Original Research Article

MEASURING LIVELIHOOD VULNERABILITY TO LARGE-SCALE AND SMALL-SCALE MINING IN GHANA: A COMPARATIVE EXAMINATION OF AGRARIAN HOUSEHOLDS

ABSTRACT

While promoting both large-scale and small-scale mining to facilitate rural development and poverty reduction, it becomes imperative to examine the level of exposure and the risk of mining on assets and livelihoods of agrarian households in mining communities. The study was, therefore, designed to examine the differential effect of the risk of large-scale and small-scale mining on livelihoods of agrarian households which are basically agrarian. The study covered five regions in Ghana namely, Ashanti, Eastern, Western, Central and Brong-Ahafo Regions, where both large-scale and small-scale mining are pervasive. A two-stage sampling technique was used to sample 864 agrarian households in the study area for primary data. The 864 households comprised 432 households from 36 communities which are exclusively exposed to the activities of large-scale mining and 432 households from 36 communities exclusively exposed to the activities of small-scale mining. Household livelihood vulnerability (HLV) index measuring household susceptibility to the risk of mining was used to measure household livelihood vulnerability to mining. The study has established that assets and livelihoods of agrarian households are more vulnerable to the risk of large-scale mining than small-scale mining. Policy directions have been recommended to reduce the risk of both large-scale and small-scale mining on household assets and livelihoods.

Key words: Livelihood vulnerability index, exposure and risk of mining, sensitivity to risk of mining, adaptive capacity, agrarian household, large-scale mining, small-scale mining

INTRODUCTION

Livelihood is considered as the activities, the assets, and the access that jointly determine the living gained by an individual or household (Chambers and Conway, 1992). Rural livelihoods can be made up of a range of on-farm and off-farm activities that together provide a variety of procurement strategies for food and cash (Ellis, 1998). The risk of livelihood failure determines the level of vulnerability of a household to income, food, health and nutritional insecurity.

Livelihoods are secure when households have secure ownership of, or access to, resources (both tangible and intangible) and income earning activities including reserves and assets to off-set risks, ease stresses and shocks, and meet contingencies (Chambers 1988). Households have secure livelihoods when they are able to acquire, protect, develop, utilize, exchange, and benefit from assets and resources (Ghanim 2000).

Rural livelihoods in Ghana are basically agrarian since agriculture remains a dominant economic activity for rural households in Ghana, (Diao, 2010). 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. Rural environment is, however, undergoing rapid degradation and its economic value and support for rural livelihoods are diminishing from year to year, due mainly to the concentration of mining activities (Miranda *et al.* 2005). Mining in Ghana is either large-scale or small-scale mining. Large-scale mining involves the mobilization of substantial capital, heavy equipment, high and sophisticated technology and a much bigger workforce (Ghana Chamber of mines, 2013). Small-scale mining is made up of formal or informal operations with predominantly simplified forms of exploration, extraction, processing and transportation and 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 competes with rural households for agricultural lands, labor and other resources which form the bases for their livelihoods. Scarcity of agricultural labour in mining communities has increased wage rate and the cost of other agricultural inputs causing a decline in productivity (Mishra and Pujari 2008). Food security and livelihoods are threatened by mining-related factors such as loss of agricultural land; water pollution; water supply; noise; dust; and land disturbance often associated with mining activities. This trend presents a potential threat to the health and livelihood of the poor and vulnerable groups who have little mobility or means of alleviating negative impacts of mining (Weber-Fahr, 2002).

The net foreign exchange and tax revenue generated from mining, however, provide funding for rural development and poverty reduction programs (Weber-Fahr *et al.* 2002). Ghana earned $5.1 billion from mineral exports in 2013 and 148,000 people were employed in large-scale mining whilst 500,000 were employed in the small-scale sector. Mining contributes about 50% of Ghana's Foreign Direct Investment (FDI), 37% of total exports, 19% of revenue collected by the Internal Revenue Service and 1.7% of Gross Domestic Product (Ghana Chamber of Mines, 2015).

Though, mining facilitates rural development and poverty reduction (Weber-Fahr *et al.* 2002), it has negative economic impact on rural livelihoods (Obiri *et al.*, 2016). While promoting both large-scale and small-small scale mining to facilitate rural development and poverty reduction, it becomes imperative to examine the level of exposure and the risk of mining on livelihoods of agrarian households in mining communities. The objective of the study was to examine the differential effect of the risk of large-scale and small-scale mining on livelihoods of agrarian households.

The Concept of Livelihood Vulnerability

Livelihood is also conceptualized as the capabilities, activities, the assets, and the access that jointly determine the living gained by an individual or household (Chambers and Conway, 1992). Rural livelihoods can be made up of a range of on-farm and off-farm activities that together provide a variety of procurement strategies for food and cash (Ellis, 1998). Each household may have several possible sources of livelihood entitlement which are based on the endowments that a household has, and its position in the legal, political, and social framework of society (Frankenberger *et al.*, 2000). The DFID (1999) framework breaks household assets into five types of capital namely: Human, social, natural, physical and financial capital. The risk of livelihood failure determines the level of vulnerability of a household to income, food, health and nutritional insecurity. How well a household can draw on 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, 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. It 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 *et al.*, 2009) and is influenced by socio-economic status of individuals or households (Ribot, 2010). Hahn *et al*. (2009) used eight major areas to construct household vulnerability index namely: 1) Natural Disasters, 2) Climate Variability, 3) Socio-Demographic Profile, 4) Livelihood Strategies, 5) Social Networks, 6) Health, 7) Food and 8) Water, to study livelihood vulnerability index. They classified the eight areas under the three major domains of vulnerability classified by Heltberg and Bonch-Osmolovskiy (2010) by putting the first two under exposure, the next three under sensitivity to risk and the last three under adaptive capacity in that order. They used the three major domains of vulnerability to construct vulnerability index to study household vulnerability to climate change by adapting the UNDP Human Development Index. The UNDP used the Human Development Index to calculate the life expectancy index, which is the ratio of the difference of the actual life expectancy and a pre-selected minimum, and the range of predetermined maximum and minimum life expectancy (UNDP, 2013).

METHODOLOGY OF THE STUDY

The study covered five regions in Ghana namely, Ashanti, Eastern, Western, Central and Brong-Ahafo Regions, where both large scale and small-scale mining are pervasive. Large-scale gold mining companies in Ghana identified by Ghana Chamber of Mines (2013) operate in the five regions selected for the study. At the time of the study 12 large-scale mining companies were operating in Ghana specifically in the five regions selected for the study. The large-scale mining

companies were: Adamus Resources Ltd, Anglogold Ashanti (Iduapriem) Ltd, Chirano Gold Mines, Gold Fields Ghana, Golden Star Ltd, Newmont Ghana Gold Ltd. Kenyasi, Newmont Golden Ridge Resources, Perseus Mining (Ghana) Ltd, Prestea sankofa Gold Ltd, Medimining, Asanko Gold (Ghana), Kibi Goldfiels. Minerals Commission (2007) has designated groups of communities in Ghana called blocked-out areas where gold and diamonds are known to occur for small-scale mining. Out of seven (7) areas blocked out exclusively for small-scale mining, six (6) are identifiable in the five regions selected for the study. These regions of Ghana fall within the forest and the forest-savanna transitional zones of Ghana. The area is endowed with vegetation, edaphic conditions and copious rainfall vital for agricultural production. Mineral deposits also abound in the area and this has attracted both large scale and small-scale miners.

Sample Size, Sampling Technique and data Collection

A two-stage sampling technique was used to sample 864 agrarian households in the study area for primary data approximated from *Equation 1* developed by Cochran (1963). The 864 households comprised 432 households from 36 communities which are exclusively exposed to the activities of large-scale mining and 432 households from 36 communities exclusively exposed to the activities of small-scale mining. At the first stage of sampling, three (3) agrarian communities in each of the operational areas of the 12 large-scale mining companies were purposively sampled to select 36 agrarian communities that were exclusively influenced by large-scale mining activities. Similarly, 6 communities were purposively sampled from each of the 6 blocked-out areas for small-scale mining to select 36 agrarian communities that are exclusively influenced by small-scale mining activities. The total number of communities sampled for the study was 72. The second stage of sampling involved randomly selecting 12 households from each of the 72 communities to obtain a total sample size of 864 agrarian households distributed in Table 1.

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

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, $e = 0.045$ (i.e. +/-4.5% margin of error meaning the study accommodated 4.5% 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). The sample size distribution is shown in Table 1.

Table 1: Sample size distribution

Large-Scale Mining	Mining Communities	Provincial District of	Region of selected	Number of

	Company	selected for the study	selected communities	communities	households
1	Adamus Resources Ltd., Teleku Bukazo	Teleku Bukazo	Ellembele	Western Region	12
		Anwia	Ellembele	Western Region	12
		Salman (Resettled)	Ellembele	Western Region	12
2	Anglogold Ashanti (Iduapriem) Ltd., Tarkwa	Tebrebie	Tarkwa/Nauaem	Western Region	12
		Adeyie/Mile 8	Tarkwa/Nauaem	Western Region	12
		Domeabra/Mile 5	Tarkwa/Nauaem	Western Region	12
3	Chirano Gold Mines, Chirano	Akoti	Wiaso	Western Region	12
		Praboase	Wiaso	Western Region	12
		Etweabo	Bibiani/Anhwiaso	Western Region	12
4	Gold Fields Ghana (Tarkwa/Darmang)	Darmang	Prestia/Huni-Valley	Western Region	12
		Huniso	Prestia/Huni-Valley	Western Region	12
		Abekoase	Prestia/Huni-Valley	Western Region	12
5	Golden Star (Wasa) Ltd., Akyempem	Akyempem	Mpoho East District	Western Region	12
		Juabeng	Mpoho East District	Western Region	12
		Kubekro	Mpoho East District	Western Region	12
6	Newmont Ghana Gold (Ahafo) Ltd., Kenyasi	Gyedu	Asutifi North	Brong-Ahafo Region	12
		Ntotroso	Asutifi North	Brong-Ahafo Region	12
		Tutuka	Asutifi North	Brong-Ahafo Region	12
7	Newmont Golden Ridge (Akyem) Resources, New Abirem	Adausena	Abirem	Eastern Region	12
		Hweakwae	Abirem	Eastern Region	12
		Yaayaaso (resettled)	Abirem	Eastern Region	12
8	Perseus Mining (Ghana) Ltd. Ayanfuri	Ayanfuri	Upper Denkyira West	Central Region	12
		Fobinso	Upper Denkyira West	Central Region	12
		Abenabena	Wasa Amenfi East	Central Region	12
9	Golden Star Ltd (Bogoso/Prestea Mines)	Nsuta	Prestea Huni-Valley	Western Region	12
		Bondai	Prestea Huni	Western Region	12
		Gambia	Prestea Huni	Western Region	12
10	Medimining (Elite Minerals Resources Ltd.), Akyem Takyiman	Sarfo	Kwaebibirem	Eastern Region	12
		Dokyi	Kwaebibirem	Eastern Region	12
		Mempeasem	Kwaebibirem	Eastern Region	12
11	Asanko Gold (Ghana), Manso Nkran	Manso Koninase	Amansie West	Ashanti Region	12
		Manso Nkran	Amansie West	Ashanti Region	12
		Manso Dadiease	Amansie West	Ashanti Region	12
12	Kibi Goldfiels, Osino	Juaso	Abuakwa	Eastern Region	12
		Saaman	Abuakwa	Eastern Region	12
		Apese	Abuakwa	Eastern Region	12
	Sub-Total for Large-Scale Mining Area				**432**

Table 1 Cont'd: Sample size distribution

	Blocked out area for Small-Scale 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	Assin Asaman	Assin North	Central Region	12
		Assin Awusam	Assin North	Central Region	12

		Assin Nyadowam	Assin North	Central Region	12
		Twifo Mokwaa	Twifo/Hemang	Central Region	12
		Akwaboso	Upper Denkyira West	Central Region	12
		Tentekrom	Upper Denkyira West	Central Region	12
2	Asankrangwa Area	Mmoseaso	Wasa Amenfi Central	Western Region	12
		Bremang	Wasa Amenfi Central	Western Region	12
		Amoamang	Wasa Amenfi Central	Western Region	12
		Odaa Anhweam	Wasa Amenfi Central	Western Region	12
		Odaa Kuroforom	Wasa Amenfi Central	Western Region	12
		Nkakaa	Wasa Amenfi Central	Western Region	12
3	Bibiani Area	Nkatieso	Bibiani/Anhwiaso/ Bekwae	Western Region	12
		Asawinso Ketuam	Bibiani/Anhwiaso/ Bekwae	Western Region	12
		Ntakam	Bibiani/Anhwiaso/ Bekwae	Western Region	12
		Abrokofe	Juaboso	Western Region	12
		Kwaokrom	Juaboso	Western Region	12
		Abono	Juaboso	Western Region	12
4	Dunkwa Area	Fiankoma	Amansie Central	Ashanti Region	12
		Akutuase	Amansie Central	Ashanti Region	12
		Afraso	Amansie West	Ashanti Region	12
		Tontokrom	Amansie West	Ashanti Region	12
		Bonsaaso	Amansie West	Ashanti Region	12
		Yawkasa	Amansie West	Ashanti Region	12
5	Tarkwa Area	Wasa Afranse	Wasa Amenfi East	Western Region	12
		Wasa Mammieso	Wasa Amenfi East	Western Region	12
		Wasa Nkyiase	Wasa Amenfi East	Western Region	12
		Wasa Saaman	Wasa Amenfi East	Western Region	12
		Wasa Tieku	Wasa Amenfi East	Western Region	12
		Wasa Adanse	Wasa Amenfi East	Western Region	12
6	Akim Oda Area	Akrofufu	Atiwa	Eastern Region	12
		Akwabuoso	Atiwa	Eastern Region	12
		Abommosu	Atiwa	Eastern Region	12
		Apapam	Abuakwa	Eastern Region	12
		Afiesa	Abuakwa	Eastern Region	12
		Adadientam	Abuakwa	Eastern Region	12
	Sub-total for Small-Scale Mining Area				**432**
	Total Sample Size from Large Scale and Small-Scale Mining Areas				**864**

Measuring Household Livelihood Vulnerability (HLV) to 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 *nth* domain ($zind_{ni}$) 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).

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

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.

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

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).

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

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 lists all the indicators that were standardized and used to measure the HLV index.

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
	ESPOSURE		
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		
	Sex of household head	0=Head is male; 1=Head is female	

Household Socio-economic profile contributing to reducing the risk of mining on household assets and livelihoods	dependency ratio of household	*18 years and above not working + < 18 years* / *18 years and above who are working*	$zind_{ni} = \frac{ind_i - ind_{min}}{ind_{max} - ind_{min}}$
	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	$HLV_{ci} = \frac{\sum_{n=1}^{5} w_n HLS_{ni}}{\sum_{n=1}^{5} w_n}$

Source: Author's Construct

RESULTS AND DISCUSSION

The differential effect of the risk of large-scale and small-scale mining on assets and livelihoods of agrarian households are presented and discussed under this section.

Household Livelihood Vulnerability and Vulnerability Index

Livelihood vulnerability Index measures household susceptibility to stresses emanating from natural disasters or human economic activities (Hahn *et al.* 2009) such as mining. 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 of mining (Islam *et al*, 2014). Following the conceptualization of vulnerability by Heltberg and Bonch-Osmolovskiy (2010), household vulnerability to the stress of 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 the risk of mining by adapting the UNDP Human Development Index (UNDP, 2016a, 2016b).

Indicators that affect household susceptibility to the stress of mining were examined under the three major domains and used to measure vulnerability index for each agrarian household and the result is summarized in Table 3. Indicators under exposure domain measured the risk of mining on household assets and livelihoods. Indicators under sensitivity domain measured health, food and water factors that make household susceptible to the risk of mining. Indicators under adaptive domain measured household socio-economic profile, household livelihood strategies, and household social network, contributing to reducing the risk of mining on household assets and livelihoods. Indicators with higher values contributed to building a higher livelihood vulnerability index making households more vulnerable to the stress of mining.

The maximum and minimum values of these indicators exhibited in Table 3 were used to compute livelihood vulnerability index under each domain of vulnerability and a composite index for each household.

Table 3: Indicators under the three major domains of household livelihood Vulnerability

Sub-components of vulnerability domains	Indicators of household livelihood Vulnerability	Large Scale Mining Area N=432	Small Scale Mining Area N=432

		Min	Max	Min	Max
	Exposure				
Risk of mining on household assets and livelihoods	Percentage of household total farming land taken by mining	0.00	97.96	0.00	97.96.00
	Percentage of household agricultural Labour force drifted to mining	0.00	66.67	0.00	66.67
	Number of on-farm enterprises (income sources) lost as a result of mining	0.00	9.00	0.00	10.00
	Number of off-farm/processing income enterprises (sources) lost as a result of mining	0.00	1.00	0.00	1.00
	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	0.00	1.00
	Household access to sand and clay deposit for use. 1=No, 0=Yes	0.00	1.00	0.00	1.00
	Number of household members under 15 years actively engaged in mining (drop-out from JHS)	0.00	0.00	0.00	2.00
	Number of household members between 15 and 18 years actively engaged in mining (drop-out from SHS)	0.00	2.00	0.00	1.00
	Household natural water source is polluted by mining. 1=Yes, 0= No	0.00	1.00	0.00	1.00
	Sensitivity				
Health factors that make household susceptible to the risk of mining	distance to get to nearest Hospital (km)	0.15	32.00	0.15	18.00
	Percentage of household members with chronic illness	0.00	100	0.00	90.00
	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	0.00	180.00
	Percentage of household members that do not sleep under mosquito nets	0.00	100.00	0.00	100.00
	Community is periodically sprayed against mosquitoes. 1=No, 0=Yes	0,00	100.00	0.00	100.00

Table 3 Cont'd: Indicators under the three major domains of household livelihood Vulnerability

Sub-components of vulnerability domains	Indicators of household livelihood Vulnerability	Large Scale Mining Area N=432		Small Scale Mining Area N=432	
		Min	Max	Min	Max

Sensitivity					
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	0.00	12.00
	Household farm as major source of household staple food 1=Yes, 0=No	0.00	1.00	0.00	1.00
	Availability of food stock for use in difficult times: 1=No, 0=yes	0.00	1.00	0.00	1.00
	Inverse of number of food crops grown by household	0.11	1.00	0.10	1.0
Water factors that make household susceptible to the risk of mining	Household access to water resources (streams, rivers, dams etc.) for fishing or farming. 1=No, 0=Yes	0.00	1.00	0.00	1.00
	Typical time (minutes) used to fetch water	1.00	60.00	1.00	90.00
	River/Stream is wholesome for domestic purposes. 1=No, 0=Yes	1.00	0.00	1.00	0.00
	Rain water is wholesome for domestic purposes. 1=No, 0=Yes	1.00	0.00	1.00	0.00
	Number of water conflict within the last six months	0.00	15.00	0.00	90.00
	Number of months in year with scarce water sources	0.00	6.00	0.00	10.00
Adaptive Capacity					
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	0.00	1.00
	dependency ratio of household= $\frac{[18\ years\ and\ above\ not\ working\ +<18\ years\ ]}{18\ years\ and\ above\ who\ are\ working}$	0.00	9.00	0.00	9.00
	Percentage of active members (18 years and above) who are unemployed	0.00	80.00	0.00	87.00
	percentage of household livelihood income from farming (crop, livestock, fish)	0.00	100.00	0.00	100.00
	Inverse of number of years spent in school by household head with 10 as maximum value	0.06	10.00	0.05	10.00
	Inverse of average number of years spent in school by household adult members 18 years and above	0.08	10.00	0.06	10.00
	Farming technology mainly practiced by household: 1=Traditional, 0=modern	0.00	1.00	0.00	1.00
	Inverse of household total agricultural livelihood portfolios	0.25	1.0	0.33	1.0

Table 3 Cont'd: Indicators under the three major domains of household livelihood Vulnerability

Sub-components of vulnerability domains	Indicators of household livelihood Vulnerability	Large Scale Mining Area N=432	Small Scale Mining Area N=432

		Min	Max	Min	Max
Adaptive capacity					
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)	25.00	100.00	33.33	100.00
	Household engagement in off-farm activities: 1=No, 0=Yes	0.00	1.00	0.00	1.00
	Household engagement in non-farm local activities (artisanship and local services):1= No, 0=Yes	0.00	1.00	0.00	1.00
	Household engagement in local trade and commerce: 1= No, 0=Yes	0.00	1.00	0.00	1.00
	Household engagement in formal employment (salaried work excluding mining): 1= No, 0=Yes	0.00	1.00	0.00	1.00
	Rearing of farm animals by household: 1=no animals kept, 0=animals are kept	0.00	1.00	0.00	1.00
	Engagement in alternative livelihood in non-traditional agriculture: 1=No, 0=Yes	0.00	1.00	0.00	1.00
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	7.5	0.00	50.00
	Receive per give in the past 12 months (in terms of number)	0.00	50.00	0.00	20.00
	Number of living assistance obtained from mining organization in 12 month	0.00	1.00	0.00	0.00

Source: Survey data, 2017

Household Exposure to Large-Scale and Small-Scale Mining

Household exposure index of vulnerability to mining measures the risk of mining on assets and livelihoods of households on a scale of 0 to 1 such that the closer it is to 1 the higher the exposure. Though the mean exposure indices of 0.2912 and 0.2301 measured respectively for large-scale and small-scale mining as shown in Table 4 suggest low exposure generally, the risk of large-scale mining on household assets and livelihoods was significantly higher than that of small-scale mining. The maximum values of exposure indices represented by 0.754 and 0.625 respectively for large-scale mining and small-scale mining indicate that some agrarian households are severely impacted by the risk of both large-scale and small-scale mining. While large-scale mining is normally undertaken upland denying rural households of arable lands, small-scale mining was identified to be carried out in wetlands which are normally not priorities for many on-farm activities.

Household Sensitivity to Large-Scale and Small-Scale Mining

Sensitivity index of vulnerability to mining measures the susceptibility of household assets and livelihoods to the risk of mining emanating from households' health, food and water factors on a scale of 0 to 1 such that the closer it is to 1 the higher the sensitivity. The sensitivity of households to the risk of large-scale mining was significantly higher than that of small-scale

mining as suggested by mean sensitivity indices of 0.3632 and 0.3270 respectively shown in Table 4. The maximum values of these indices confirm that agrarian households are more sensitive to large-scale mining than small-scale mining. The negative effect of large-scale mining on health, food and water factors of households was higher than that of small-scale mining.

Household Adaptive Capacity to reduce the risk of Large-Scale and Small-Scale Mining

Adaptive capacity index of vulnerability to mining measures the capacity of household's socio-economic profile, livelihood strategies and social networks, to reduce the risk of mining on assets and livelihoods on a scale of 0 to 1 such that the closer it is to 1 the poorer the capacity. From Table 4, the mean adaptive capacity indices of 0.4545 and 0.4560 respectively for households in large-Scale Mining Area and Small-Scale Mining Area were equally high suggesting that households in both mining areas could not reduce the risk of mining on household assets and livelihoods. The mean adaptive capacity indices for households were generally higher than the indices of the other two vulnerability domains meaning that Socio-economic profile, livelihood strategies, social network of agrarian households were not robust enough to reducing the risk of mining on household assets and livelihoods.

Household Livelihood Vulnerability to Large-Scale and Small-Scale Mining

The net effect of exposure, sensitivity and adaptive capacity indices is manifested in the composite household livelihood index which measures households stress emanating from mining. As is evident in Table 4, sensitivity and adaptive capacity indices of vulnerability to the risk of large-scale and small-scale mining were the major contributors to the composite livelihood vulnerability index making agrarian households vulnerable to the risk of mining. The mean household livelihood vulnerability (HLV) index of 0.3889 and 0.3686 for households in Large-Scale and Small-Scale Mining Areas respectively suggest low vulnerability generally (Thabane, 2015) as a result of low exposure of mining on household assets and livelihoods. However, maximum values of HLV indices indicate that livelihoods of some agrarian households were more vulnerable to the stress emanating from mining. Both the mean and maximum HLV indices indicate that livelihoods of agrarian households were significantly more vulnerable to the risk of large-scale mining than small-scale mining. This observation could be attributed to the negative effect of large-scale mining on health, food and water factors of households that make them more sensitive to large-scale mining and reduce their capacity to combat the risk of mining on livelihood assets.

Table 4: Statistical Summary of Household Livelihood Vulnerability (HLV) Indices

Household Livelihood Vulnerability Index(LVI)	Large Scale Mining Area N=432				Small Scale Mining Area N=432				t-statistic	P-value
	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.		
Exposure Index	0.000	0.754	0.2912	0.13784	0.000	0.625	0.2301	0.10445	7.343	0.000
Sensitivity Index	0.107	0.608	0.3632	0.09896	0.169	0.523	0.3270	0.07253	6.132	0.000
Adaptive Capacity Index	0.198	0.752	0.4545	0.09416	0.210	0.792	0.4560	0.97134	-0.047	0.975
Composite Livelihood Vulnerability Index (HLV_c)	0.223	0.597	0.3889	0.07019	0.226	0.549	0.3636	0.06170	5.627	0.000

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

CONCLUSION AND RECOMMENDATION

Exposure of large-scale mining on assets and livelihoods of agrarian household was higher than that of small-scale mining. As a result, households were more sensitive to the risk of large-scale mining. Agrarian households equally had poor capacity to reduce the risk of mining. Though, the net effect of the three sub-vulnerability domains suggest low vulnerability to the risk of mining, assets and livelihoods of agrarian households are more vulnerable to the risk of large-scale mining than small-scale mining.

The following emerging recommendations provide policy directions for reducing livelihood vulnerability to both large-scale and small-scale mining:

i. Mining regulations need to be strictly enforced by Metropolitan and District Assemblies, Environmental Protection Agency and Minerals Commission of Ghana to minimize the exposure of large-scale and small-scale mining on household assets and livelihoods,
ii. Health, food and water factors of agrarian households in mining communities need to be strengthened by Metropolitan and District Assemblies and Mining Companies to make them less sensitive to the exposure of mining, and
iii. Agrarian households need to be trained and equipped to improve on their livelihood assets, strategies and adaptive capacity to combat the risk of mining

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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