood diversification and found, as evident in Table 13, a significant and positive relationship between them. This observation compares favourably with the findings of Nasa *et al*. (2010) in a similar study. It was established that households that had access to land banks for staple food production were able to improve their involvement in constructing diverse livelihood portfolios by 17% more than their counterparts without access. Making arable lands available for staple food production in the small-scale mining communities reduces household expenditure on household staple food which would have otherwise been purchased from the local markets with escalating prices due to the influx of miners. This income effect improves the financial capital of agrarian households needed to finance the construction of diverse livelihood portfolios. Providing for land banks in mining communities holds a potential prospect for improving household financial capital needed to construct diverse livelihood portfolios.

Proximity to agricultural input shop

Access to agricultural inputs and equipment improves the physical assets of rural households which are needed to pursue household livelihood activities. Making agricultural inputs readily available to farmers facilitates livelihood activities of rural households. The study revealed a significant and positive relationship between distance to agricultural input shops and household vulnerability to small-scale mining. As distance to the nearest agricultural input shop increased, livelihoods of households became more vulnerable to the risk of mining. Agricultural inputs are known to improve productivity of on-farm activities and can substitute effectively for land taken up by mining.

Community radio/information centre

Community radio or information centres in rural communities are tools for communication and serve as physical capital that facilitates information flow needed by households to carry on their livelihood activities. The study has established a significant and negative relationship between household livelihood vulnerability index and access to community information centre. Community radio also significantly and positively influenced household livelihood diversity index. As is evident in Table 13, agrarian households that had access to community radio could reduce vulnerability to the risk of small-scale mining by 6% and improved diversification of income sources by 17%. Such households were better informed of livelihood opportunities and technical information needed to make them less sensitive and build their adaptive capability to reduce the risk of mining on assets and livelihoods. Community radio facilitates access to marketing outlets for household production and broadens the financial capital of households needed to possess entitlement to other assets to fuel the construction of diverse livelihood portfolio.

Livelihood security

Livelihood security which is a composite measure of economic security; food security; health security; educational security; and empowerment security of a household (Akter and Rahman, 2012; Lindenberg, 2002; Frankenberger *et al*. 2000) is the ability to meet its basic needs (United Nations, 2011). A household that have strong ability to provide for its basic needs is believed to have the capacity to adapt and reduce its susceptibility to an environmental risk. As is \

shown in Table 13, the study found a strong significant and negative relationship between household livelihood vulnerability to small-scale mining and its livelihood security. Livelihood security of a household was also found to positively influence household livelihood diversity. Increasing ability to meet basic needs improves financial capital of households needed in building household socioeconomic profile, livelihood strategies and social network to reduce their susceptibility to the risk of small-scale mining. Empowering agrarian households to participate in community decisions, providing for their educational, health and food production needs, and facilitating improvement in their economic status improve their livelihood security and build their capacity to identify, exploit livelihood opportunities and construct diverse livelihood portfolios.

Institutional Factors influencing Household Livelihood Vulnerability to Small-Scale Mining, Household livelihood Security and Household Livelihood Diversity

Institutional framework of mining examined comprises the regulatory framework for mining and rural livelihood interventions including: agricultural livelihood interventions; livelihood restoration interventions; socio-economic and poverty reduction interventions; educational interventions; health interventions; and water and sanitation interventions (Brown 2002). These interventions were either provided by miners as corporate social responsibilities or by traditional authorities and or Municipal and District Assemblies through collection of royalties and tolls from the miners. While the implementation of institutional framework of mining significantly and negatively influenced household livelihood vulnerability, it had a significant and positive association with household livelihood security and diversity. It was revealed, as in Table 13, that agrarian households who perceived the implementation of the institutional framework were less vulnerable to the devastating effect of mining. They were likely to reduce livelihood vulnerability to the risk of small-scale mining by 10%. Such households could improve livelihood security by 10.6% and increase the proportion of their involvement in other income sources by 33.0%. This observation corroborates with Qaisrani *et al.* (2018) who established that provision of livelihood opportunities reduces livelihood vulnerability and improves rural livelihoods.

Regulatory framework for mining protects the natural capital of agrarian households needed to pursue household livelihood objective. While the implementation of regulatory framework reduced the exposure of small-scale mining on assets of agrarian households, livelihood interventions were found to reduce their sensitivity to the effect of mining, improve their adaptive capacity making them less vulnerable.

CONCLUSION AND RECOMMENDATION

Livelihood assets describing the socioeconomic characteristics of agrarian households in small-scale mining communities in the form of human, social, natural, physical and financial capital are poorly developed. Households have negative perception on the implementation of the institutional framework for small-scale mining in Ghana. Though the exposure of the risk of small-scale mining on assets and livelihoods of agrarian households is low, agrarian households are vulnerable to small-scale mining. They are highly sensitive to the risk of mining due to poor health, food and water factors. Livelihood security of agrarian households in small-scale mining communities, measured as the combined effect of economic security, food security, health security, educational security and empowerment security, is moderately low. Economic security is the weakest of the five sub-livelihood security indices resulting probably from the combined effect of poor implementation of livelihood interventions. The major contributors to household livelihood security in small-scale mining communities are health security and education security. Agrarian households do not generally diversify livelihood portfolios to supplement income from on-farm activities which are adversely affected by small-scale mining.

A couple of socioeconomic and institutional factors are identified to influence livelihood development of agrarian households in the face of small-scale mining. Agrarian households with increasing number of years in farming experience do not have the desire and appropriate skills to pursue alternative livelihood activities to facilitate livelihood diversification. Provision of agricultural extension services, however, reduces vulnerability to the risk of mining, improves livelihood security of agrarian households and facilitates their involvement in constructing diverse livelihood activities to supplement on-farm livelihood. Direct linkages to mining authorities improves social capital of agrarian households and serves as an effective tool for streamlining mining activities to reduce vulnerability to small-scale mining. Forests reserves in mining communities improve livelihood security and contribute to broadening natural capital of agrarian households needed to facilitate the construction of diverse livelihood portfolios. Providing for land banks in mining

communities holds a potential prospect for improving household financial capital needed to construct diverse livelihood portfolios. Proximity to agro-input shop facilitates timely procurement of agricultural inputs needed to pursue livelihood activities and reduce vulnerability to small-scale mining. Community radio is a physical capital that has the potential to facilitate access to livelihood opportunities, technical information and marketing outlets. It contributes to reducing vulnerability to the risk of mining and fuel the construction of diverse livelihood portfolio among agrarian households. Empowering agrarian households to participate in community decisions, providing for their educational, health and food production needs, and facilitating improvement in their economic status improves financial capital and livelihood security of agrarian households. This reduces their vulnerability to the risk of small-scale mining and builds their capacity to identify and exploit diverse livelihood opportunities to supplement on-farm activities. Implementation of institutional framework for mining, basically regulatory framework for mining and rural livelihood interventions, in small-scale mining communities improves the livelihood security of agrarian households, make them less vulnerable and build their capacity to diversify livelihood income sources.

The following emerging recommendations provide policy directions for reducing livelihood vulnerability to small-scale mining, and improving livelihood security and diversity of agrarian households in small-scale mining communities.

i. Households need to be retrained and financed by District Assemblies to take up alternative livelihood options such as mushroom, snail, honey production etc.
ii. Agricultural extension contacts need to be strengthened among agrarian households in small-scale mining communities by the Ministry of Food and Agriculture (MoFA)
iii. Traditional Leaders need to facilitate direct linkages between agrarian households and mining authorities to reduce vulnerability to the risk of mining
iv. Traditional Leaders and District Assemblies need to embark on acquisition of community arable land bank complement household staple food production
v. Forest reserves in mining communities need to be protected by Forestry Commission to make room for collection of fruits, medicinal herbs, weaving materials, wood for carving etc., by agrarian households
vi. There is the need to ensure wider distribution network of agricultural inputs in mining communities by MoFA and other State Agencies
vii. Opinion Leaders in small-scale mining communities need to promote the establishment of radio/communication centre in small-scale mining communities
viii. Regulatory framework of mining needs to be rigorously enforced in small-scale mining communities by Regulatory Agencies such as EPA, Ghana Chamber of mines, Minerals Commission of Ghana and MMDAs
ix. Rural livelihood interventions need to be implemented in small-scale mining communities by MMDAs and Minerals Commission

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