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USING INSTRUMENTAL VARIABLES TO ESTABLISH THE RELATIONSHIP BETWEEN HOUSEHOLD PRODUCTION DIVERSITY AND HOUSEHOLD DIETARY DIVERSITY IN NORTHERN GHANA

Sienso G[1]*, Lyford C[2] and W Oldewage-Theron[3]

Gifty Sienso

*Corresponding author email: giftysienso@yahoo.com

[1]Department of Applied Economics, University for Development Studies, Ghana
ORCID ID: https://orcid.org/0000-0003-3864-1893

[2]Department of Agricultural and Applied Economics, Texas Tech University, USA

[3]Department of Nutritional Sciences, Texas Tech University, USA

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ABSTRACT

Despite the potential for agricultural diversification to improve nutrition, little scientific evidence exists in low- and middle-income countries on how the linkages between agriculture and nutrition work. In order to develop effective policies to address the nutrition-agricultural linkages in Ghana, it is important to understand and analyze the relationship between these variables. Agricultural production influences dietary quality because many rural households primarily depend on the food they produce. Households' access to a diverse diet could enhance nutrition security as well as reduce mortality related to malnutrition. Thus, if households adopt a nutrition-sensitive approach in their production process, this may provide the necessary ingredients for diverse diets. However, over the years agricultural interventions in many developing countries have focused mainly on selected crops, particularly cereals, which may not meet household nutritional requirements. While these efforts have contributed to the reduction in hunger, over 800 million people in developing countries still suffer from hunger and micronutrient deficiencies. These effects show that eradicating hunger alone is not enough to ensure nutrition security. However, a potential solution comes from the agricultural sector through farm production diversity. A survey of rural farm households in Northern Ghana was conducted in the major and minor production seasons. Data were collected from six districts using a semi-structured questionnaire. The head of household (main decision maker) (n=505) and a woman mainly in charge of food preparation in the house were the main respondents in the surveys. Household dietary diversity score (HDDS) was measured as the number of counts of 12 food groups eaten by households within 24 hours prior to the interview and household production diversity score (HPDS) was measured as the total number of counts of crops and animals produced by the household in the last twelve months based on the same twelve food groups used in HDDS. A two stage least square with instrumental variables model was developed and estimated. After correcting for endogeneity, increased HPDS increased HDDS while increased distance to the nearest market, household size, proportion of produce sold, income, and price of maize decreased HDDS. Households are encouraged to diversify production but with caution because diversifying production may be unreliable due to the heavy reliance on rainfall in the area which is often unpredictable.

Key words: production diversity, dietary diversity, nutrition-sensitive agriculture, instrumental variables, nutrition

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BACKGROUND

Consuming a healthy and nutritious diet is critical for human development and economic growth and the agricultural sector has a vital role to play in this transformation, particularly for rural households. However, this linkage is often not focused on sufficiently [1]. Over the past years, agricultural interventions have mainly focused on increases in cereal and grain production. These efforts, while contributing to the reduction in hunger and increasing access to energy-dense foods, often came at the neglect of nutritional quality [2]. It is reported that the number of people who suffered from hunger in 2020 ranged from 720 to 811 million. These projections showed that an additional 118 million (figure is based on middle of the projected range) and 161 million (figure based on the upper bound range) more people faced hunger in 2020 than in 2019 [3]. This shows that eradicating hunger alone is not enough to ensure nutrition security. However, a potential solution comes from the agricultural sector in curbing the two problems.

The agricultural sector plays an important role in the Ghanaian economy employing about half of the labor force in the country and contributing 19.7% to gross domestic product (GDP) [4]. While the country is on course to meeting its target on under-five overweight, stunting and wasting, the country is off course on some other health indicators. For example, 46.4% of women of reproductive age have anemia while 16.6% of women and 4.5% of men are obese [5]. Available literature also shows that the prevalence of micronutrient deficiencies may be reduced through the consumption of diverse diets [6, 7]. Furthermore, household access to a diverse diet could enhance the nutrition security of households [8]. Additionally, households' access to diverse diets is essential for reducing maternal and child mortality around the globe [9]. This implies that if households adopt a nutrition-sensitive approach in their production process, this may provide more diverse household diets.

Diversification in production is often viewed as an alternative way to improve dietary quality and diversity [7, 10], particularly for rural smallholder farmers. The relationship between agriculture and nutrition can be traced through different pathways. According to the World Bank, the agricultural sector influences the quality of diets of small farming households through the following ways: (1) the production of food crops and rearing of animals consumed directly by the household, and (2) the sale of agricultural goods that affect household incomes and as such their food purchases and consumption [11]. Farmers participate in markets as both suppliers and demanders of goods, because they sell part of their farm produce and obtain cash which can be used to purchase other diverse food to improve their nutritional wellbeing [12]. Also, the agricultural sector through increased production can increase government revenue to fund health, infrastructure and nutrition interventions [1].

Despite the potential for agricultural diversification to improve nutrition, little scientific evidence exists in low- and middle-income countries including Ghana on how the linkages between agriculture and nutrition works [13]. In order to develop effective policies to address the nutrition-agricultural linkages in the country, it is important to understand and analyze the relationship between these variables. This study contributes to the literature not only by finding the association between household production scores and household dietary diversity score (HDDS) but also used instrumental variables to control for the problem of endogeneity. This more firmly establishes the relationship between production diversity and HDDS.

MATERIALS AND METHODS

Data: The data used in this study were collected from rural farm households in Northern Ghana through two cross-sectional surveys that were timed to address seasonal differences, (a) lean season (April to May, 2017) and (b) harvest season (January to February, 2017). Prior to data collection, approval was given by the Institutional Review Board (IRB) (IRB number: IRB2016-1016) of Texas Tech University to ensure that the ethics in data collection were adhered to by the researchers. Additionally, informed consent was obtained from the respondents before the questionnaires were administered. A two-stage sampling procedure was employed in selecting respondents for the study. In the first stage, proportionate sampling procedure was used to select six (6) districts in the Northern Region of Ghana. In the second stage, simple random sampling was used to select 505 households. The same sampling procedure was used for both rounds of data collection in the lean season.

The sample size for the study was calculated following the formula used by Charan and Biswas [14]. Thus, this sample is representative of farm households in the northern region of Ghana. Structured questions related to the study objectives were administered to respondents assisted by field workers. The selection of enumerators was based on education and employment as agricultural extension officers, as well as fluency in the local dialect and experience in data collection. Questionnaires were pretested before data collection so that errors and omissions were corrected to ensure quality and reliability of data collected. Supervision of data collection was done by the researchers during the pretesting and data collection stages. The questionnaires were administered to the household heads (main decision makers) and the women mainly in charge of food preparation in the homes. In the absence of the head of household, the next adult in the household who was a main contributor to household decision making was interviewed. The women were asked questions on the ingredients that were used to prepare the dishes that household members ate within 24 hours prior to the time of interview. The foods/ingredients were then grouped according to the food group they belonged to. A household scored one (1) if it consumed from a particular food group and zero (0) otherwise. Thus, a household could score a minimum of zero (0) and a maximum of twelve (12). The HDDS was then calculated as the total number of food groups consumed by the household. Household Dietary Diversity Scores (HDDS) for both harvest and lean seasons were calculated and the mean score for the two seasons was used for the analysis.

Analytical approach

The econometric analysis of this study focused on the relationship between household dietary diversity and household food production diversity as was done in other research [15, 16,17]. The effect of farm production diversity on HDDS is estimated by a regression model of the general form:

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$$HDDSi = \beta Xi + \delta Pi + Ui \quad (1)$$

where $HDDS_i$ is a measure of household dietary diversity of household i, P_i is the measure of farm production diversity, and X_i include farm characteristics such as land area, market access and sociodemographic characteristics such as household size, age of head of household, gender of head of household, total household income, household monthly expenditure on food, household monthly expenditure on non-food items and education. The coefficients β and δ are to be estimated and Ui is the random error term.

Measurement of household dietary diversity score **-** The dependent variable of interest in this study is HDDS and is measured as the average value of HDDS in the lean (minor) and harvest seasons (major) [16]. Household dietary diversity score is a count measure which represents the number of counts of different food groups consumed by a household within 24 hours prior to the time of interview. Following the FAO food group classification, foods consumed were grouped into twelve different food groups, namely: cereals, white tubers and roots, legume products, nuts and seeds, vegetables and vegetable products, fruits, meat, eggs, fish and fish products, milk and milk products, sweets, sugars and syrups, oils and fats and spices, condiments and beverages [18,19]. Each food group counts towards HDDS if that food group was consumed by members of the household. The greater the number of different food groups consumed by the household, the more likely it is that household members are supplied with essential nutrients (vitamins, minerals, proteins, carbohydrates, fats and water) provided by a healthy diet. Furthermore, food group diversity scores (FGDS) for the 12 of the food groups were calculated to determine how diversity within the food groups changed during the harvest and lean seasons.

Measurement of household Production Diversity Score **-** Production diversity score was measured by collecting data on all crops and animals produced by the household in the last twelve months. These crops and animals were grouped based on the same twelve food groups used in calculating HDDS [9]. Thus, different species produced on the farm counted as one if they belonged to the same food group (for example, maize, wheat and sorghum belong to the cereal group).

Measurement of plot size: Plot size may be an underlying factor for household total production diversity (HTPD) and might therefore, confound the relationship between HDDS and HTPD. Plot size was measured as the number of total acres cultivated by household.

Measurement of total household income: This was measured as the total amount of income received by members of households from both agricultural and non-agricultural activities. Income is an indicator of purchasing ability and may directly influence the quantity and quality of household diets particularly in the dry season [20]. This is particularly important because a household in this study is regarded as members living together and eating from the same source.

Measurement of educational level of head of household: this was measured as the highest level of education attained by the head of household. Education is expected to

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have a positive impact on household dietary diversity. An educated individual may better learn and know the different compositions of food that are entailed in a balanced diet [21].

Measurement of market access: This was measured as the distance between household residences to the nearest market in kilometers. Farmers typically participate in markets as both sellers and consumers. Access to market tends to improve household income through the household participation in markets through selling their produce. Households closer to market centers are more likely to sell their produce at better prices. Thus, a negative relationship is expected on market distance. Larger distance means worse market access [22, 23].

Measurement of household size: This is measured as the number of people living and eating together. A negative relationship between household size and HDDS is expected. With many people to feed, diet quality might be compromised if the household budget cannot afford diversity.

Measurement of proportion of produce sold by household: The production orientation of farm households (that is, subsistence or market) was assessed by calculating the proportion of household food produced that was consumed by the household and that which was sold per production season. Assessment of household production orientation is crucial to understand the relative importance of subsistence versus market-oriented production in influencing household diets [7].

Measurement of access to nutrition education: Access to nutrition information/education was measured as the number of times the household had received nutrition information, the sources of information, and the kind of information received. However, for estimation, the number of times nutrition information was received was used in analysis.

Regression Estimators

From the regression model described in equation (1), HDDS is the dependent variable while P is an independent variable. However, P is likely an endogenous variable because despite the inclusion of a rich set of control variables, the relationship described in equation (1) may be affected by unobserved characteristics that are correlated with household's production diversity and also with diet diversity. For example, households that have diversified production may share a common trait of caring more (or less) about household members' health and hence their diet diversity [21]. In this case, two stage least squares with instrumental variables can be employed to control for endogeneity because household production diversity is likely correlated with other unobservable variables such as production knowledge or preferences in the error term in the outcome equation. However, these variables are difficult to observe, and thus, may be deposited in the error term. Because of this, household production diversity may be correlated with the error term, and thus, an ordinary least squares (OLS) estimation of Equation (1) likely generates bias and inconsistent estimates because $E\,[P_i\ \mu_i.] \neq 0$. Thus, instead of the effect of HTPD on HDDS being estimated as in equation (1) it is as:

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$$HDDS_i = X_i\beta + \delta P_i + \overbrace{Pf_i + \pi_i}^{U_i} \qquad (2)$$

where $HDDS_i$ is a measure of household dietary diversity of household i, P_i is the measure of farm production diversity, and X_i includes farm characteristics such as land area, market access and sociodemographic characteristics such as household size, age of head of household, gender of head of household, total household income, household monthly income and $U_i = (Pf_i + \pi_i)$ which is the biased error term if OLS is used in estimation. However, since other variables influence household's production diversity, this implies that (P) is correlated with the error term U_i, and the coefficient δ in Equation (2) is biased if OLS is used.

Identification of appropriate instruments for production diversity

For a variable to be considered a valid instrument, two conditions must be met:

1. *The exogeneity assumption*, that is Cov[z, υ] = Cov[μ, z] = Cov[x, μ] = 0. That is instruments are uncorrelated with the error term.
2. *The relevance assumption*, that is Cov[P, z] ≠ 0. That is production diversity and instruments are highly correlated.

If an instrument fails the first condition, the instrument is said to be an invalid instrument. If an instrument fails the second condition, the instrument is an irrelevant instrument, and the model may be unidentified if too few instruments are relevant. Additionally, when very low correlation exists between the instrument and the endogenous variable being instrumented, the model is said to be weakly identified and the instrument is called a weak instrument [24]. For this study, three instruments were identified for production diversity.

The first candidate for the instrument was average rainfall (2001-2011): This satisfies the two conditions, for instance farmers adapt their production choices according to the local climate. Average rainfall was used to proxy for climatic conditions at the district level. The data for this variable came from the Regional Agricultural Department of the Northern Region which records monthly rainfall in the districts. While climate shocks such as rainfall may have an effect on dietary diversity via price variation, the econometric specification includes distance to market and proportion of produce sold in the estimation process. Furthermore, rural Ghanaian markets seem to be sufficiently integrated [25] that local climate variability causes reduction in yields for local farmers, but these climate induced yield variations have small effects on equilibrium prices. Hence, the pathway through which climate variation affects dietary diversity is through the quantity of crops available for the household's own consumption thus making average rainfall a good instrument for production diversity.

A second candidate for the instrument was the presence of a resident agricultural extension agent in the community: This satisfies condition 2 as there is no reason to believe that a resident agricultural extension officer has a direct effect on household total production diversity. Intuitively, if an agricultural extension agent resides in the

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community, farmers have easy access to these agents who can give them quick responses and advice on problems they are having in their production. Agricultural agents also advise farmers on good farm practices and farming systems to boost their outputs.

A third possible candidate for the instrument was the educational level of the local extension agent because new technology and innovations in the agricultural sector are communicated to farmers through the extension agents. Thus, a high educational level of the extension agent may imply that such new innovations and technology may be more effectively communicated to farmers and induce farmers' participation and adoption.

In identifying if these our instruments were strong, the F statistic, which represents the joint significance of the relationship between the three instruments and household production diversity, was obtained in the first stage regression. The F-statistic was 17.88 which indicates high strength of the identified instruments. According to Hausman, Stock and Yogo [26] a minimum F statistic of 10 was set as a standard for strong and reliable instruments.

RESULTS AND DISCUSSION

This study analyzed the relationship between household production diversity and household dietary diversity using an instrumental variable approach. The use of instrumental variables addressed the common problem of endogeneity in order to better establish causality between household production diversity and HDDS [27,28]. Table 1 provides a description of the characteristics of sampled households. Generally, the majority (85%) of households were headed by men and farming was also prominent (92%) as a major occupation for many heads of households. Furthermore, the majority (72%) of the heads of households had no formal education and majority (96%) were married.

Table 2 presents the results on household production diversity, the majority (79.1%) of households produced more than four food groups indicating that many households practiced some level of production diversity in their production system. Regarding livestock farming, the majority of households kept at least one to two animals. The majority (72%) of the households also produced more than 4 kinds of food crops. Producing different variety of crops and animals means households will have access to a variety of food groups. Also, excess production can be sold and the money used for purchasing other food items not produced by the household.

Table 3a and 3b display food group distribution within HDDS in the harvest and lean seasons. By comparison, the results show that households consumed a more diverse diet (Maximum HDDS=12) in the harvest season than in the lean season (Maximum HDDS=5). The results for the harvest season further show that households with HDDS above six had a uniform distribution of consuming from each of the food groups. In contrast to the harvest season, in the lean season, vegetable consumption and meat consumption were low. The households that scored the maximum HDDS of five were

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the only households that consumed vegetables. The distribution of meat consumption was also skewed towards households whose HDDS was three.

Table 4 displays the HDDS for twelve food groups for the harvest and lean seasons. In the lean season, the majority (95.83%) of the households were classified under low HDDS (consuming 0-3 food groups) followed by 4.17%, under medium HDDS (consuming 4-5 food groups) [19]. None of the households was classified under the high HDDS (consuming 6-12 food groups) and none of these households consumed from all the eleven food groups in the lean season. In the harvest season, however, the scenario was reversed as the majority (96.43%) of households were classified under high HDDS (consuming 6- 12 food groups) and 3.57% under medium HDDS (consuming 4-5 food groups). None of the households recorded a low HDDS (consuming 0-3 food groups).

Table 5 shows the analysis of a 24-hour recall for twelve (12) food groups in both the lean and harvest seasons. The results showed that there was statistically significant higher diversity in all the food groups in the harvest season except for cereals, roots and tubers, and pulses and nuts. During the lean season, very low diversity (FGDS<1) was observed for the vegetable, fruit, dairy (milk and milk products), meat, and fat and oil groups. These groups showed a significant improvement in diversity during the harvest season. These changes relate to positive improvements in dietary diversity of households as all are good sources of micronutrients. Particularly the diversity of vegetables improved significantly from a mean FGDS of 0.002 to 5.375 during the lean and harvest seasons, respectively. The types and sources of foods consumed by households vary according to the crop cycles harvest in the area [29, 30].

The diversity of the different food groups was subject to seasonal variation and indicated that the availability, distribution and consumption of food groups are significantly affected by seasonal variation. Agriculture in the study area is mainly one-season rain-fed and because of that, some food group consumption, in particular fruits and vegetables, are seasonally affected. Fresh fruit and vegetables are usually more available and cheaper during the harvest time of the year. However, because fruit and vegetables cannot be stored for long periods, their availability and cost often act as a barrier to their consumption in the lean period.

Table 6 presents the key variables used in the econometric modelling. An average household had 8 members in the household with an average of 4 children and 4 adults per household. This indicates a relatively large household size in the area compared to a national household size of 4 persons. This may affect both household production as well as HDDS either positively or negatively [20]. The average age of a head of household was found to be 43.7 years.

The average income earned by a household was 266 Ghana Cedis (45.71 USD) per month while the average expenditure on food per month was found to be 156 Ghana Cedis (26.81 USD) in the study area. The average household earned 86.3 Ghana Cedis (14.83 USD) from non-farm sources while engaging on average in 1.44 non-farm income generating activities. The average rainfall recorded in the area from January

2011 to December 2015 was 76.5 millimeters. Households cultivated on an average of 2.5 acres plot size farms and grew on average 6.5 crops and reared 2.4 animals respectively. The average distance to the nearest market by households was 16.5 Km. These results suggest that households' access to markets may be difficult due to long travel distances to these market centers. On average, households sold 35% of their own production. The average price of a major staple (maize) was found to be 107.5 Ghana Cedis (18.47 USD) for 100kg.

Table 7 presents the main results of the estimation of the relationship between household production diversity and HDDS. The first column of the table shows the results for an OLS specification which were included for comparison purposes. The OLS results show a statistically significant positive correlation between production diversity and HDDS. The second column on Table 6 shows the first stage results of the 2SLS specification. The first stage results establish the relationship between instrumental variables and production diversity. According to the results, higher average annual rainfall is associated with higher production diversity.

The third column of Table 6 presents the results of the second stage of the IV estimation. According to the results, household production diversity has a significant effect on HDDS. The results also show that the set of instruments are strongly correlated with the endogenous variation with an F-statistic of 17.9. The F-statistic is above the standard cut-off value of 10 [26] which indicates that the instruments used in the estimation are not weak instruments. Additionally, the model passed the Hausman specification test under the null hypothesis that: the efficient estimator (OLS) is consistent with a Chi-square value = 6.73 (P-val=0.009). Hence, the null hypothesis was rejected at 5% and the use of 2SLS over OLS was justified. The model also passed the under-identification test under the null hypothesis that: the matrix of reduced form coefficients has rank=K1-1 (under identified) with an LM statistic of 47.92 (p-val=0.000). Hence, the null hypothesis was rejected at 1%, which indicated that the matrix of reduced form coefficients was identified. The production diversity also passed the Sargan-Bassman over identification test with Chi-square value = 0.11 (P-val = 0.95).

The results further showed that a 10% increase in household production diversity increased HDDS by 2.5% ceteris paribus from the results of second stage IV as expected. These findings are in line with previous studies [20, 21, 22,23, 31, 32, 33], but contradict the findings of Sibhatu and Qaim [7] that used data from more commercially oriented farms in Indonesia, Kenya and Uganda. It has been observed that, for areas with more commercialized farms with better market access, increasing the number of food groups produced on a farm may mean lower cash revenues and foregone benefits from specialization [23].

Significant relationships were also found between HDDS and distance to the nearest market, household size, total household income, proportion of produce sold and price of 100 kg bag of maize. A 10% increase in distance to the nearest market, household size, proportion of produce sold, and price of maize would decrease HDDS by 0.07%,

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0.48%, 17.38% and 0.21%, respectively. The results also show a positive significant relationship between HDDS and household income. A 10% increase in household income increases HDDS by 0.01%.

Markets play a major role in HDDS because households' market proximity contribute to higher HDDS. The results found in this study are consistent with prior research [17,34]. Farm households commonly use markets to sell agricultural produce and to buy foods that they do not or cannot produce themselves. As reported in other studies, not all foods that are produced on the farm can be stored for the entire year [29], as such, issues of seasonality are particularly important for such food with short shelf life (example, fresh fruits and vegetables).

The results show that, household income is positively associated with higher HDDS. The availability of income is an indicator of market access [23] as many subsistence households complement their own production with some purchases from the markets particularly in the lean seasons and years of poor weather conditions. Thus, household income increases households' ability to purchase diverse foods from the market. The results also showed that households that sold a significant proportion of their produce had a negative effect on HDDS. These findings contradict that of Sibhatu and his colleagues who found a positive relation between proportion of households' produce sold and HDDS but confirms the study by Chegere and Stage who asserted that market orientation of households has no clear effects on HDDS [35]. This result suggests that sales from farm produce may not necessarily be used in purchasing other quality and diverse diets from the market as reported by Sibhatu *et al.* [23] which may affect HDDS negatively. Furthermore, selling too much food by these subsistence households may impact HDDS negatively.

CONCLUSION

This research analyzed the relationship between household production diversity and household dietary diversity using an instrumental variable approach. The study found that production diversity, and household income significantly affected HDDS positively while household size, distance to market, and proportion of produce sold and price of maize negatively affected HDDS. Individual food group diversity score was found to be subject to seasonal variation.

The findings of the survey showed that household production diversity has a positive effect on HDDS in the study area. Therefore, it is recommended that households should be encouraged to diversify production to help in improving HDDS. However, diversifying production may be unreliable due to the heavy reliance on rainfall for production, which is often unpredictable in the area. To solve this problem, agricultural interventions such as the provision of irrigation facilities to provide reliable water sources for all year production may improve HDDS. The provision of irrigation facilities may also promote the cultivation of perishable goods such as vegetables and fruits. This may also increase household income from the sale of some of the vegetables and fruits.

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This study also showed that access to market plays a key role in improving HDDS. Improving market access may provide opportunities to households to sell their farm produce to enhance their income and hence purchasing power for other foods they do not cultivate. Also, by improving market access, competition may be encouraged thus leading to lower prices for food items. Household size and proportion of household produce sold were also found to adversely affect HDDS. Policies aimed at encouraging behavior change such as family planning education to smaller household sizes and the education of households are of the importance for enhancing household nutrition. These results show the importance of infrastructure to link farmers to markets.

Limitations and further studies

While our research provides insights to the relationship between production diversity and dietary diversity in Northern Ghana, it has certain limitations. This study did not capture all the possible variables that can influence HDDS such as types of markets and the use of additional instruments, such as, temperature. Apart from the provision of food, production diversity has other environmental benefits that were not analyzed in this study. The role of food items from hunting and trapping could also be useful for inclusion in future research in rural households. Furthermore, it will be of interest to study the effects of intra household production diversity on maternal and child HDDS and overall nutritional status.

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Table 1: Sample characteristics of households

Variable	Freq. (N=504)	Percent (N=504)
Gender head of household		
Female	77	15.28
Male	427	84.72
Marital status of head of household		
Single	18	3.57
Married	486	96.43
District of residence		
Central Gonja	84	16,67
East Mamprusi	84	16.67
Gushegu	84	16.67
Mion	84	16.67
Tolon	84	16.67
Zabzugu	84	16.67
Education level of head of household)		
No formal education	363	72.02
Primary education	51	10.12
Secondary education	43	8.53
Tertiary education	47	9.33
Primary occupation of head of household		
Other jobs	40	7.94
Farming	464	92.06

Table2: Household Farm production diversity scores

Variable	Freq (N=493)	percent (N=493)
Production diversity (Total crop count)		
0(nothing)	7	1.42
1-2	44	8.93
3-4	86	17.44
>4	356	72.21
Production diversity (Food groups)		
0(nothing)	3	0.61
1-2	23	4.67
3-4	50	15.62
>4	390	79.1
Livestock production		
0(nothing)	98	19.88
1-2	168	34.07
3-4	163	33.06
>4	64	12.99

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Table 3a: Food groups distribution within dietary diversity scores of households in the harvest season

HDDS	n(%)	Cereals & Grains	Vegetables	Roots & Tubers	Fruits	Meats	Eggs	Fish	Legumes & Nuts	Milk& Milk products	Fats & Oils	Sweets	Spices & Condiments
0	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
1	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
2	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
3	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
4	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
5	1(0.2)	0.2	0.2	0	0	0.3	0	0.2	0	0	0	0	0.2
6	18(3.6)	3.6	3.6	3.5	0.7	0	0	3	1.1	0	0.9	3	3.6
7	52(10.3)	10.3	10.3	8.2	5.6	4	0.7	8.8	6.7	2.2	5.6	8.8	10
8	84(16.7)	16.7	16.7	14.5	4.2	14.9	2	14.9	17.2	5.4	13.8	13.9	16.4
9	103(20.4)	20.4	20.4	17.3	9.4	20.9	3.4	20.8	21.7	15.3	22.8	21.3	20.6
10	83(16.5)	16.5	16.5	18.3	23.4	19.9	7.5	17.4	17.8	8.6	18.9	17.9	16.4
11	50(9.9)	9.9	9.9	11.7	17.1	11.9	9.5	10.7	10.9	17.6	11.7	10.8	10.1
12	113(22.4)	22.4	22.4	26.5	39.5	28.1	76.9	24.2	24.6	50.9	26.3	24.3	22.7

HDDS: Score based on FAO 12 food group classification for households

Table 3b: Food groups distribution within dietary diversity scores of households in the lean season

HDDS	n(%)	Cereals & Grains	Vegetables	Roots & Tubers	Fruits	Meats	Eggs	Fish	Legumes & Nuts	Milk & Milk Products	Fats & Oils	Sweets	Spices & Condiments
0	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
1	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
2	46(9.1)	9.1	0	6.8	9.1	0	9.1	14.3	9.6	19.4	9.6	9.6	9
3	137(27.2)	27.2	0	24.6	27.2	100	27.2	42.9	28.4	27.8	28.9	27.3	26.7
4	301(59.7)	59.7	0	65.8	59.7	0	59.7	35.7	57.9	52.8	56.3	58.9	60.3
5	20(4)	4	100	2.8	4	0	4	7.1	4.1	0	5.2	4.2	4
6	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
7	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
8	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
9	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
10	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
11	0(0)	0	0	0	0	0	0	0	0	0	0	0	0
12	0(0)	0	0	0	0	0	0	0	0	0	0	0	0

HDDS: Score based on FAO 12 food group classification for households

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Table 4: Summary of Food Group Diversity Scores

Number of food groups Consumed (n=11)	Harvest season		Lean season	
	Frequency	percentage	Frequency	percentage
1	0	0	0	0
2	0	0	46	9.1
3	0	0	137	27.2
4	0	0	301	59.7
5	1	0.2	20	0.4
6	18	3.6	0	0
7	52	10.3	0	0
8	84	16.7	0	0
9	103	20.4	0	0
10	83	16.5	0	0
11	50	9.9	0	0
12	113	22.4	0	0
Total	**504**	**100**	**504**	**100**

Low=≤3 food groups; Medium=4-5 food groups; High ≥ 6-11

Table 5: Analysis of 24-hour recall: mean food group diversity score of households analyzed by paired t-test

Food group	Food group diversity score (FGDS) in harvest season (n=504)		Food group diversity score in lean season (n=504)		Significance level (two-tailed)
	Mean	SD	Mean	SD	
Cereals & Grains	3.768	1.939	3.768	1.939	
Vegetables	5.375	2.016	0.002	0.044	***
Roots & Tubers	1.799	1.411	1.799	1.411	
Fruits	1.841	3.105	0.000	0.000	***
Meats	2.750	3.833	0.002	0.044	***
Eggs	0.649	1.201	0.000	0.000	***
Fish	1.883	1.757	0.026	0.159	***
Legumes & Nuts	2.448	2.092	2.302	2.126	
Milk & Milk products	0.722	1.087	0.062	0.240	***
Sweets	.269	0.755	1.175	0.746	**
Spices &Condiments	1.768	0.989	1.768	0.989	

*** - significance at the p= 0.01 level

** significance at the p=0.05 level

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Table 6: Sample summary statistics

Variable	Description	Mean	Std. Dev.	Min	Max
Household	Number of people living together and eating from the same pot	7.5	2.05	1	11
Children	Total number of children below 15 years in the household	3.88	2.04	0	9
Adults	Total number of adults in the household	3.61	1.97	1	10
Household total non-farm income	Ghana Cedis	86.31	100.82	0	520
Non-farm income sources	Total number of non-farm income sources	1.44	1.06	0	5
Household food expenditure	Total amount spent on food per month in Ghana Cedis	156.4	59.22	56	329
Household income	Total amount of income received by household per month	266.02	140.2	0	800
Distance to market	Kilometers	16.70	20.86	0.05	81
Plot size	Acres	2.51	1.24	1	6
Household size	Number of people eating from the same pot	5.59	1.23	2	9
Access to nutrition information	Number of times household received nutrition information	1.9	3.21	0	7
Age of head of household	Years	43.70	10.26	21	78
Proportion of food sold	The proportion of household production sold	0.35	0.78	0	0.82
Total crop count	Total count of crops grown by households	6.45	2.94	0	14
Total production	Total count of crops and animals grown by households	8.85	2.94	0	18
Total production diversity	Number of crops and livestock groups produced	6.21	2.10	0	10
Total animal count	Total count of only animals grown by households	2.39	1.75	0	6
Household dietary diversity score for harvest season	Total count of food groups consumed by household from 12 food groups	9.56	1.79	5	12
Household dietary diversity score for lean season	Total count of food groups consumed by household from 12 food groups	3.59	0.71	2	5
Overall household dietary diversity score	Mean dietary diversity score for lean and harvest seasons	6.5	1.07	4	8
Average rainfall	Average district level rainfall from 2001-2011 measured in mm	76.47	8.63	67.31	93.96
Price of maize	Average price of maize adjusted by CPI	107.54	7.16	97.03	117.39

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Table 7: Relationship between production and household dietary diversity scores

Variable	OLS	1st Stage IV	2nd Stage IV
Production diversity (food groups)	0.532**		0.257***
	(0.261)		(0.087)
Instrumental variables			
Average rainfall		0.068***	
		(0.009)	
Resident agricultural extension officer		0.573	
		(0.242)	
Educational level of agricultural extension officer		0.061	
		(0.433)	
Distance to nearest market	-0.002	0.031***	-0.007**
	(0.003)	(0.004)	(0.003)
Household size	-0.012	0.127***	-0.048*
	(0.023)	(0.039)	(0.028)
Access to nutrition information	0.178	0.857***	0.016
	(0.160)	(0.262)	(0.180)
Total household income	0.001***	-0.0004	0.001***
	(0.0003)	(0.001)	(0.000)
Age of head of household	0.005	0.0005	0.005
	(0.005)	(0.008)	(0.005)
Male head of household	0.008	0.421*	-0.056
	(0.132)	(0.218)	(0.140)
Plot size	-0.032	0.081	-0.049
	(0.038)	(0.062)	(0.040)
Proportion of produce sold	-0.619*	5.752***	-1.738***
	(0.323)	(0.479)	(0.563)
Primary education	-0.003	0.044	-0.018
	(0.159)	(0.263)	(0.167)
Secondary education	-0.018	0.021	-0.038
	(0.170)	(0.281)	(0.178)
Tertiary education	0.191	-0.116	0.213
	(0.179)	(0.295)	(0.188)
Maize price	-0.023***	-0.0003	-0.021**
	(0.007)	(0.012)	(0.007)
Constant	8.308***	-4.532**	7.811***
	(0.864)	(1.974)	(0.926)

Dependent variable = HDDS; Number of observations = 504
Under identification test (LM statistic): Chi-sq (3) = 47.92 P-val = 0.000; Weak identification test (Wald F statistic) = 17.88
Hausman specification test: Chi-sq (1) = 6.73 P-val=0.009**; Sargan statistic (over identification test): Chi-sq(2) = 0.11 P-val = 0.95

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