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GEOGRAPHY | RESEARCH ARTICLE

Challenges of income diversification and food security in Northern rural Ghana

Gamel Abdul-Nasser Salifu[1]* and Zubeiru Salifu[2]

Abstract: The relationship between income diversification and food security gained considerable attention in the academic literature in the last two decades. Smallholder farmers undertake income diversification activities to ensure improved food security amidst changing patterns of climate and rural socio-demographics. Understanding challenges of smallholder farmers in income diversification strategies is critical to assess the effectiveness of food security measures in savannah regions threatened by weather variability and environmental shocks. The aim of this study is to shed light on the challenges of income diversification in Northern rural Ghana and to add to the growing body of research seeking to understand the challenges of income diversification and its link to food security status of smallholder farmers in the deprived context of rural Africa. By exploiting a unique sample

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PUBLIC INTEREST STATEMENT

One of the main development objectives of the UN's Sustainable Development Goals is to reduce poverty and improve food security. The goals are articulated in the development strategies of African governments. In Ghana for instance, comprehensive policy frameworks ranging from Ghana Poverty Reduction Strategy (GPRS I & II), Ghana Shared Growth & Development Agenda and Planting for Food and Jobs (PFJ) have been implemented since 2002 to underscore the welfare impacts of rural income diversification in Ghana. The main justifications for diversification are the need to raise capital for farming, invest in education, create employment opportunities for rural youth, improve living standards , and protect natural resources. Food insecurity remains a looming threat to rural folks despite several interventions by government and policy makers. Many households still struggle with food shortages, particularly during hard times. This contributes to malnutrition and the employment of unsustainable economic coping mechanisms by households as national food inflation exceeds the global average in less than one year. As a result, poverty in the nation continues to be pervasive, impeding government attempts to combat the economic downturn.

of 500 agricultural households in rural Ghana, we show that income diversification and food security status of smallholders is positively related for both food access and nutritional diversity. Our results show that income diversification played a significant role in improving food access and dietary consumption. Highly diversified households were more likely to report being food secure as higher income diversification translated into higher incomes and food security. The single most important factor which stood out as an explanatory variable for food security in Northern rural Ghana was spousal incomes generated from diversification. Spousal incomes accounted for (29.2%) of the share of total household incomes used to purchase food for farm families in distress seasons. The findings support the use of spousal income diversification pathways as a means of reducing the negative impacts of food insecurity in the Yendi and Bimbilla Municipalities of Northern Region. The study highlights the need for Ghana's economic policy frameworks to address the following three cardinal challenges of income diversification : (1) poor access to start-up capital or funds, (2) poor condition of infrastructure, and (3) high costs of transportation, directly linked to the under development of Northern Ghana.

Subjects: Rural Development; Economics and Development; Gender & Development; Research Methods in Development Studies; Sustainable Development

Keywords: income diversification; sustainable livelihoods; climate change; household food security; smallholder farmers; rural development policy; Ghana

1. Introduction

Research on income diversification has a long tradition. For decades, one of the most popular ideas in development literature is the notion that a key technique for addressing the difficulties faced by emerging nations is to diversify their agricultural practices. Recent theoretical developments have revealed that income diversification of the non-farm sector can increase the profitability and general stability of the economy to increase the long-term viability of agriculture. Income diversification follows the paradigm of development economics widely considered to be a good way to boost agricultural revenue, create more jobs, stabilize farm revenue over time, and protect natural resources (Salifu, 2019b). Income diversification turns out to be problematic for smallholder farmers shifting to other economic enterprises without the needed government assistance interms of provision of supportive policies and better infrastructure.

Agriculture is the second largest employer of households in the Ghanaian economy (Mensah, 2023). Hence, constitutes an important source of livelihood for smallholder farmers who derive income from crop and livestock farming (Alam et al., 2023; Kissi & Herzig, 2023; Rock, 2023). However, in recent times smallholder farmers in rural Northern Ghana have experienced declining farm incomes due to multifarious shocks bedeviling the agricultural sector (Boakye et al., 2021). The challenges of raising farm incomes to improve food security are compromised by environmental shocks, policy myopia, market failure, financial and infrastructural deficits (Ashraf & Javed, 2023). These developments have seriously limited the potential of agriculture as a viable option for sustaining rural livelihoods.

Smallholder farmers have encountered more floods, droughts and insect invasion incidents than any time in the history of agriculture in study area (Alam et al., 2023). They have also struggled with institutional and market bottlenecks such as price fluctuations, market integration challenges and other disadvantages (Alvar-Beltrán et al., 2023; Ellis, 1998).

Smallholder farmers threatened by these challenges are therefore forced to seek alternative sources of livelihoods from income generation activities in the rural non-farm economy. They diversify from farm to non-farm sector as a means of earning incomes from multiple sources to supplement income deficits from farming. Some of the non-farm income generation activities they undertake include part-time retail businesses, provision of labour services to other industries such as construction and manufacturing sectors (Getahun et al., 2023; Haggblade et al., 2010).

Diversification from farm sector provides resilience against income shocks caused by climate change and other weather variability indices detrimental to optimal income realization from farm enterprises (Kehinde & Ogundeji, 2023). Income diversification is a strategy to reduce risks arising from income variability (Olutumise, 2023). Income from diversification contributes an important share to total household incomes. Non-farm incomes are essential for achieving food security and poverty reduction (Zhou et al., 2023). These objectives are directly linked to goal 1 (No Poverty) and goal 2 (Zero hunger) of the global sustainable development agenda. The current study contributes to sustainable development goals in rural Africa. The novelty of this study comes from its examination of the motives and challenges of income diversification and its linkage to household food security (Zero hunger) in a previously unreported area in rural Africa

This study is underpinned by utility and portfolio theories. Agricultural households derive maximum benefit from the use of capital inputs to generate income from a portfolio of non-farm activities. This rational behavior is aimed at improving livelihoods and building resilience against hunger in distress periods (Usman & Callo-Concha, 2021). The households learn to minimize production risk by deciding not to "put all their eggs" in one basket (Do, 2023). In this study, sampled households shift from crop and livestock farming into non-farm businesses. Diversification of income sources as a risk mitigation strategy for food security is an essential feature of smallholder livelihoods but existing studies (Canagarajah et al., 2001; Ellis, 1998; Niehof, 2004; Salifu & Anaman, 2019a; Yaro, 2006), have failed to address the secondary motives and challenges of smallholder farmers in their attempt to diversify income sources within the rural African context. Therefore, how income diversification activities translate into food security outcomes for households in northern rural Ghana remains largely unknown. As far as we know, no previous research has investigated the challenges of income diversification and food security in northern rural Ghana. As the agricultural sector, which is the backbone of the Ghanaian economy continues to suffer from global shocks such as the COVID-19, Russian-Ukraine war and Israel -Hamas conflict in Gaza, analysis of income diversification as a strategy for improving food security, becomes ever imperative to document.

Against this background, this study assesses the challenges faced by rural households in diversifying sources of income from agricultural activities in rural northern Ghana, which is heavily influenced by international forces. We focus on the municipalities of Yendi and Bimbilla in rural northern Ghana, where the primary source of income is agriculture. These regions serve as the capitals of the Dagomba and Nanumba Kingdoms in Northern Ghana, where the majority of the people practice Islam. From a political standpoint, Northern region Ghana has traditionally produced the largest number of Vice Presidents of Ghana. For the first time in political history of Ghana, a muslim vice president has been elected as a flagbearer of the ruling government.

The novelty of this study is the demonstration of income diversification and its relationship with food security in a previously unreported region of Ghana. The results of this study therefore reflect current trends in income diversification and food security in Ghana, reflecting both Ghana's response to international factors and Ghana's attempts to diversify naturally out of poverty.

Moreover, the proposed framework overcomes the existing definitional fragmentation of food security measures in deprived communities and raises the awareness of spousal income diversification in the conceptualization of rural households' capacity for resiliency against food insecurity in rural Africa.

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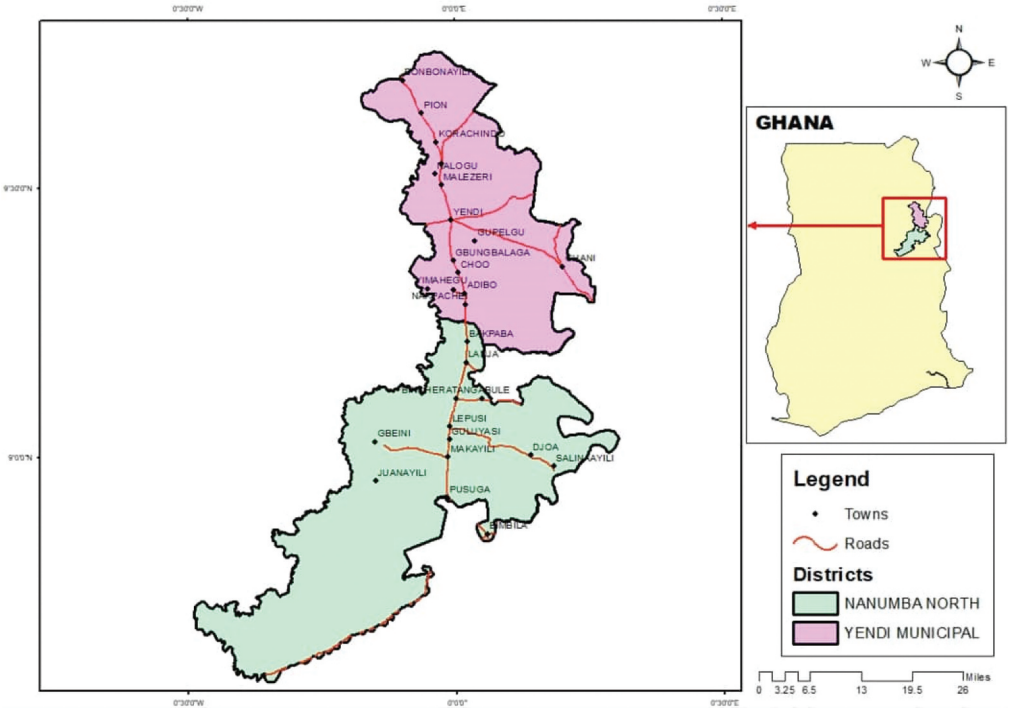

Figure 1. Location map of Yendi and Nanumba North (Bimbilla) income diversification Zones.

Source: Ghana Survey Department, 2020.

2. Brief description of the study areas

The research area, which is the northern portion of Ghana, is 97,702 km2 in size and is located between latitudes 8°N and 11°N. The rain in Northern Ghana is divided into two distinct seasons: the Rainy Season, which lasts from May to October and provides sufficient rainfall for agricultural productivity, and the Dry Season, which lasts for around seven months from October/November to April/May. Northern Ghana, which is made up of the Northern, Upper East, and Upper West regions, is situated in the sub-humid to semi-arid Guinea Savannah and arid Sudan Savannah zones of Ghana. Here, the annual precipitation ranges between 400 and 1200 mm, and agriculture—which supports about 70% of the population—is entirely dependent on rain. The location map of the study areas (Yendi and Bimbilla) are presented in Figure 1.

3. Materials and methods

Through the use of multistage random sampling procedures, survey data from agricultural households homes were gathered for the current study. Through in-person interviews, information from household heads was gathered. This strategy was used for two factors. First, sending surveys through email may have increased the likelihood that respondents would not answer. Second, the bulk of household heads are illiterate and unable to access print media other than through personal interviews. The questionnaire used to gather the data asked questions on the socio-economic characteristics of the respondents, the causes and justifications for income diversification, and details about their level of food security. A pretesting survey of the intended questionnaire was done with 25 farmers who were excluded from the final dataset prior to the start of the formal survey.

3.1. Study design

For the purpose of gathering data at the micro level, this study used a cross-sectional survey design. It was a quantitative research design that provided "quantitative or numeric description of trends, attitudes or opinions of a population by studying a sample of that population" (Creswell, 2013, p. 13). The quantitative research design for this study involved sampling approach and techniques adopted to collect survey data for the analysis of income diversification activities of

rural households (Chen & Guo, 2023). This quantitative design was completed by a limited qualitative study involving confidential interviews of local experts and several focus-group discussions with selected people and informants.

A universally accepted advantage of quantitative research survey is its usefulness for prediction. A limitation is its inability to identify other influential variables or factors (described as extraneous variables or confounding variables) considered to be important. For this study, this limitation was partially overcome by the use of cross-sectional survey design, which collected information directly from the respondents from June to December in 2019.

3.2. Sample design

Based on multi-stage cluster sampling methods, the sample design for this study was developed (Anaman, 2014). Listing the main sampling units of the target population was part of the multi-stage cluster sampling design. From the two districts of the Northern region's primary sampling units, a sample of households was then chosen. In a research study that employed a multi-cluster sample strategy, the whole list of residences or houses in the two districts was utilized to choose the study's participants.

Every rural household in the survey region had an equal chance of being chosen for the sample, which was the main justification for the sample design. To accomplish this goal: From a list of districts in Ghana's Northern region, the Yendi and Nanumba North districts were ramdomly selected. The population in the two districts were then clustered on the basis of rural-urban characteristics using the latest housing and population census data. From these clustered population, rural households were randomly sampled. The random selection method was applied based on probability proportionate to the population size of the district. The sample frame for this survey included rural households in the two districts. A multi-staged stratified/clustered, systematic, and simple-random strategy was used in the sample design. Based on a likelihood proportionate to the size of the two districts' populations, the ideal sample size for the study was determined.

3.3. Sample size determination

This study required a minimum sample size of 500 rural households. To account for up to 50% non-response, a sample of 600 respondents was chosen at the household level. The optimal sample size was determined based on the following assumptions (de Souza et al., 2023).

(I) A confidence interval of 95% was assumed for the study. At a 95 percent confidence level of statistical significance, it is assumed that the study's sample size decision was sound. (Alemu, 2023).

(II) The significance level of 5 percent. The likelihood of discovering the results only by chance will be less than 5% at this statistically significant level. To put it another way, there are around 5 in 100 possibilities that the research will reject the null hypothesis when it should be accepted.

(III) The study made the assumption that the response rate would be 90% as the researcher had no influence over the survey respondents;

(IV) The goal of determining the sample size was to find the number of instances that will produce the smallest effect size for any test that could be performed using the survey;

(V) It was assumed that heads of rural households would complete the study's questionnaire.

All rural households in the Northern area were included in the sample frame, which was created using data from the 2010 Population and Housing Census. Based on how Ghana is administratively divided into regions, districts, and residential areas as urban and rural, the study determined that 500 people would make the best sample size. This indicates that a sample of all 500 cases was chosen at random from the adult population, with a significance level of 0.05 percent at a 95% level of confidence. Using the fundamental statistical ideas of the binomial and normal probability distribution as a foundation,

the survey's decision on the ideal sample size for data collection was made. In order to establish the smallest statistically valid sample size, a "simplified formula was used to calculate sample sizes" (Yamane, 1967:886). A 95% confidence level and $P = 0.05$ are assumed. It states that;

$$n = \frac{N}{(1 + N(\alpha^2)} \tag{1}$$

Where: n = Sample Size; N =sample frame or total rural households in the two districts; α = confidence interval or level of precision; and 1 = constant. Thus, when this formula was applied, the sample size was determined from sampling frame of 58,236 rural household populations.

By substitution, using the above statistical or mathematical formula at 95 percent confidence interval or precision level with 0.05 percent error margin (i.e. $n = \frac{N}{(1+N(\alpha^2)}$);

where n = sample size, N= sampling frame (58,236), α = confidence interval (0.05), 1= constant, therefore, $n = 499.99 = 500$ respondents.

As a result, the statistically significant sample size for the survey was determined to be 500 or n. However, 100 was added to the ideal sample size of 500 to account for non-responsiveness, resulting in the ideal sample size of 600 respondents. Therefore, 600 responders represented the ideal sample size for this investigation. By stratifying the optimal sample size of 600, based on proportions of population of the selected districts for this study, this formula was used: $n_1 = n_o (\frac{N_0}{N})$

n_0 = Desired Sample Size; n_1 = Total Sample Size; N_0 = Total Rural Household Population; N_1 = District population. The population of study and sample size distribution is shown below.

3.4. Measurement and analysis of non-farm income diversification

The Simpson Index (SI) is a popular metric for assessing the diversity of non-farm income. The Herfindahl-Hirschman Index (HHI) for a household serves as the basis for this measurement. The household portfolio's share of income is squared for each asset or activity to get the HHI, which is then totaled across all the squares. The SDI is derived as 1-HHCI. The SDI measures the spread of all income-generating activities rather than the concentration implied in HHCI. SDI is expressed mathematically in Equation 2as follows:

$$\text{SDI} = 1 - \sum \text{Pi}^2 \tag{2}$$

Where SDI is the Simpson diversification index for a household. Pi is the share of total gross income of a household coming from source i. The HHCI for a household is denoted by $\Sigma \text{Pi}^{2.}$

Standard multiple regression was used to establish the linkage of non-farm diversification to welfare outcomes such as food security (Salifu & Anaman, 2019a). The variables used in modelling the linkage of non-farm income diversification to food security status of rural households in the study areas are presented in the appendix.

3.5. Significance of the study

This study documents several key contributions to the field of development economics. The contributions made here have wide applicability in economics and social science research. It provides important clues to fill the information gap on income diversification of rural agricultural households in northern Ghana where Islamic religious practices are dominant. The study's findings, in particular, offer some contributions and benefits for academics, policymakers, implementers, and researchers. For academics, it may provide insights towards the application of maximum likelihood procedures (Poisson and tobit regression models), Herfindahl-Hirschman Concentration Index, Simpson diversification index (SDI) and linear programming techniques in development, energy and financial economics. In addition, the findings of this study can help different governmental and nongovernmental implementer organisations, such as the USAID,

ACDI/VOCA, to provide catalytic and innovative financing to Small and Medium Enterprises (SMEs) operating in food systems in Africa. Moreover, the study generated first-hand information on income diversification strategies of rural households in a previously unreported area. It is of interest to agricultural economists conducting policy research in Northern Ghana where spousal income diversification is strongly emerging as a major driver of household food security. This paper deals with the fundamental gender issue of women's access to capital inputs for income diversification in a typical patriarchal society of Northern Ghana where women encounter high levels of social stress in their efforts to fulfill their social function of meeting the food security needs of their families.

4. Results and discussions

4.1. Motives for non-farm income diversification

Table 1 provides a list of reasons indicated by the 500 sampled household heads in the Yendi and Bimbilla districts for engaging in income-diversification activities. The most important reason indicated by the household heads was declining farm incomes, which had an average score of 4.832 on the zero-to-five Likert linear scoring scale. Investment in personal development and family members was ranked second with an average score of 4.826. Raising capital and additional funds for farming ventures was ranked third with an average score of 4.820. Two additional important factors indicated for engagement in income-diversification activities were sustaining quality standard of living (average score of 4.638) and the creation of employment opportunities for family members (average score of 4.506). It must be noted that the five most important factors driving income diversification activities were essentially related to income generation, employment opportunities and raising for capital for farming ventures

Table 1. The sampling frame of Yendi Municipality

Community Name	Total Population	Total Number of Households	Total Number of Houses	Number of Houses
Nakpachei	2,883	292	251	20
Adibo	2,795	251	253	20
Gbungbalga	2,697	250	228	18
Kuga (Kpatuya)	2,321	255	324	25
Sakpiegu	2,071	126	120	9
Bonbona Yili	1,982	203	189	15
Yareni	1,923	220	213	17
Tindang	1,691	351	329	26
Bachabodo	1,611	131	121	9
Sabare No.Ii	1,583	90	91	7
Kpalsoni	1,521	128	142	11
Maabamboli	1,449	139	115	9
Sukaani	1,439	119	85	7
Bonbonayili	1,304	162	141	11
Nyankani	1,149	100	88	7
Wambung I & II	1,135	132	109	9
Nalorgba	2,883	103	105	8
Gnani	2,795	131	129	10
Tusani	2,697	112	117	9
Total	**2,321**	**3,295**	**3,150**	**246**

designed to create higher incomes. Surprisingly, income diversification, as a tool for insurance or mitigation of risks was ranked of lowly importance (average score of 2.472).

4.2. Challenges of non-farm income diversification

The ranking of the importance of the constraints impeding income diversification activities are outlined in Table 2. The three most important constraints in order of importance were (1) poor access to start-up capital or funds, (2) poor condition of infrastructure, and (3) the high costs of transportation, which is linked directly to the poor infrastructure. Poor skills and knowledge, price fluctuations related to inputs and produce, risks involved in the income diversification, and the high-level of competition were assessed as moderately important constraints. Bad weather and socio-cultural beliefs, often cited in the development literature, were ranged as unimportant by the household heads in the Yendi and Bimbilla.

4.3. Results of analysis of income-generating sources of households

As indicated in Table 3, the number of broad income-generating activities (NBIGA) of the sampled households ranged from one to 10 with an average value of 7.07 and a standard deviation of 2.21. These ten broad income-generating activities were as follows: (1) remittance received by the household head, (2) rental income received by the household head, (3) wage-based income received by household head, (4) non-farm business income received by the household head, (5) all other sources of non-agricultural income received by the household head or in combination with the spouses (s), (6) income from crop farming, belonging to both household head and spouse, (7) income from livestock farming, belonging to both household head and spouse, (8) wage-based income received solely earned by the spouse(s) of the household head, (9) non-farm enterprise income solely generated by the spouse(s) of the household head, for example, from sewing and food preparation businesses, and (10) remittance income received solely by the spouse(s).

Table 2. The sampling frame of Nanumba North (Bimbilla) municipality

Community Name	Total Population	Total Number of Households	Total Number of Houses	Sample Size Number of Houses
Bakpaba	2,961	380	321	**26**
Lepusi	2,579	356	316	**25**
Nakpa-Gbeini	2,548	347	303	**24**
Sabonjida	2,220	283	253	**20**
Kimoateek	1,784	271	212	**17**
Lanja	1,710	222	200	**16**
Gulnyansi	1,650	231	182	**15**
Dakpam	1,502	188	289	**23**
Dipah	1,243	185	130	**10**
Sogun No.2	1,183	199	157	**13**
Taali	1,154	196	144	**12**
Sogun No.1	1,141	165	140	**11**
Salnayili Battor	1,057	211	159	**13**
Pusiga	1,024	115	111	**9**
Binalogdo Katajeli	1,018	143	88	**7**
Dangbe	991	163	170	**14**
Total	**29,554**	**3,655**	**3,175**	**254**

Table 3. Ranking of the importance of the motives for non-farm income diversification indicated by the sampled agricultural household heads

Influencing Factor	No.	Average score of importance	Standard deviation of score	Ranking
Declining farm incomes	500	4.832	0.374	1
Investment in personal development and education of household members	500	4.826	0.380	2
To raise capital for farming	500	4.820	0.400	3
To sustain quality standard of living	500	4.638	0.734	4
To create employment opportunities for my family	500	4.506	0.756	5
Seeking insurance against agricultural production risks	500	2.472	2.200	6
Other economic activities offer better returns than farming	500	2.014	1.601	7
Other activities are more prestigious than farming	500	0.410	0.535	8

Source: Derived from survey data, June to December 2019.

Notes: In terms of factors influencing the choice of the household for income diversification, the scoring is based on 5 denoting that item is extremely important, 4, very important, 3 moderately important, 2 less important, 1 least important, and zero not considered as a factor at all.

The non-farm income diversification analysis in the Yendi and Bimbilla districts can be envisioned as a game played by the household against hunger and poverty. Unlike, the Ghana Living Standards Survey (GLSS) datasets, which have not emphasized the separate sources of incomes earned by spouse(s), this study sought to identify all the possible sources of separately-managed incomes earned by spouse(s); it identified three broad sources of income: wage-based income, non-farm enterprise income, and remittances received solely by the spouse(s).

The total household income was derived as the sum of all ten sources of income. The proportions of the total number of respondents who derived incomes from each of the ten sources are also listed in Table 4. The overall diversification measure the Simpson index averaged 0.7958 (79.58%) with a standard deviation of 0.074 (7.4%). The range of the Simpson index was from 0.41 to 0.89 (41% to 89%) suggested a generally-high level of income diversification by rural households. As revealed by Table 4, all 500 sampled households earned some rental income; this was due to the imputed value of rents arising from the use of the house of the household head for living purposes. Almost all households (97.58%) were engaged in non-farm business income activities. Households which earned some wage-based income accounted for over nine out of ten sampled household heads (92.73%). Agriculture provided a core income-generating activity for the sampled households with 92.32% engaging in agricultural activities. Finally, about five out of six (84.24%) households had spouse(s) generating separate incomes from various activities.

Table 4. Ranking of constraints impeding income diversification by sampled agricultural household heads

Impeding Factor	No.	Average score of importance	Standard deviation of score	Ranking
Poor access to start-up capital	500	4.810	0.422	1
Poor condition of infrastructural facilities	500	4.636	0.735	2
High cost of transportation	500	4.316	0.465	3
Poor skills and knowledge	500	3.686	0.932	4
Price fluctuations	500	3.518	0.500	5
Risks involved	500	3.136	0.864	6
High level of competition	500	3.122	1.179	7
Poor pricing	500	3.008	1.384	8
Small household size	500	1.482	1.320	9
Bad weather	500	0.682	1.188	10
Socio-cultural beliefs	500	0.386	0.634	11

Source: Derived from survey data, June to December 2019.

Notes: In terms of factors impeding income diversification, the scoring is based on 5 denoting that item is extremely important, 4, very important, 3 moderately important, 2 less important, 1 least important, and zero not considered as a factor at all.

4.4. Results of analysis of shares of total household incomes

The average total household income and the average of all the ten component sources of total household incomes are reported in Table 5. The shares of each source of income as a proportion of the total household income were calculated and are reported in Table 6. Livestock production provided the biggest source of income for the households, accounting on average 4,783.42 Ghana cedis per household during the 2018/2019 production year. Livestock production constituted about 22.61% of the total household income of 21,208.93 Ghana cedis during the 2018/2019 production year. The dominant livestock activity was goat rearing, which accounted for about half of the total livestock income and one-ninth of the total average household income (refer to Table 7).

4.5. Results of analysis of the linkage between non-farm income diversification and food security of agricultural households

Our results demonstrated that there is a relationship between the overall diversification index and the food security of households. The implications of these findings are discussed in this section. The overall diversification index used in this study is the Simpson Index (SDI). Two measures of food security are used in the study. These are (1) the elicited food access index based on an average linear Likert scoring scale from zero to 5.0 with zero indicating complete lack of food access and 5.0 the maximum possible food access. The second was the nutritional diversity measure ascertained from household heads on the accessibility and availability of various types of nutritious ingredients in the meals of the household. The nutritional diversity measure was also based on average Likert linear scoring scale from zero to 5.0 with zero representing the absence of any nutritional diversity from the diets and meals of the household and 5.0 being the maximum nutritional diversity score.

Table 5. Sources of incomes received by sampled agricultural households

Item	Value
Number of broad income-generating activities, **NBIGA**	7.07
Overall measure of diversification: **The Simpson Index**	79.58%
Household heads who got remittance money as a percentage of all respondents in the sample	68.49%
Household heads who reported receiving rental income as a percentage of all respondents in the sample (including imputed owner-occupied households)	100.00%
Household heads who earned money from wages as a percentage of all respondents	92.73%
Household heads as a percentage of all respondents in the sample who reported having income from non-farm sources	97.58%
Households that earned money from all other non-agricultural sources as a percentage of all respondents in the sample	23.84%
Household heads that earned money from Crop production as a percentage of all respondents in the sample	85.86%
Household heads that earned money from livestock production as a percentage of all respondents in the sample	92.32%
Households with spouses who earned money from wage-based sources as a percentage of all sampled households	84.24%
Households with spouses who earned money from non-farm business sources as wage-based sources as a percentage of all sampled households	84.24%
Households with spouses who earned remittance money as a percentage of all sampled households	84.24%
Agricultural households as a as a percentage of all sampled households	92.32%

Source: Derived from survey data, June to December 2019.

Table 7, provides a summary of the results of the multiple regression analysis of the food access index versus the Simpson Index (SDI) measure of overall income diversification, the household size and the sex of the household head (SEXHH). Because SDI was not significantly related to HOUSEHOLDSIZE and SEXHH, based on the results from Table 8, all these three variables could be used as independent variables in the model to ascertain their linkage to food access.

The results from Table 9 indicate that the power of the model was very high as indicated by the R^2 of 0.954. The model was also correctly specified based on the Ramsey Test result with the computed *p* value of the test of 0.880 far above the maximum critical value of 0.10. As assessed by the LM heteroscedasticity test, the model had no significant problem with heteroscedasticity with the computed *p* value of the test being 0.110. Hence, the regression results reported in Table 9 could be used for further interpretative analysis and the development of conclusions.

The results from Table 9 indicate that all the independent variables significantly influenced the elicited food access index with the exception of SEXHH. The results are consistent with the findings of previous studies on the linkage between off-farm work and food security (Abebaw, et al., 2020; Dzanku, 2019). Assuming all other things constant, food access index increased with increasing household size. However, the sex of the household head had no significant effect on the food access index. The effect of SDI on the food access index showed a linear shape with food access

Table 6. Shares of total household incomes

Income Source	Percentage of Total Household Income
Remittances from the household head	3.72
Rental property income for the head of the household	10.23
Wage-based income of the head of the household	16.69
Non-farm business income of the household head	8.93
All other sources of income earned by the household head	4.15
Household crop production	4.48
Household livestock production	22.61
Wage-based income earned by the spouse(s)	16.38
Non-farm business income earned by the spouse(s)	4.48
Remittances received solely by spouse(s)	8.33
Total agricultural income (both crop and livestock)	27.09
Total income from household head	39.56
Total income from spouse(s)	29.20
Total jointly-managed income (all other sources of household incomes plus income from crop and livestock)	31.24
Total household income	100.00

Source: Derived from survey data, June to December 2019.

increasing with increasing income diversification without any turn. The estimated food access equation is reported in Equation 3.

$$\text{FOODACCESS} = 1.839 + \mathbf{1}.684\text{SDI} + 0.166\text{HOUSEHOLDSIZE} - \mathbf{0}.019\text{SEXHH} \quad (3)$$

Table 6 summarizes the results of the regression analysis of food nutritional diversity versus SDI, HOUSEHOLDSIZE and SEXHH as independent variables. Similar to the food access regression model, the food nutritional diversity model had a very high power with R^2 and adjusted R^2 being 0.984. Further, the food nutritional diversity was correctly specified based on the Ramsey Reset Test result and had no significant heteroscedasticity as ascertained from the reported LM heteroscedasticity test result.

The results from Table 6 indicate that all the independent variables were statistically significant in terms of influencing nutritional diversity. These results go beyond previous reports (Dzanku & Sarpong, 2011; Kirk et. al., 2018; Lang & Barling, 2012; Rawlins et al., 2014) on income diversification and food security, showing that there is a linkage between income diversification and nutritional diversity. Assuming all other things constant, we have demonstrated that nutritional diversity deteriorated with increasing household size. We have also verified that, households headed by males had lower nutritional diversity scores compared to households headed by females.

In contrast to the results for food access, the effect of SDI on nutritional diversity had inverted U shape, with food security access increasing with income diversification (SDI) until at a certain turning point when nutritional diversity declined with increasing income diversification. The estimated nutritional diversity equation is reported in Equation 4

$$\begin{aligned}\text{NUTRITIONALDIVERSITY}_i = {} & 95,011.61 + 7.004\text{SDI}_i - \mathbf{4}.003\text{SDISQUARED}_i \\ & - 0.014\text{HOUSEHOLDSIZE} - 0.087\text{SEXHH}\end{aligned} \quad (4)$$

Differentiating NUTRITIONALDIVERSITY with respect to SDI, the optimal SDI (turning point) is derived as follows: $7.004 = 4.003 \times 2$ (SDI). The turning point SDI = 0.8748.

Table 7. Results of the multiple regression analysis of Determinants of non-farm income diversification (SDI)

Explanatory Variable	Unstandardised Parameter Estimate	Standardised Parameter Estimate	Student t Test Value	Significance Probability	Variance Inflation Factor
INTERCEPT	0.804	0.000	28.940	0.000***	0.000
AGEHH	0.000	−0.025	−0.936	0.350	4.185
SEXHH	0.001	0.002	0.114	0.909	2.176
SPOUSESHAREHHINCOME	−0.051	−0.050	−2.084	0.038**	3.544
CURRENTLYMARRIED	0.035	0.079	3.700	0.000***	2.751
FORMALEDUCATION	−0.111	−0.330	−9.136	0.000***	7.868
TECHNICALEDUCATION	0.568	1.171	27.845	0.000***	10.683
HOUSEHOLDSIZE	0.001	0.016	0.840	0.401	2.097
REMITTANCEHH	0.001	0.085	6.349	0.000***	1.076
RENTALPROPERTY	−0.011	−0.034	−1.561	0.119	2.801
EXTENSIONVISITS	−0.002	−0.007	−0.223	0.823	5.961
TIMETOCLINIC	0.000	−0.018	−0.474	0.636	8.772
FALLARMYWORM	−0.008	−0.046	−1.822	0.069*	3.825
INSECTSINVASION	−0.021	−0.071	−3.228	0.001***	2.942
FLOODS	0.019	0.061	2.276	0.023**	4.307
DISTANCETOINPUTSMARKET	−0.002	−0.126	−3.662	0.000***	7.160
DISTANCETOPRODUCEMARKET	−0.001	−0.067	−3.509	0.000***	2.191
RADIO	0.028	0.074	3.165	0.002***	3.267
MOBILEPHONE	0.017	0.044	1.175	0.241	8.519
ISLAM	0.000	0.000	−0.019	0.985	2.436
NANUMBA	0.010	0.030	1.688	0.092*	1.964
KOKOMBA	0.006	0.017	0.754	0.451	3.037

Source: Derived from survey data, June to December 2019

Notes: *** 1%, ** 5%, * 10% significance levels. Sample size = 495. R^2 = 0.922 Adjusted R^2=0.918

Probability significance level of Ramsey Reset Test for correct model specification 0.446

based on the null hypothesis of adequately-correct model specification

Probability significance level of Langrange-Multiplier test of no heteroscedasticity

based on the null hypothesis of homoscedasticity or no heteroscedasticity 0.195

Table 8. Multiple regression analysis of food security access index versus the overall diversification index (SDI), household size, and the sex of the household head (HHSEX) dependent variable is the elicited average food access index measured from 0 to 5 on the Likert scale

Explanatory Variable	Unstandardised Regression Parameter Estimate	Standardised Regression Parameter Estimate	Student t value	Probability Level of Significance	Variance Inflation Factor
INTERCEPT	1.839	0.000	0.474	0.636	0.000
SDI	1.684	0.252	5.481	0.000***	22.641
HOUSEHOLDSIZE	0.166	0.744	27.463	0.000***	7.851
SEXHH	−0.019	−0.007	−0.186	0.852	13.622

Source: Derived from survey data, June to December 2019

Notes: Sample size used for the analysis was 495.

R^2 0.954***

Adjusted R^2 0.954***

Probability significance level of Ramsey Reset Test for correct model specification based on the null hypothesis of adequately-correct model specification 0.880

Probability significance level of Langrange-Multiplier (LM) test of no heteroscedasticity based on the null hypothesis of homoscedasticity or no heteroscedasticity 0.110

Significance level:*** = 1% ** = 5% .* = 10%.

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Table 9. Results of the multiple regression analysis of food security nutritional diversity index versus the overall diversification index (SDI), household size, and household head (HHSEX). Dependent variable is elicited household average nutritional diversity measured from 0 to 5 on the Likert scale

Explanatory Variable	Unstandardised Regression Parameter Estimate	Standardised Regression Parameter Estimate	Student t value	Probability Level of Significance	Variance Inflation Factor
INTERCEPT	95,011.61	0.000	0.504	0.614	0.000
SDI	7.004	2.054	21.706	0.000***	256.021
SDISQUARED	−4.003	−1.053	−10.952	0.000***	264.276
HOUSEHOLDSIZE	−0.014	−0.048	−5.190	0.000***	2.486
SEXHH	−0.087	−0.033	−4.289	0.000***	1.657

Source: Derived from survey data, June to December 2019.

Notes: Sample size used for the analysis was 496.

R^2 0.983***

Adjusted R^2 0.983***

Probability significance level of Ramsey Reset Test for correct model specification based on the null hypothesis of adequately-correct model specification 0.103

Probability significance level of Langrange-Multiplier (LM) test of no heteroscedasticity based on the null hypothesis of homoscedasticity or no heteroscedasticity 0.236

Significance level:*** = 1% ** = 5% .* = 10%.

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From the results of this particular regression analysis, it is clear that income diversification improved nutritional diversity continuously until the SDI turning point of 0.8748, after which nutritional diversity would start to deteriorate. Based on the survey data analysis, only 1.01% of the household heads had SDI beyond the turning point of 0.8748. This result now provides evidence to support the argument that overall income diversification improved nutritional diversity for around 99% of the households. Thus, on the basis of nutritional diversity, income diversification would need to be encouraged.

5. Conclusion, policy recommendation and future outlook

In conclusion, income diversification seems to improve food security. This may be considered as a further validation of the fact that income diversification leads to welfare. As we have argued elsewhere, the need for rural income diversification is motivated by declining farm incomes, investment in personal development, and education of household members, to raise capital for farming and to create employment opportunities. As climate change and weather conditions associated with farming increases, the risk and uncertainty of conventional farming in areas prone to environmental hazards such as droughts, floods and insect attacks, increases. This allows the conclusion that farmers are seeking a way out of poverty by pursuing alternative livelihood paths through market-oriented income diversification activities.

The findings of this study can be understood as a key aspect of the United Nation's sustainable development agenda for achieving "zero poverty" and "zero hunger" globally. The study assessed the challenges of income diversification and food security of smallholders in rural Ghana. For this purpose, we employ survey data collected from 500 households using structured questionnaire and focus group discussions from two municipalities (Yendi and Nanumba North) of Northern rural Ghana. The survey was undertaken from August to November, 2019 after a small pretesting survey had been conducted in June, 2019. As a supplement to the primary data, a total of 15 community-based push and pull factors that influenced income diversification activities were identified through consultations with local experts, focus group and key informant discussions using an interview guide. Some of the local experts were officials from government agencies working in Northern Ghana. Multiple regression techniques were used to estimate drivers of income diversification and linkage to food security. The household hunger scale was used to measure the food security scores of sampled households. The choice of this index of food security was to overcome the weaknesses of earlier studies on income diversification and food security in rural Africa. The study further evaluated the motives and challenges of income diversification. Importantly, our results provide evidence for 39.56% of the total household incomes accounted for by incomes generated from activities solely under the control of the household head. Jointly-generated incomes (including crop and livestock production, which were managed by both the household head and his/her spouse(s) accounted for 31.24% of the total household income, of which 27.09% of the total household income came from crop and livestock production. Nevertheless, we found, the important role of separate spousal-generated incomes in total household earnings. This particular share of income source made the difference between food security and destitution in rural households. Our data indicate that Spousal incomes accounted for 29.20% of the total household incomes in northern rural Ghana: a result that cast a new light on gender studies and food security. To the best of our knowledge, this is the first report of spousal income diversification and food security in patriarchal societies of rural Ghana. These findings provide a potential mechanism for streamlining income diversification options among rural households.

Future investigations are necessary to validate the kinds of conclusions that can be drawn from this study. It is important that future research will investigate the potential effects of spousal income diversification activities more carefully, given the prevalence of polygamous marriages and restriction of women's access to capital inputs required to opportunistically diversify from the farm sector. The role of women in the uptake of income diversification activities and its contribution to household food security is largely missing in the development literature. The resulting contribution

of Spousal incomes to food security has the potential to yield interesting insights and policy relevance for development work in rural Africa.

6. Limitations of the study

This work is limited to two districts and a data set of 500 agricultural households. The study covers the understanding of how agricultural households respond to income diversification opportunities in Northern rural Ghana. There is wide heterogeneity in the rural economy and of data limitations that long-term impacts of income diversification on agricultural households in Northern Ghana, and its role in the broader structural transformation of rural Ghana was not tackled by the study. This study was based on a cross-sectional survey rather than a longitudinal data. The study revealed more about rural income diversification in a rural context and at different points in time than about income diversification as a dynamic process in the livelihood transformation of agricultural households for upward mobility out of poverty.

The goal of this study, which was to examine and clarify whether income diversification activities could actually improve the food security status of small holder farmers in a social environment, mitigates the effects of this limitation on the generalizability of this study, despite the fact that it presents a limitation to this study's generalizability. As a result, given the paper's emphasis, the numerous insights and views it creates concerning income diversification schemes offer utility to theory and policy that clearly surpasses this limitation

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Data availability statement
Data will be made available on request from the authors

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Appendix

Definition of Variables Used in the Income Diversification Regression Model

Based on the framework for sustainable livelihoods, risk management, and structuralism political economy theories, the independent factors influencing income diversification are generated from the seven groupings of capital inputs. These variables are described below.

(1) AGEHH (continuous) is average age of the household head.

(2) AGEHHSQ is the square of age. This is used to analyse the impact of increasing age of the household head and the extent of income diversification activities undertaken by the household. These first two variables are related to human capital.

(3) AGECUBIC is the cubic form of age or age multiplied by itself twice. This variable reflects the three-stage component of the life cycle theory of behaviour of a household over the lifespan of his/her life. At very young ages, income diversification activities are limited or are even reduced in scope due to the household head engaging or re-engaging in schooling and training. From then onwards, starting from a particular young age, income diversification activities increase gradually until a certain old age when the household head is nearing retirement, and then income diversification activities begin to decline.

(4) DISABLED (dummy), one or more impairments related to eyesight, hearing, speech and the use of the limbs.

(5) SEXHH (dummy), sex of household head with 1 denoting female and zero for male. This could be envisioned as structuralism political economy variable.

(6) SPOUSESHAREHHINCOME is the share of the total household income attributed solely to the specific activities of the spouse(s) which are also managed by the spouse(s). This could be envisioned as structuralism political economy variable.

(7) CMARRIED (dummy), household head's current marital status. The value of 1 is used for those heads who are currently married and zero for those not currently married. This could be envisioned as structuralism political economy variable.

(8) FORMALEDUCATION (dummy), indicating whether the household head has ever had any years of formal schooling. A value of 1 represents formal schooling and zero the absence of any type of formal schooling. This is a human capital variable.

(9) TECHNICALEDUCATION (dummy), with a value of 1 if the household head completed post-secondary technical or vocational education and zero otherwise. This is a human capital variable.

(10) APPRENTICESHIP is a variable that deals with the availability of persons within the household who have undergone various forms of apprenticeship training or informal technical and/or vocational training. This variable is designated as a dummy variable with 1 denoting the presence of persons in the household with apprenticeship training and zero for the lack of any persons with apprenticeship training. This is a human capital variable.

(11) APPRENTICETECHNICALEDUCATION (dummy), with a value of 1 for households who have had apprenticeship training and/or who has received post-secondary training in a technical school or vocational institute or zero otherwise. The variable analyses household heads with acquired skills through hand-on apprenticeship training or through formal post-secondary schooling. This variable is useful especially for data sets where there are very limited numbers of household head with just apprenticeship training or post-secondary technical/vocational schooling. This is a human capital variable.

(12) HHSIZE is the number of persons in the household including the household head and the spouse(s). This is a human capital variable.

(13) REMITTANCEHH is the monies received by the household head as remittances from both local and overseas sources. This is financial capital variable.

(14) RENTALPROPERTY (dummy), with value of 1 for household heads with a property that generates rental income and zero otherwise. This is physical capital variable.

(15) HOUSEOWNERSHIP is a dummy variable with the value of 1 assigned for the ownership of the residential house by the household head and spouse(s). The value of zero is used for the lack of ownership of a house. This is physical capital variable.

(16) TIMETOCLINIC is the time required by the householder to visit the nearest clinic or hospital from his/her own home measured in minutes. This variable deals with infrastructural capital.

(17) FALLARMYWORM is a dummy variable with a value of 1 if the household head indicated the presence of fall army worms in his/her locality during the previous 12 months before the survey. A value of zero reflects the absence of fall army worms in the locality. Fall army worms represents an environmental or natural capital constraint as they directly affect the production of crops and other livelihood activities.

(18) INSECTSINVASION is a dummy variable used to indicate the presence of insects that attack crops or damage livelihood activities during the previous 12 months before the survey. It takes a value of 1 for the presence of insects and zero for the absence of insects. This variable is an environmental and natural capital constraint.

(19) FLOODS is a dummy variable with a value of 1 for the occurrence of moderate-intensity of floods in the locality during the previous 12 months before the survey and zero for the absence of floods. Floods could be both an environmental or natural capital constraint or endowment. Severe floods can destroy properties of the household including crops and livestock. However, moderate-type floods bring extra rain and moisture required for sustained production of crops.

(20) DISTANCETOINPUTSMARKET is the distance from the home of the household head to the nearest market for which farm inputs can be purchased. This is measured in kilometres and represents an infrastructural capital variable.

(21) DISTANCETOPRODUCEMARKET is the distance from the home of the household head to the nearest market for which farm produce could be sold. This is measured in kilometres and represents an infrastructural capital variable.

(22) EXTENSIONVISITS is a dummy variable with a value of 1 for households which received visits from various government and non-governmental organizations dealing with the provision of information concerning livelihood activities not necessarily restricted to agriculture. A value of zero is used to denote households who were not visited by any extension agents during the previous 12 months prior to the survey. This variable deals with informational capital and the variable is related to the access of government services by the householders.

(23) OWNERSHIPOFRADIO. It is a dummy variable used to indicate ownership of a radio. It takes 1 referring to ownership of radio sets and zero indicating no ownership of radio within the household. This is an informational capital variable.

(24) TELEVISION is a variable assigned for the ownership of a television set by the household. (30) MPHONE is a dummy variable with 1 indicating ownership of one or more mobile phones by adult members of the household and zero for no ownership of mobile phones in the household. This is an informational capital variable.

(25) SEWMACH refers to the possession of a sewing machine by the household. A value of 1 is assigned for its ownership while the value of zero is used to denote lack of ownership. This is a physical capital variable that allows householders, especially the spouse(s) to earn incomes through non-farm business ventures.

(26) BCYCLE is a dummy variable with a value of 1 for ownership of a bicycle and zero for lack of ownership by an adult household member.

(27) DAGOMBA is used for the ethnic origin of the household head. It takes a value of 1 if the household head is a Dagomba and a value of zero if the household head is not a Dagomba. This is a structuralism political economy variable.

(28) KOKOMBA is used for the ethnic origin of the household head. It takes a value of 1 if the household head is a Kokomba and a value of zero if the household head is not a Kokomba. This is a structuralism political economy variable.

(29) NANUMBA is used for the ethnic origin of the household head. It takes a value of 1 if the household head is a Nanumba and a value of zero if the household head is not a Nanumba. This is a structuralism political economy variable.

(30) ISLAM is a dummy variable with 1 referring to household heads practising Islamic faith and zero for non-muslim household heads. This is a structuralism political economy variable.