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Factors Affecting Food Security among Households in Nigeria: The Role of Crop Diversity

Ifeoluwapo Oluwaseun Amao [1], Adebayo Isaiah Ogunniyi [2,*], George Mavrotas [3] and Abiodun Olusola Omotayo [4]

1 National Horticultural Research Institute, Idi-ishin, P.M.B. 5432, Ibadan 200272, Nigeria; ifeluv@yahoo.com
2 International Fund for Agricultural Development (IFAD), Abuja 900211, Nigeria
3 Institute of Development Policy, University of Antwerp, 2000 Antwerpen, Belgium; george.mavrotas@uantwerpen.be
4 Food Security Niche Area, Faculty of Natural and Agricultural Sciences, North West University, Mmabatho 2735, South Africa; 25301284@nwu.ac.za
* Correspondence: a.ogunniyi@ifad.org; Tel.: +234-806-787-9846

Abstract: Agriculture is central in order to achieve nutrition goals through the provision of food, energy and essential micronutrients for the physical and mental development of humans. Dietary diversity is a good indicator of human food security status. Using a dataset obtained from the World Bank's Living Standards Measurement Study—Integrated Surveys on Agriculture (LSMS-ISA), this paper examines the linkages between crop diversity and food security (measured as dietary diversity) among farming households in Nigeria using ordinary least squares, Poisson regression, and instrumental variables (IV) Poisson regression to estimate the relationship. In addition, we investigate the determinants that lead to the consumption of each food groups considered for generating dietary diversity using a logit regression model. The results show that food expenditure, asset ownership and location of households are the key factors driving the types of food consumed by the households. Furthermore, increased food expenditure and access to credit were found to positively influence food security. The result established a positive and significant relationship between crop diversity and dietary diversity. Our findings call for more attention to diet diversity, as well as the need to harmonize the roles of rural income improvement, especially through non-farm livelihood diversification in tackling multiple nutritional deficiencies in Nigeria.

Keywords: crop count; agricultural revenue; food groups; Nigeria

Citation: Amao, I.O.; Ogunniyi, A.I.; Mavrotas, G.; Omotayo, A.O. Factors Affecting Food Security among Households in Nigeria: The Role of Crop Diversity. *Sustainability* **2023**, *15*, 8534. https://doi.org/10.3390/su15118534

Academic Editors: Michael S. Carolan and Marian Rizov

Received: 28 February 2023
Revised: 16 May 2023
Accepted: 18 May 2023
Published: 24 May 2023

1. Introduction

It is well known that increased malnutrition can be caused by poor diversification of diets while the consumption of various nutritious food contributes to good health, and the consumption of diets from animal sources, vitamin-rich fruits and vegetables as well as nutrient-rich legumes can help substantially to reduce malnutrition [1,2]. According to the FAO, IFAD and WFP, about 700 million people go to bed hungry each night, and of equal significance, more than two billion of world's population suffer from hidden hunger due to lack of essential micronutrients, such as vitamin A, iron and zinc in diets [3–5]. Furthermore, nutritional deficiencies result in impaired physical and mental development of humans, loss of productivity, and susceptibility to various diseases among others [6,7].

Nutritional deficiencies are caused not only by low quantities of food consumed but also by poor dietary diversity since dietary diversity is a good indicator of broader nutritional status [8]. More diverse diets are also associated with lower rates of nutritional problems in many parts of the world [9,10]. Therefore, in order to improve nutrition, it is important to increase the diversity of healthy diets consumed. Dietary diversification (through increased availability and accessibility to nutritionally diverse foods) and bio-fortification (by increasing nutrients in existing staple grains) are suggested solutions for mitigating hidden hunger. Since bio-fortified staples are not able to provide all needed nutrients for humans, dietary diversification is a reliable option to improve dietary quality [11].

At the same time, despite the efforts of the international development community in recent years to make further progress in achieving "zero hunger" and "food and nutrition security" by 2030 in line with the 2030 Agenda, there is still an unprecedent high level of global food and nutrition insecurity. Globally, over 274 million people are currently estimated to require humanitarian assistance and protection, which will cost about USD 41 billion [12]. The Sub-Saharan Africa (SSA) region in particular is disproportionately affected by this unprecedently high food and nutrition insecurity due to existing poor institutions and bad governance, which seems to undermine the impact of capital flows on food and nutrition security in the region [13–15]. In addition, many SSA countries are highly dependent on imported crops (e.g., rice and wheat) and agricultural inputs (e.g., fertilizers), which put such countries at a greater risk of food and nutrition insecurity due to the global supply chain disruption, recently exacerbated by the COVID-19 pandemic and the ongoing Ukraine war [16].

Small-scale farmers and their households are disproportionately vulnerable to all forms of malnutrition [17–20]. It has also been noted that in Africa and Asia, the majority of malnourished people are rural dwellers who are smallholder farmers [21–23]. To improve their nutrition, the production diversification of their small farms is important [24–27]. Key interventions targeted at dietary diversity and food insecurity in rural Africa include (1) focus on income and promotion of commercial agriculture which will avail the rural dwellers improved purchasing power [28] and (2) focus on households by supporting on-farm production and making food available locally in order to reduce food insecurity [28]. Nutrition is closely linked to agriculture since it is the sector that produces food but many of the undernourished are smallholder farmers [23,29].

Previously, the agricultural policy response to under-nutrition involved strengthening staple food production through price incentives and the promotion of improved farm technologies [30–32]. Targeted crops included cereal crops such as wheat, rice and maize [33]. This strategy helps reduce hunger but contributes to a lower level of crop species diversity [34,35]. Crop diversification can serve as a tool for generating employment, alleviating poverty and an important strategy to overcome emergencies faced in developing countries [36,37]. However, the majority of the low-income households in developing countries are characterized by engagement in farming activities which lack crop diversification [38].

Moreover, high transportation costs and the remoteness of the villages force the rural dwellers to rely on their production or locally produced crops for their nutritional needs. Thus, their diets often lack basic micronutrients which in turn increase their susceptibility to infections and diseases in the short run and major cognitive impairment in the long run [38,39]. In the same vein, low levels of dietary diversity have been observed to lead to a high rate of micronutrient deficiencies and other negative health consequences [40–43]. Despite the fact that the increased diversification of agricultural and food systems could help improve dietary quality and nutrition [33,44–46], empirical studies on this are rather scarce.

Since nutrient deficiencies still pose a great challenge in Africa, it is important that agricultural growth and transformation are nutrition-sensitive in order to achieve sustainable food systems, create jobs, improve livelihoods and provide more diverse and nutritious diets [47,48]. Countries need to have the political will to prioritize nutrition in all areas of government including agriculture, health and rural development. Additionally, they should increase investments in infrastructure and public goods and services. An important economic policy decision in Africa is the elimination of malnutrition since the cost of under-nutrition has been observed to be 11% of Gross Domestic Product (GDP) on average [49]. This is also due to the fact that the economic return from investing in nutrition is rather high, with USD 1 invested generating USD 16 [50].

Turning to Nigeria, 70% of the population lives in the rural areas, while the agricultural sector employs about 90% of the rural dwellers [51,52]. The majority of these rural dwellers engaged in agriculture are small-holder farmers who produce about 9% of the total agricultural output of the country on less than 2 hectares of land. Seventy-five percent of total land area in the country is potential agricultural land with only 48.5% of this area being under cultivation, while only 7% of the total irrigable land is being put to use [53–55]. In recent years, the Federal Ministry of Agriculture and Rural Development (FMARD) has inaugurated an Inter-Ministerial Agriculture/Nutrition Working Group, which is saddled with the responsibility of designing strategies for the promotion of healthy living, addressing malnutrition and increasing hygienic food production, thus placing particular emphasis on issues related to food and nutrition security in the country. This adds further to the policy relevance of this study which seeks to examine the linkages between crop diversity and dietary diversity in Nigeria.

Against this background, this paper contributes to the growing literature on the agriculture–nutrition–health nexus by using household survey data, the Living Standards Measurement Study—Integrated Surveys on Agriculture (LSMS-ISA) General Household Survey Panel Data conducted between 2012 and 2013 in the case of Nigeria, in order to specifically examine the relationship between crop diversity and dietary diversity in the country. In addition, we examine the factors influencing the consumption of each group items. These objectives will be useful to understand what drives the consumption of food group items and how the number of crops cultivated by the households affects the number of food groups consumed in the household accordingly. This study explores the two mechanisms by which agricultural pathways can increase nutrition, i.e., one of the pathways supports the fact that income generated from crop production can be used to purchase the non-cultivated food items to enhance their dietary diversity, while the second mechanism is through own-production to reflect cultivated crop and dietary diversity.

2. Review of the Relevant Literature

Previous studies have established linkages between land cropping patterns and the dietary diversity of households [56–58]. Some other studies have focused on the determinants of crop diversity or dietary diversity, but most of them have not examined the causal linkages between these two variables [59,60]. The relationship between farm diversity and dietary diversity among households in Tanzania and Kenya was examined by Herforth and Ahmed [44] and Jones et al. [61]. For instance, Jones et al. [61] found that the association between farm diversity and dietary diversity was positive among the households ($p < 0.05$). Additionally, Ochieng et al. [62], Rajendran et al. [63] and Habtemariam et al. [64] examined crop diversity and dietary diversity by specifically investigating whether the inclusion of vegetables in maize-based farming systems significantly improved the dietary diversity of the Tanzanian farming households involved in the study. Habtemariam et al. [64] found that production diversity is significantly and positively associated with dietary diversity.

The findings also revealed that the educational status of female heads of households and opportunities for women to earn income should be prioritized in order to extract further gains in dietary diversity [65]. For example, agricultural intensification programs in Northern Ghana, which targeted the low-income and female-headed households, significantly increased the production diversity of participating farmers [66–68]. Furthermore, for enhanced dietary quality among vulnerable households, attention should be paid to variables such as the cost of access to infrastructure, transport and food storage facilities.

Higher production diversity has also been found to improve dietary diversity [69], and it should therefore be encouraged to achieve enhanced nutritional outcomes for rural households, especially those in remote areas with difficulty in accessing markets [28,70,71]. Other studies examined the determinants of crop diversification with specific focus on micronutrients; the Household Dietary Diversity Score and Household Micronutrient Access Indicators were used to estimate the effect of crop diversification on household access to zinc, iron, vitamin A and folate. The findings emerging from these studies revealed that crop production diversification can be used to achieve nutrition-sensitive agriculture [72–74]. Zezza and Tasciotti [75] examined the relationship between urban agriculture and household food security, dietary diversity and calorie intake in 15 developing/transition countries. The study showed that there is an association between urban agriculture, dietary diversity and calorie intake, and it is closely related to food security. Two-thirds of the countries analyzed showed that there is a correlation between the active participation of urban households in agricultural activities and greater dietary diversity after controlling for economic welfare and a set of household characteristics. African countries included in the above study include Ghana, Malawi, Madagascar and Nigeria.

Turning to specific studies in Nigeria, Dillon et al. [76] examined the effect of exogenous variation in planting season decisions as a result of climate variability on household dietary diversity. The results showed that improving dietary diversity may not be achievable by agricultural income growth or increased crop diversity, a finding also in line with the study of Mulmi et al. [77]. Furthermore, when agricultural revenues increase, the diet composition of respondents remained unchanged. However, when considering the effect of agricultural income on the share of calories by food groups, diet composition changes a great deal [78–80]. At the same time, in Nigeria, there have been studies on food security, nutrition and agriculture mostly using primary data in different states of the country. Babatunde et al. [81] examined income and calorie intake among farm households in rural areas of Kwara State, Nigeria. The study showed a positive relationship between income and calorie intake as calorie intake does not increase substantially with income.

Other studies from Nigeria also show that households with large members have a negative relationship with food and nutrition security [82] and that education beyond the primary level, in particular, is effective in reducing malnutrition in young children as it increases nutritional and health knowledge for mothers to make better nutrition and health choices for the family [82,83]. Few empirical studies, however, have been carried out to examine the causal linkage between crop diversity and dietary diversity in sub-Sahara Africa and specifically in the case of Nigeria.

2.1. Data, Descriptive Statistics and Methodology

The source of the data is the household survey data of the LSMS-ISA General Household Survey (GHS) Panel Data. The survey is a nationally representative survey of approximately 5000 households conducted between 2012 and 2013. It is a long-term project that is aimed at the collection of household-level panel information, with data on household characteristics, welfare and agricultural activities. The GHS sample is comprised of 60 Primary Sampling Units (PSUs) or Enumeration Areas (EAs) chosen from each of the 37 states in Nigeria, thus making a total of 2220 EAs nationally. Each EA contributes 10 households to the GHS sample, resulting in a sample size of 22,200 households. Out of these 22,000 households, 5000 households from 500 EAs were selected for the panel component and 4916 households completed their interviews.

Given the panel nature of the survey, some households had moved from their location by the time of the Wave 2 visit, resulting in a slightly smaller sample as compared to Wave 1 (conducted in 2010–2011), with 4716 households in total for Wave 2 (conducted in 2012–2013) (NBS/FMARD, 2014). Data used in the analysis were from 2640 households in the dataset; this is because they were the households with the complete information needed to examine the objectives of the present study.

Table 1 shows the food consumed by households across the country using 12 food groups which include: cereals, spices, eggs, fish, fruits, meat, milk, oil and fat, pulses, roots and tubers, sweets and vegetables. The food groups consumed were profiled by gender of the households (male, female) and location of residence (rural, urban) of the households. From the aggregated data, most households consumed cereals (96.85%), vegetables (95.79%), oil and fat (93.37%) among others, while the less-consumed food groups were eggs, fruits and milk, representing 11.89%, 28.48% and 31.97% of the households consumed, respectively (Table 1). On the disaggregated data, we found that more male-headed households consumed cereals (97.20%) than female-headed households (93.97%), while for vegetables, the reverse was the case (97.18% versus 95.59%).

Table 1. Food groups consumed: Aggregated and disaggregated.

Food Group	Female-Headed Households	Male-Headed Households	Rural	Urban	All Households
Cereals	93.97	97.20	96.67	98.77	96.85
Spices	97.87	92.37	92.46	96.74	92.95
Eggs	12.06	11.87	10.89	19.54	11.89
Fish	87.23	57.55	58.77	75.37	60.72
Fruits	41.13	26.97	26.67	42.35	28.48
Meat	49.65	62.59	59.49	74.27	61.21
Milk	38.30	31.21	29.62	49.84	31.97
Oil and fat	94.32	93.26	93.31	93.81	93.37
Pulses	86.87	81.21	80.62	90.88	81.81
Root and tuber	96.10	66.20	67.85	81.11	69.39
Sweets	47.52	60.69	58.42	65.79	59.28
Vegetables	97.18	95.59	95.54	97.72	95.79

Source: LSMS-ISA dataset (2013).

More female-headed households also consumed eggs, fish, fruits, milk and pulses (12.06%, 87.23%, 41.13%, 38.30 % and 86.87%, respectively) than male-headed households (11.87%, 57.55%, 26.97%, 31.21% and 81.21%, respectively). This implies that female-headed households are more conscious of the benefits derived from the consumption of these food groups, which are major sources of proteins. Eggs, fruits and milk were the least-consumed food groups in rural areas (10.89%, 26.67% and 29.62%, respectively). Additionally, few urban households consumed eggs, fruits and milk (19.54%, 42.35% and 49.84%). However, more households consumed these items in the urban areas than the rural areas. It was expected that rural households consume more eggs and fruits as these could be readily available in the location. Thus, this finding could be due to the fact that most of the rural households with access to these food items sell them off without considering the importance of consuming them for their health benefits. This is also consistent with the findings of Rajendran et al. [63].

2.2. Methodological Framework

The specific variables of interest in this study include dietary diversity and crop diversity, which we discuss below in detail, including the methodology used in the study.

2.2.1. Measures of Dietary Diversity and Crop Diversity

Dietary diversity: This is closely related to calorie adequacy and anthropometric outcomes [27,84], and as such, it can be used as a proxy food security in nutrition surveys. It can be defined as the number of different foods or food groups consumed over a given reference period [8]. There are two measures of dietary diversity: Food Consumption Score and the Household Dietary Diversity Score. This study used the Household Dietary Diversity Score. While the Dietary diversity score is an identified key indicator for surveillance of actions that aim to tackle various nutrition-related problems and food insecurity [1], it is also an effective indicator of food utilization [8,10].

Dietary diversity "measures the degree to which the variety of food consumed by households differs in terms of nutrient intakes over a given period of time" [85]. The Household Dietary Diversity Score (HDDS) is normally constructed using data on dietary intake in the previous 24 h, but in the absence of such data, a modified HDDS can be used which is based on food consumed in the household over the previous 7 days [86,87]. There were 12 categories of food groups used, with each food group having a score if anyone in the household consumed any food item from the specific group in the previous 7 days. The food groups used to calculate the score was similar to that of Snapp and Fisher [28], which included: cereals, roots and tubers, vegetables, fruits, meat and poultry, eggs, fish and seafood, pulses, legumes and nuts, milk and milk products, oils and fats, sugar and honey, and miscellaneous (such as condiments, coffee and tea).

Crop diversity: This is measured using crop count and agricultural revenue according to [76,88,89]. Crop count is the total number of different crop species cultivated by the household in a cropping year. Count variables have been previously used in the relevant literature to assess biodiversity and farm genetic diversity [61,90–92].

2.2.2. Econometric Approach

Firstly, the logistic regression method was used to estimate the factors affecting the choice of food groups consumed by the households. Logit estimations are used when the outcome variable takes two possible states, hence the name binary models [93]. This will identify the variables that have significant influence on probability of consuming a food group in rural households. In this analysis, food group consumption (Z) is the dependent variable which takes the value of 1, if consumed among the farming households, and 0 otherwise, i.e.,

Z = 1, if a particular food group is consumed in the household, 0 otherwise.

The logistic model postulates the probability (P_i) that food group consumption is a function of an index (Z_i),

where:

(Z_i) is an inverse of the standard logistic cumulative function of P_i, i.e., $P_i(y) = f(Z_i)$

(Z_i) is also an inverse of the standard logistic cumulative function of P_i

i.e., $P_i(y = 1) = f(Z_i)$

The probability of food group consumption is given by

$$P_i(y = 1) = \left(\frac{1}{1 + e}\right)^{-Z_i} \tag{1}$$

where e represents the base of natural logarithms (2.718).

The probability that a food group is consumed is calculated from Z_i value:

$$Z_i = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \ldots + b_n x_n \tag{2}$$

where:

X_1–X_n are the independent variables;

Z_i = food group consumption in a household (1 if yes, 0 otherwise);

b_0 = constant;

b_1 = is the coefficient of the x's variables;

Z_i = food group consumption (1 if yes, 0 otherwise).

Exogenous variables (X) used in the model include: household characteristics such as age, gender, years of education of the household's head, household size, monthly per capita expenditure on food items, monthly per capita expenditure on non-food items, ownership of assets (such as television, radio), farm size, and access to credit including regional dummies.

To examine the linkage between crop and dietary diversity, multiple linear regression was used following [61]; the Poisson model was also used following [28]. The Poisson estimator is commonly used for count data models [94]; furthermore, an auxiliary regression test (such as heteroskedasticity) [95] was used to tackle the problem of over dispersion or under dispersion that may occur in Poisson estimations. In short, unlike linear regressions, Poisson regressions allow for dependent variables to be censored at zero, and allow for non-continuous dependent variables, but at the same time, they make the strong assumption that the variance is equal to the mean. In addition, we employed the Instrumental Variable (IV) Poisson regression to account for possible simultaneity between the two variables [96]. The equation is as follows:

$$DD_i = \gamma_2 X_{2i} + \beta_{2i} CD_i + r + \epsilon_{i2} \tag{3}$$

Exogenous variables (X) used in the model were based on previous studies [28,96], and include: household characteristics such as age, gender, regional dummies, agricultural revenue, ownership of assets (such as television, radio), household size, extension services, access to credit, monthly per capita expenditure on food items, farm size, monthly per capita expenditure on non-food items and marital status, while ϵ = random error term. The dependent variable is dietary diversity (HDDS) and the key independent variable is crop diversity—crop count and agricultural revenue. For the IV-Poisson, crop diversification variables were instrumented with one variable: access to extension services (such as seed services, market services as well as fertilizer distribution); the interaction with farmers' groups (and extension) is expected to influence farmers' knowledge about different crops and access to agricultural inputs [96]. We assumed (and tested) that this variable is correlated with the crop diversification variables, but not with the dietary diversity variable.

3. Results and Discussion

In this section, we discuss the findings regarding the factors influencing the consumption of each of the food groups—cereals, miscellaneous (such as condiments, coffee and tea), eggs, fish and seafood, fruits, meat and poultry, milk and milk products, oils and fats, pulses, roots and tubers, sweets (sugar and honey), and vegetables—used in assessing the household dietary diversity score (HDDS). Following that, we estimate the effect of crop diversification on dietary diversity.

3.1. Determinants of Food Groups Consumed by Households in Nigeria

A logistic regression was carried out to examine the socio-economic characteristics of households that determine their consumption of each of the 12 food groups. The results reported in Table 2 revealed the following:

Table 2. Determinants of food groups consumed in Nigeria.

Variables	Cereals	Spices_Condiments_Bev	Eggs	Fish_Seafood	Fruits	Meat	Milk	Oil_Fat	Pulses	Root_Tuber	Sweets	Vegetables
Sex of the household's head (male)	−0.184	−0.323	0.160	−0.452 ***	0.290 **	0.213 *	0.146	−0.0319	0.0147	−0.376	0.137	0.108
	(0.230)	(0.240)	(0.168)	(0.155)	(0.131)	(0.125)	(0.133)	(0.204)	(0.151)	(0.231)	(0.124)	(0.244)
Age of the household's head	−0.00535	0.00197	−0.00408 *	0.00430 **	0.000172	−0.00276	−0.00578 ***	−0.00338	−0.00161	0.000554	−0.00477 **	0.00159
	(0.00428)	(0.00296)	(0.00276)	(0.00220)	(0.00225)	(0.00206)	(0.00223)	(0.00306)	(0.00229)	(0.00246)	(0.00204)	(0.00352)
North Central	0.490 *	−0.371 *	−0.419 ***	−0.602 ***	−1.006 ***	−0.340 **	−0.798 ***	−1.286 ***	−0.739 ***	−0.799 ***	0.528 ***	−0.744 **
	(0.260)	(0.214)	(0.150)	(0.147)	(0.133)	(0.135)	(0.137)	(0.260)	(0.159)	(0.263)	(0.130)	(0.371)
North East	0.0514	−0.546 **	−0.779 ***	−0.226 ***	−1.004 ***	−0.0701	−0.870 ***	−0.979 ***	−0.408 **	−2.240 ***	0.887 ***	−0.859 **
	(0.254)	(0.213)	(0.164)	(0.150)	(0.136)	(0.140)	(0.141)	(0.266)	(0.164)	(0.259)	(0.133)	(0.372)
North West	0.914 ***	−0.0958	−0.455 ***	−0.505 ***	−1.111 ***	−0.273 **	0.0137	−0.382	−0.426 ***	−2.246 ***	0.869 ***	−0.665 *
	(0.284)	(0.212)	(0.148)	(0.146)	(0.132)	(0.133)	(0.129)	(0.270)	(0.159)	(0.256)	(0.128)	(0.369)
South East	−0.194	0.232	−0.0505	0.409 ***	0.546 ***	−0.00746	0.803 ***	0.887 ***	0.781 ***	1.638 ***	0.00822	1.056 ***
	(0.254)	(0.272)	(0.173)	(0.181)	(0.137)	(0.144)	(0.140)	(0.322)	(0.189)	(0.432)	(0.139)	(0.445)
South South	−0.252	0.336	0.645 ***	0.528 ***	0.579 ***	−0.0336	0.414 ***	0.094 ***	0.751 ***	2.035 ***	−0.244 ***	0.908 ***
	(0.280)	(0.328)	(0.156)	(0.202)	(0.141)	(0.151)	(0.144)	(0.378)	(0.202)	(0.429)	(0.144)	(0.462)
Agricultural revenue	0.00884	−0.0403	0.0614 **	−0.0279	−0.0875 ***	−0.000461	0.00299	−0.0375	0.0137	0.0210	−0.0211	0.0563 **
	(0.0372)	(0.0293)	(0.0253)	(0.0192)	(0.0181)	(0.0176)	(0.0185)	(0.0303)	(0.0203)	(0.0226)	(0.0170)	(0.0280)
Assets owned	0.343 ***	0.0764 **	0.0302 ***	0.00860	0.0573 ***	0.0694 ***	0.0828 ***	−0.0207	0.0594 ***	0.152 ***	0.0508 ***	0.0598
	(0.0965)	(0.0338)	(0.0127)	(0.0161)	(0.0171)	(0.0217)	(0.0173)	(0.0167)	(0.0241)	(0.0254)	(0.0189)	(0.0296)
Household size	−0.00874	0.00734	−0.0319 ***	0.0208 **	−0.0458 ***	−0.0253 ***	−0.0756 ***	0.0117	−0.0176	−0.0466 ***	−0.000681	−0.0353 **
	(0.0218)	(0.0151)	(0.0135)	(0.0111)	(0.0115)	(0.0106)	(0.0117)	(0.0159)	(0.0117)	(0.0124)	(0.0105)	(0.0162)
Extension service	0.0369	0.0506	−0.0496	−0.318 **	0.127	0.235	0.766 ***	−0.0254	−0.494 ***	−0.295 **	0.237 *	0.0683
	(0.417)	(0.203)	(0.168)	(0.137)	(0.142)	(0.143)	(0.133)	(0.241)	(0.134)	(0.137)	(0.142)	(0.232)
Access to credit	0.210	0.198	0.163	0.233	0.402 ***	0.135	0.286 **	0.0967	0.0625	1.098 ***	−0.156	0.548
	(0.368)	(0.255)	(0.149)	(0.162)	(0.129)	(0.139)	(0.132)	(0.214)	(0.167)	(0.285)	(0.130)	(0.427)
Food expenditure	0.403 ***	0.159 ***	0.455 ***	0.348 ***	0.314 ***	0.703 ***	0.527 ***	0.324 ***	0.411 ***	0.107 ***	0.550 ***	0.319 ***
	(7.68×10^{-5})	(2.08×10^{-5})	(1.25×10^{-5})	(1.11×10^{-5})	(1.13×10^{-5})	(1.64×10^{-5})	(1.21×10^{-5})	(2.65×10^{-5})	(1.90×10^{-5})	(1.38×10^{-5})	(1.55×10^{-5})	(2.91×10^{-5})
Land size	0.164 **	−0.0113	0.0194 **	0.0112	−0.00213	0.0746 ***	−0.0124	−0.00715	−0.0156 *	−0.00396	−0.00388	−0.00612
	(0.0859)	(0.00772)	(0.00851)	(0.00948)	(0.00838)	(0.0203)	(0.0108)	(0.00818)	(0.00875)	(0.00934)	(0.00697)	(0.0109)
Non-food expenditure	−0.0338	0.106 ***	0.154 ***	0.0963 ***	0.0597 ***	0.0686 ***	0.122 ***	0.0372	0.0438 **	0.0350 *	0.112 ***	0.131 ***
	(0.0374)	(0.0221)	(0.0328)	(0.0190)	(0.0219)	(0.0183)	(0.0249)	(0.0228)	(0.0189)	(0.0199)	(0.0187)	(0.0234)
Marital status	0.161	−0.0816	−0.0803	0.273 ***	−0.117	−0.137 **	−0.107	0.213 **	−0.0321	0.0432	−0.0861	0.0154
	(0.155)	(0.0995)	(0.0894)	(0.0721)	(0.0757)	(0.0698)	(0.0737)	(0.102)	(0.0762)	(0.0789)	(0.0691)	(0.116)
Constant	1.901 **	1.717 **	−2.519 ***	0.728	0.657 *	−0.312	−0.709 *	1.662 ***	0.605	3.581 ***	−1.694 ***	1.389
	(0.938)	(0.676)	(0.514)	(0.445)	(0.392)	(0.389)	(0.410)	(0.621)	(0.450)	(0.717)	(0.374)	(0.984)

Notes: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Cereals: It was found that, compared to the southern region, households from the northern region of Nigeria (North Central and North West) have the higher likelihood to consume cereals. This is rather expected because most cereal production in Nigeria emanates from the northern region relative to southwest. Additionally, asset ownership, food expenditure and land size all significantly increased the likelihood of consuming cereals (Table 2). Moreover, the results implied that as households increase their food expenditure, the consumption of cereals increased. This is consistent with the findings of Musyoka et al. [97] and Torres [98]. The increase in land size could lead to having more land being used to produce cereals, which could make households increase their consumption of cereals. This finding is also in line with Yawson et al. [99], that land size plays a significant role in expanding production cereals.

Spices: It was observed that food expenditure and asset ownership increase the likelihood to consume spices. In Nigeria, the southern region is known to be high consumer of spices compared to the northern region. In corroboration, we found that living in the northern Nigeria (North Central and North East) reduces the probability of consuming spices. On the other hand, increased food expenditure and ownership of assets increased the likelihood of consuming more spices. Increased income vis-à-vis assets strengthens the purchasing power of households to expend more on food.

Eggs: The households of the northern region are known as higher consumers of eggs compared to the southern region. Contrary to this belief, we found a negative association between egg consumption and the northern region. The probable reason for this might be a result of conflict and extreme terrorism that have afflicted the region in recent years. This is consistent with the findings of [100], asserting that conflict, social crises and terrorism are responsible for increased food poverty in the region, among other things. Additionally, the age of the household's head significantly reduced the likelihood of consuming eggs. This observation is in accordance with the belief that eggs are consumed by younger individuals and not for older individuals. Conversely, food expenditure and agricultural revenue significantly increased the consumption of eggs as a food group, implying that households with more proceeds from agricultural production are able to consume more eggs with the revenue accrued from the sales of their produce.

Fish and sea foods: Increased food expenditure significantly increased the consumption of fish and sea foods. This could be due to the fact that the higher the amount of money allocated for food consumption, the higher the probability of dietary diversification. For those in South East and South South zones, a significant increase was observed in the consumption of fish and sea foods relative to those in the South West. This could be due to the fact that the South South is a riverine area with abundant fish and other sea foods. Additionally, marital status, increased age of the household's head, household non-food expenditure and household size increased the consumption of this food group. This supports the belief that older people should consume less meat and more fish and sea foods. In the same vein, being married increased the consumption of fish and sea foods. This is in line with the result on household size—this finding could be due to the fact that married people are expected to have large households, and as such, are expected to purchase more fish and sea foods as a good source of protein, especially for the children in the households.

Fruits: The sex of the household's head (male), asset index, and food expenditure positively and significantly determined the consumption of the fruit food group in the study area. Being a male-headed household, increasing food expenditure of the household and asset index increased the consumption of the fruit food group. However, residing in the region of the country (North Central, North East and North West) where there is conflict negatively determined households consuming fruits. In addition, household size negatively determined the consumption of fruits as a food group. This implies that an increased number of household members decreased the consumption of fruits.

Meat: Meat is a very good source of protein and its consumption is very important for improving nutrition outcomes, especially among children. We found that being a male household head, asset index, household food expenditure, land size and non-food expenditure positively and significantly determined a households' consumption of meat. This implies that male-headed households are more likely to consume meat than female-headed ones, as the male head allocates more expenditure on food, influencing the decision of a household caregiver to purchase more meat for the household's consumption. This is supported by Abubakar [101], who observed that female-headed households are less likely to report meat consumption than the males. On the other hand, being married, the age of the household's head, residing in North Central, North West and South East relative to the South West showed a negative and significant consumption of meat. The finding that being married reduces the consumption of meat supports earlier findings that married households consume more fish and sea food. Moreover, even though households in the northern region practice animal husbandry, they eat less meat than those in South West. The reason is that the northern herdsmen rear meat-producing animals for generating income rather than for consumption.

Milk: We found that regarding asset ownership, households having access to extension services and food expenditure positively and significantly determined households' consumption of milk in the study area (see Table 2). An increased asset ownership implies that there is an increase in income; hence, households are rich enough to purchase milk. Households can acquire knowledge on the consumption of different food groups (in this case, milk) through nutrition information they received from extension workers. In the same vein, households who can afford to increase their non-food expenditure can also increase their consumption of milk. However, the age of the household's head, household size and food expenditure negatively determined the consumption of milk as a food group. Larger household sizes consuming less milk could be due to the cost implication of its purchase. In addition, there is an increase in milk consumption as a result of households' increased food expenditure. The consumption of milk as a food group was negatively and significantly determined by residing in the North Central and North East geopolitical zones relative to the South West. As previously observed, residents in the northern zones as compared with the southwest consume less animal-sourced protein-rich foods.

Oil and Fat: Being married and household food expenditure positively and significantly determined the consumption of oil and fat (Table 2). Consistently, dwelling in the South East and South South positively and significantly determined the consumption of oil and fat. It is believed that these regions in Nigeria consume a lot of oil and fat compared to other regions, such as the northern parts. Additionally, residing in the North Central and North East zones relative to the South West negatively determined the consumption of oil and fat.

Pulses: Food and non-food expenditure positively and significantly determined the likelihood of households to consume pulses (Table 2). In the same vein, residing in the South East relative to being in the South West positively and significantly determined the likelihood of consuming pulses. However, a negative significance was observed when North Central, North East and North West zones were considered relative to the South West. This implies that pulses are less consumed by households in the northern region, while they are more consumed by people in the South West. Land size and access to extension services were also negatively related to the consumption of pulses.

Root and tuber: From Table 2, we can see that socio-economic characteristics negatively and significantly determine the consumption of roots and tubers, including: age of the household's head, access to extension services, access to credit from cooperatives and food expenditure. The same was observed with households residing in the North Central, North East and North West zones relative to the South West. This is because roots and tubers are not a key component of diets in northern Nigeria. On the other hand, asset index and non-food expenditure of the household positively and significantly determined the consumption of roots and tubers.

Sweets: Furthermore, the results revealed that asset index, access to extension services, food and non-food expenditure all positively and significantly determine the consumption of sweets (Table 2). The same was observed with households residing in the North Central, North East, North West, and geopolitical zones relative to the South West zone.

Vegetables: Agricultural revenue, household food and non-food expenditure positively and significantly determined households' consumption of vegetables. Thus, increasing the agricultural revenue of households as well as expenditure on food and non-food increases their consumption of vegetables because the households have enough money to purchase these vegetables. On the contrary, residing in the North Central, North East and North West relative to South West negatively and significantly determined the consumption of vegetables. The results imply that households in northern Nigeria consume fewer vegetables as compared to those in the South West zone.

3.2. Summary Statistics of Crop Diversity and Dietary Diversity

In order to measure crop diversity, the number of crops grown was counted (Table 3). The maximum number of crops grown in Nigeria was nine. On average, farmers grow 1.846 ± 1.001 (2 crops). This depicts that most crop farmers in Nigeria carry out mixed cropping (75.92% of the farmers cultivate more than one crop). Based on the sector of residence, the average shows that there is somewhat a difference in the number of crops grown in rural households (1.87) and urban households (1.65). The number of food groups consumed was used to calculate the Household Dietary Diversity Score—used as a dependent variable (Table 3). The maximum number of food groups consumed in the entire country was 12, with an average of 7.8 ± 2.00 (approximately 8 food groups); households in the urban areas consume more (approximately 8.85 ± 1.83) food groups (9) on average than those in rural areas 7.70 ± 1.98 (approximately 8 food groups). The result seems to suggest that the average dietary diversity of the households is rather fair.

Table 3. Crop and household diversity scores.

Variable	Obs.	Mean	Median	S.D.	Variance
Crop diversity	2640	1.8458	2	1.0006	1.0012
Urban	307	1.6514	1	0.8776	0.7702
Rural	2333	1.8714	2	1.0130	1.0263
Household diversity score	2640	7.8375	8	2.0020	4.0080
Urban	307	8.8599	9	1.8319	3.3561
Rural	2333	7.7029	8	1.9848	3.9396

3.3. Crop Diversity and Nutrition Diversity

The three regression models (OLS, Poisson and IV-Poisson) used in the analysis showed the relationship between crop diversity and nutrition diversity. Two indicators were used to measure crop diversity: Firstly, crop diversity considered as crop count (that is, the number of crops grown by the households) was used. Secondly, we proxied crop diversification with agricultural revenue from the different crops grown in the households. The rationale of the link emerges from the assumption that even though smallholder farmers are involved in mixed cropping, they cannot produce all the food items that would be consumed in the households. Hence, income generated from crop diversification can be used to purchase non-cultivated food items to enhance their dietary diversity. The analysis was carried out for the entire country using pooled data (Table 4); the disaggregated results by sector of residence (urban and rural) are presented in Tables 5 and 6. Although three regression results (OLS, Poisson, and IV-Poisson) are presented, our main focus is on the IV-Poisson estimation strategy results. The OLS results were found to be biased as they failed to fulfill the assumption of count variables. According to Greene [102], a common approach for count data models is to use a Poisson estimator. The Poisson estimator assumes equi-dispersion; that is, the mean and variance of the dependent variable are assumed to be equal. This assumption is often violated and can lead to incorrect standard errors. Overdispersion, where the conditional variance exceeds the conditional mean, is a common phenomenon. However, due to possible endogeneity between crop diversity and dietary diversity [27,61,96], we used the IV-Poisson estimation technique to explore the relationship between crop diversification and dietary diversification.

Table 4. Crop diversity and nutrition diversity (all households).

VARIABLES	OLS	Poisson	IV-Poisson	OLS	Poisson	IV-Poisson
Crops grown	0.0616 *	0.00751	0.0882 ***			
	(0.0317)	(0.00737)	(0.0338)			
Agricultural revenue				−0.00951	−0.000974	0.0886 ***
				(0.00928)	(0.00207)	(0.0288)
Sex of the household's head (male)	0.00548	0.00103	−0.0825 ***	0.00859	0.00145	−0.270 ***
	(0.123)	(0.0280)	(0.0172)	(0.123)	(0.0280)	(0.0562)
Age of the household's head	−0.00753 ***	−0.000953 *	0.000616 *	−0.00739 ***	−0.000934 *	−0.00292 ***
	(0.00216)	(0.000507)	(0.000316)	(0.00216)	(0.000506)	(0.000731)
Asset ownership	0.0508 ***	0.00394	0.00931 ***	0.0515 ***	0.00396	0.00517
	(0.0138)	(0.00278)	(0.00332)	(0.0138)	(0.00277)	(0.00335)
Household size	−0.0309 ***	−0.00339	−0.00428 *	−0.0275 **	−0.00300	−0.0133 ***
	(0.0110)	(0.00255)	(0.00224)	(0.0108)	(0.00252)	(0.00290)
Education	0.0449	0.00576	0.00558	0.0452	0.00579	0.00263
	(0.0445)	(0.00999)	(0.00621)	(0.0445)	(0.00999)	(0.00776)
Use of firewood	0.130	0.0156	0.0368 **	0.137	0.0165	0.00869
	(0.0859)	(0.0200)	(0.0147)	(0.0858)	(0.0200)	(0.0175)
Credit access	0.276 **	0.0291	0.0435 **	0.290 **	0.0306	0.146 ***
	(0.132)	(0.0287)	(0.0210)	(0.132)	(0.0288)	(0.0325)
Food expenditure	0.000209 ***	2.21×10^{-5} ***	0.120 ***	0.000207 ***	2.20×10^{-5} ***	0.126 ***
	(1.15×10^{-5})	(2.28×10^{-6})	(0.00876)	(1.14×10^{-5})	(2.28×10^{-6})	(0.0109)
Land size	−0.00225	−0.000549	−0.00237	−0.00241	−0.000572	−0.00695
	(0.00839)	(0.00201)	(0.00154)	(0.00840)	(0.00201)	(0.00584)
Non-food expenditure	0.278 ***	0.0434 ***	0.0438 ***	0.278 ***	0.0434 ***	0.0418 ***
	(0.0198)	(0.00507)	(0.00449)	(0.0198)	(0.00507)	(0.00504)
Marital status	−0.00510	−0.00253	0.0172	0.00277	−0.00164	0.00194
	(0.0731)	(0.0172)	(0.0134)	(0.0730)	(0.0172)	(0.0158)
North Central	−1.238 ***	−0.150 ***	−0.116 ***	−1.202 ***	−0.147 ***	−0.293 ***
	(0.136)	(0.0306)	(0.0241)	(0.137)	(0.0309)	(0.0469)
North East	−1.716 ***	−0.217 ***	−0.177 ***	−1.677 ***	−0.213 ***	−0.368 ***
	(0.138)	(0.0316)	(0.0249)	(0.140)	(0.0320)	(0.0469)
North West	−1.365 ***	−0.168 ***	−0.222 ***	−1.366 ***	−0.169 ***	−0.309 ***
	(0.134)	(0.0302)	(0.0251)	(0.135)	(0.0305)	(0.0435)
South East	0.250 *	0.0304	0.00178	0.211	0.0261	0.274 ***
	(0.134)	(0.0294)	(0.0201)	(0.136)	(0.0299)	(0.0838)
South South	0.105	0.00909	−0.0381	0.0800	0.00613	0.0546
	(0.145)	(0.0317)	(0.0250)	(0.145)	(0.0317)	(0.0398)
Constant	6.301 ***	1.802 ***	2.006 ***	6.455 ***	1.819 ***	1.075 ***
	(0.269)	(0.0643)	(0.0775)	(0.274)	(0.0654)	(0.268)
R-squared	0.417			0.416		
Pseudo r-squared		0.0473			0.0473	
Observations	2640	2640	2640	2640	2640	2640

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Crop diversity and nutrition diversity (urban households).

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	**OLS**	**Poisson**	**IV-Poisson**	**OLS**	**Poisson**	**IV-Poisson**
	(0.323)	(0.0723)	(0.0759)	(0.329)	(0.0734)	(0.105)
Crops grown	0.163	0.0186	−0.146 *			
	(0.102)	(0.0231)	(0.0798)			
Agricultural revenue				0.0276	0.00302	−0.0732 ***
				(0.0249)	(0.00547)	(0.0257)
Sex of the household's head (male)	0.436	0.0468	0.110	0.543 *	0.0585	−0.160
	(0.323)	(0.0723)	(0.0759)	(0.329)	(0.0734)	(0.105)
Asset ownership	0.0746 **	0.00773	0.0121 **	0.0763 **	0.00797	0.0109 *
	(0.0348)	(0.00762)	(0.00499)	(0.0349)	(0.00761)	(0.00639)
Household size	−0.0539 *	−0.00603	−0.00160	−0.0491	−0.00557	−0.00899
	(0.0303)	(0.00698)	(0.00492)	(0.0302)	(0.00697)	(0.00638)
Education	0.0471	0.00488	0.109	0.0497	0.00507	-4.708×10^{17}
	(0.181)	(0.0429)	(0.140)	(0.182)	(0.0430)	(0)
Use of firewood	−0.162	−0.0181	−0.0107	−0.169	−0.0184	−0.0201
	(0.214)	(0.0485)	(0.0301)	(0.215)	(0.0485)	(0.0487)
Credit access	0.0688	0.00471	0.0218	0.0633	0.00411	0.110
	(0.302)	(0.0664)	(0.0466)	(0.304)	(0.0666)	(0.0848)
Food expenditure	0.000125 ***	1.38×10^{-5} **	1.10×10^{-5} ***	0.000125 ***	1.39×10^{-5} **	3.41×10^{-6}
	(2.79×10^{-5})	(6.00×10^{-6})	(4.11×10^{-6})	(2.80×10^{-5})	(6.03×10^{-6})	(6.02×10^{-6})
Land size	−0.0543	−0.00696	−0.00487	−0.0682	−0.00848	0.0286 **
	(0.0627)	(0.0144)	(0.00733)	(0.0636)	(0.0146)	(0.0141)
Non-food expenditure	0.267 ***	0.0333 *	0.0226	0.263 ***	0.0328 *	0.0449 *
	(0.0741)	(0.0178)	(0.0182)	(0.0742)	(0.0178)	(0.0267)
Marital status	0.124	0.0128	−0.00309	0.0888	0.00865	0.0432
	(0.214)	(0.0485)	(0.0335)	(0.214)	(0.0484)	(0.0451)
North Central	−0.777 **	−0.0870	−0.0273	−0.759 **	−0.0847	0.0728
	(0.322)	(0.0724)	(0.0638)	(0.322)	(0.0724)	(0.0917)
North East	−1.709 ***	−0.202 **	−0.223 ***	−1.796 ***	−0.211 **	0.0710
	(0.393)	(0.0908)	(0.0557)	(0.400)	(0.0921)	(0.140)
North West	−1.375 ***	−0.162**	−0.213 ***	−1.464 ***	−0.172 **	0.0708
	(0.317)	(0.0732)	(0.0595)	(0.323)	(0.0742)	(0.132)
South East	0.806 ***	0.0895	0.0655	0.855 ***	0.0943	−0.131
	(0.286)	(0.0627)	(0.0429)	(0.296)	(0.0647)	(0.103)
South South	0.500	0.0506	0.0552	0.499	0.0510	0.0199
	(0.338)	(0.0736)	(0.0455)	(0.338)	(0.0736)	(0.0937)
Constant	6.608 ***	1.903 ***		2.239 ***	6.634 *** 1.908 ***	2.550 ***
	(0.860)	(0.201)		(0.195)	(0.876) (0.203)	(0.302)
Observations	307	307		307	307 307	307
R-squared	0.376			0.373		
Pseudo r-squared		0.0326			0.0324	

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6. Crop diversity and nutrition diversity (rural households).

VARIABLES	OLS	Poisson	IV-Poisson	OLS	Poisson	IV-Poisson
Crops grown	0.0581 *	0.00715	0.157 ***			
	(0.0333)	(0.00783)	(0.0482)			
Agricultural revenue				−0.0136	−0.00135	0.0846 ***
				(0.01000)	(0.00225)	(0.0294)
Age of the household's head	−0.00783 ***	−0.00101 *	−0.000430	−0.00763 ***	−0.000980 *	−0.000860 *
	(0.00229)	(0.000544)	(0.000409)	(0.00229)	(0.000543)	(0.000498)
Asset ownership	0.0510 ***	0.00384	0.00499 *	0.0518 ***	0.00386	0.00505
	(0.0152)	(0.00305)	(0.00285)	(0.0152)	(0.00305)	(0.00360)
Household size	−0.0242 **	−0.00253	0.00619 **	−0.0206 *	−0.00210	−0.00362
	(0.0118)	(0.00278)	(0.00309)	(0.0116)	(0.00275)	(0.00263)
Education	0.0470	0.00627	0.00648	0.0477	0.00634	0.00302
	(0.0458)	(0.0103)	(0.00658)	(0.0458)	(0.0103)	(0.00776)
Use of firewood	0.226 **	0.0288	0.0496 ***	0.232 **	0.0297	0.0212
	(0.0965)	(0.0229)	(0.0173)	(0.0965)	(0.0228)	(0.0197)
Credit access	0.274 *	0.0295	0.0407 *	0.288 **	0.0310	−0.00912
	(0.147)	(0.0322)	(0.0231)	(0.147)	(0.0322)	(0.0376)
Food expenditure	0.000235 ***	2.52×10^{-5} ***	2.17×10^{-5} ***	0.000233 ***	2.50×10^{-5} ***	2.86×10^{-5} ***
	(1.29×10^{-5})	(2.60×10^{-6})	(2.81×10^{-6})	(1.28×10^{-5})	(2.60×10^{-6})	(3.29×10^{-6})
Land size	0.00126	4.60×10^{-5}	−0.00186	0.00123	2.83×10^{-5}	−0.00443
	(0.00846)	(0.00200)	(0.00126)	(0.00846)	(0.00200)	(0.00384)
Non-food expenditure	0.265 ***	0.0422 ***	0.0425 ***	0.266 ***	0.0422 ***	0.0409 ***
	(0.0206)	(0.00534)	(0.00472)	(0.0206)	(0.00534)	(0.00505)
Marital status	−0.0176	−0.00402	0.0229	−0.00842	−0.00293	0.00581
	(0.0779)	(0.0185)	(0.0155)	(0.0776)	(0.0185)	(0.0164)
North Central	−1.241 ***	−0.153 ***	−0.131 ***	−1.204 ***	−0.150 ***	−0.286 ***
	(0.158)	(0.0361)	(0.0267)	(0.160)	(0.0364)	(0.0516)
North East	−1.675 ***	−0.215 ***	−0.182 ***	−1.634 ***	−0.211 ***	−0.349 ***
	(0.160)	(0.0367)	(0.0280)	(0.161)	(0.0370)	(0.0503)
North West	−1.319 ***	−0.164 ***	−0.233 ***	−1.318 ***	−0.165 ***	−0.290 ***
	(0.157)	(0.0357)	(0.0311)	(0.157)	(0.0359)	(0.0475)
South East	0.199	0.0230	−0.0135	0.145	0.0172	0.261 ***
	(0.158)	(0.0352)	(0.0250)	(0.160)	(0.0357)	(0.0900)
South South	0.104	0.00813	−0.0549 *	0.0690	0.00405	0.0606
	(0.169)	(0.0374)	(0.0313)	(0.168)	(0.0374)	(0.0469)
Constant	6.254 ***	1.796 ***	2.001 ***	6.431 ***	1.815 ***	1.127 ***
	(0.292)	(0.0701)	(0.0821)	(0.297)	(0.0712)	(0.264)
R-squared	0.411			0.411		
Pseudo r-squared		0.0466			0.0465	
Observations	2333	2333	2333	2333	2333	2333

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Our main discussion of the reported findings below will focus on the results emerging from the instrumental variable approach. We found that in some cases, the age of the household's head had a negative and significant relationship with nutrition diversity (HDDS). This implies that an increase in the age of the household's head decreases the likelihood of having dietary diversification. This could be due to the fact that the older the household's head becomes, the less likely she or he is to obtain additional income from off-farm activities which can be used to purchase diverse food groups in a bid to increase dietary diversity. These findings are also consistent with those of Babatunde et al. [81].

Ownership of assets has a positive significant relationship with dietary diversity in the model (column 3) using the crop count, but not in the agricultural revenue models (column 6). This implies that the ownership of assets leads to the households consuming more diversified diets; this is in line with the findings of Pellegrini and Tasciotti [27]. The findings from the study of Mannaf and Uddin [103] also suggest that the ownership of assets (such as livestock) is expected to reduce food insecurity and increase the likelihood of diversifying diets.

Household size was found to have a negative association with dietary diversity (both in the number of crops grown and agricultural revenue models). By implication, the larger the household becomes, the lower the food groups available to members, especially in low-income households where there is weak purchasing power for many food groups. This finding confirms Babatunde et al. [81] and Adebayo et al. [100], who observed that an increase in household size increases the probability of food poverty. In addition, access to credit has a positive and significant relationship with dietary diversity. Access to financial services has been associated with the adoption of productivity-enhancing technologies [69]. Therefore, if income increases through increased productivity, this could increase the purchasing power of households so they can purchase diverse food groups for consumption.

Food expenditure is positively influencing the likelihood to diversifying nutrients in Nigeria. Various studies have revealed that increased food expenditure increases the amount allocated to each food group, which will most likely increase the possibility of diversifying the food consumed by the household [97,98,104]. Non-food expenditure has a positive significant relationship with HDDS for all the models estimated. This implies that when households spend an additional budget on non-food items, they also increase expenditure on food items (see models 2 and 3), and it is expected that their dietary diversity increases.

On the relationship between crop diversity and dietary diversity using a number of crops grown by the household, we found that crops grown positively and significantly influences the diversification of diet in the household. This is possible since as the number of food crops increases the household tends to have more option to upgrade and diversify from the consumption of unbalanced diets that possibly influence malnutrition, stunting and wasting especially among children. Thus, the higher the crop count, the higher the likelihood to consume divers' kinds of food groups. This agrees with several findings in the literature, which revealed that an increase in farm production diversity is responsible for the number of food groups consumed in the household [63,97,98,104–109].

The use of agricultural revenue as a proxy for crop diversity provided a consistent result with the number of crops grown by the households. This finding suggests that crop diversification is a key determinant of dietary diversity in Nigeria, as revealed also in other countries such as Malawi [61], Ethiopia [108] and India [63]. Additionally, the plot of polynomial associations between crop diversity and dietary diversity suggests that the higher the crop diversification, the higher the dietary diversity is in Nigeria (Figure 1).

Finally, the geopolitical zones in Nigeria were also modelled as a factor influencing dietary diversity. The estimation in all models revealed a negative and significant relationship between the region of residence and the nutritional diversity of households across Nigeria, especially for the northern region (North Central, North East and North West). Northern Nigeria have been plagued with security issues in recent years, which have contributed to a downward trend in development and growth indicators in the region, despite several interventions to reduce hunger, malnutrition and poverty.

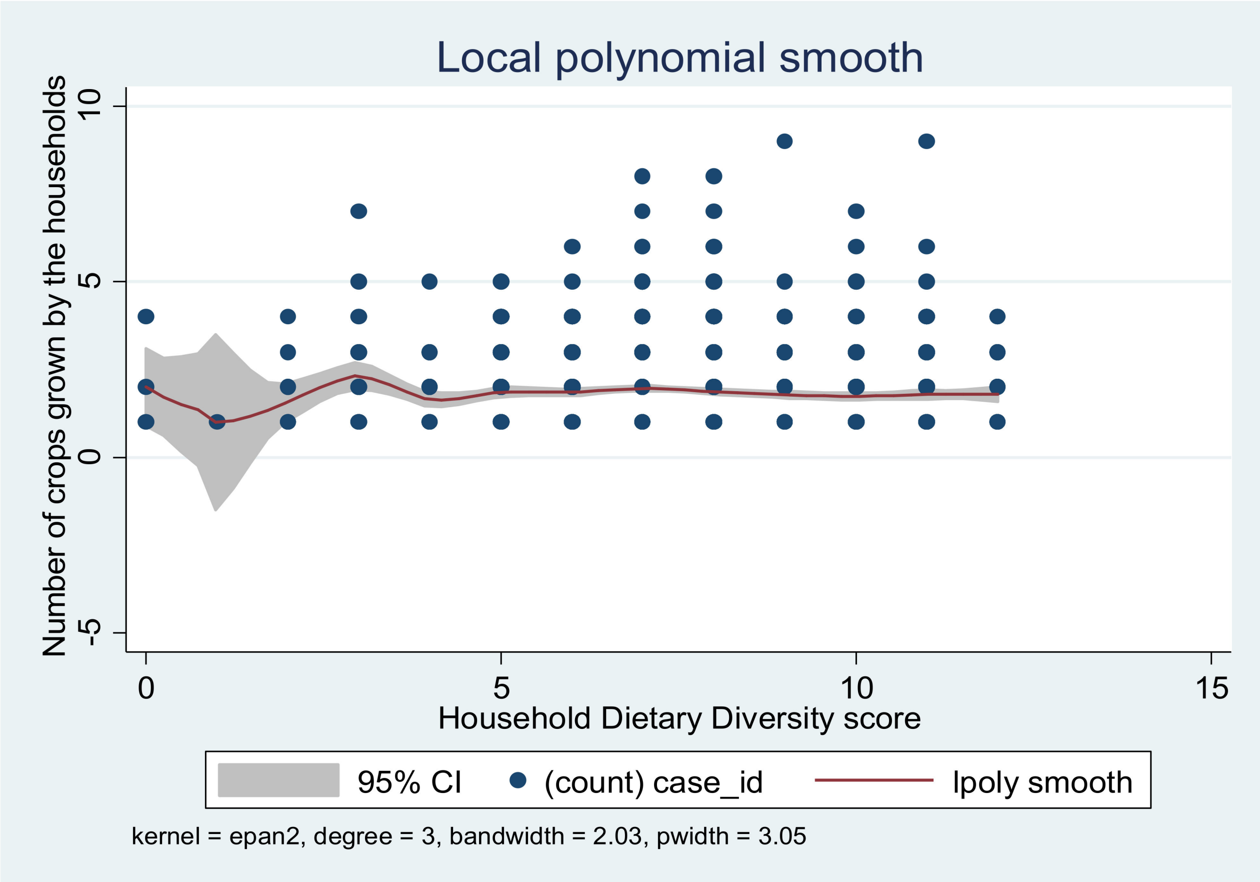

Figure 1. Plots of polynomial associations between crop diversity and dietary diversity (urban versus rural).

In order to obtain a better idea regarding the situation in rural and urban households, the data were disaggregated to investigate the relationship of crop diversity with dietary diversity. Interestingly, some similar findings were found from the relationship between the cofounding factors used along with crop counts and agricultural revenue as a function of dietary diversity. For instance, variables such as the age of the household's head, asset ownership, food and non-food expenditure as well as being resident in the northern region of the country, particularly the North East, all had a significant relationship.

However, the sex of the household's head was found to be positively related to nutrition diversity in the urban areas, while the reverse was the case in the rural areas. This implies that a male-headed household reduces nutrition diversity in rural Nigeria, while it increases it in urban Nigeria. The probable reason for this might be the empowerment, social and human capital level of male-headed households in the urban areas compared to rural households. Household size, access to credit and use of firewood significantly determine dietary diversity in rural Nigeria. Specifically, an additional member of the household reduces the nutritional diversity of such households. This could be due to the fact that an additional household member will put a strain on the consumption of the household. Access to credit, on the other hand, increases the dietary diversity of households as they will have enough funds for their expenditures.

In relation to crop diversity and nutrition diversity, we also found that crop diversification and agricultural revenue have a positive and significant relationship with dietary diversity in rural households, while an inverse relationship was recorded in the urban households. The findings suggest that low crop diversification has the likelihood of reducing dietary diversification. Although farming is a rural phenomenon compared to urban, these findings do not necessarily suggest that the rural households were able to diversify diets more than the urban households. Specifically, linking crop diversification with dietary diversification, rural households seem to be in a better position than urban households in Nigeria. Our findings suggest that crop diversification is a key factor in reducing malnutrition in Nigeria. This is further supported by the non-parametric analysis expressed in Figures 2 and 3. This finding, which is in line with the results reported by other studies, suggests that crop diversification increases the diversification of diets, especially in rural households [63,97,98,105–109].

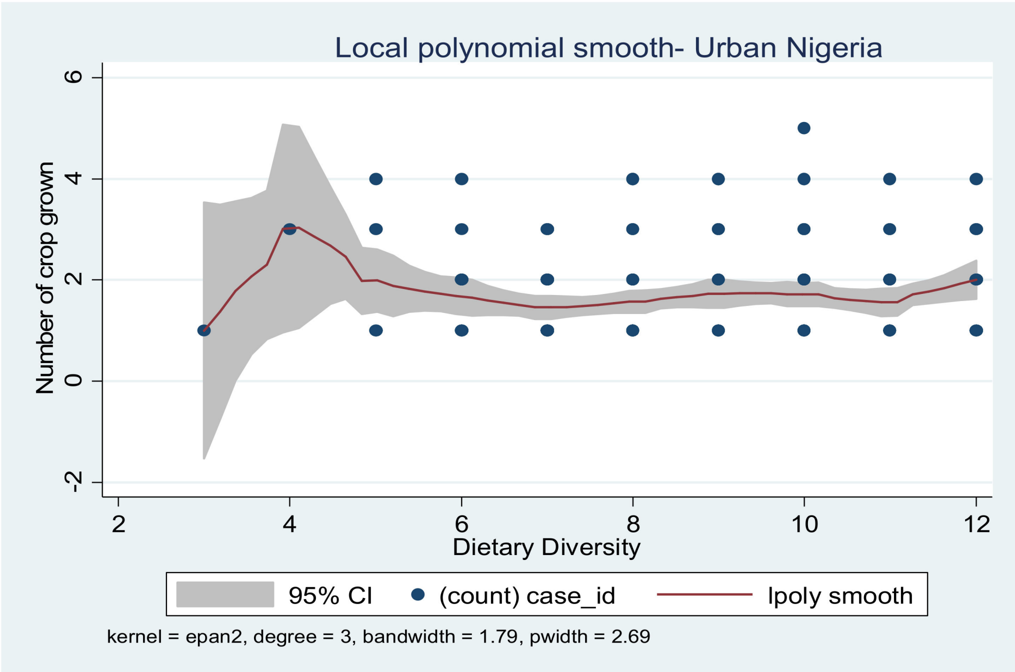

Figure 2. Plots of polynomial associations between crop diversity and dietary diversity: urban Nigeria.

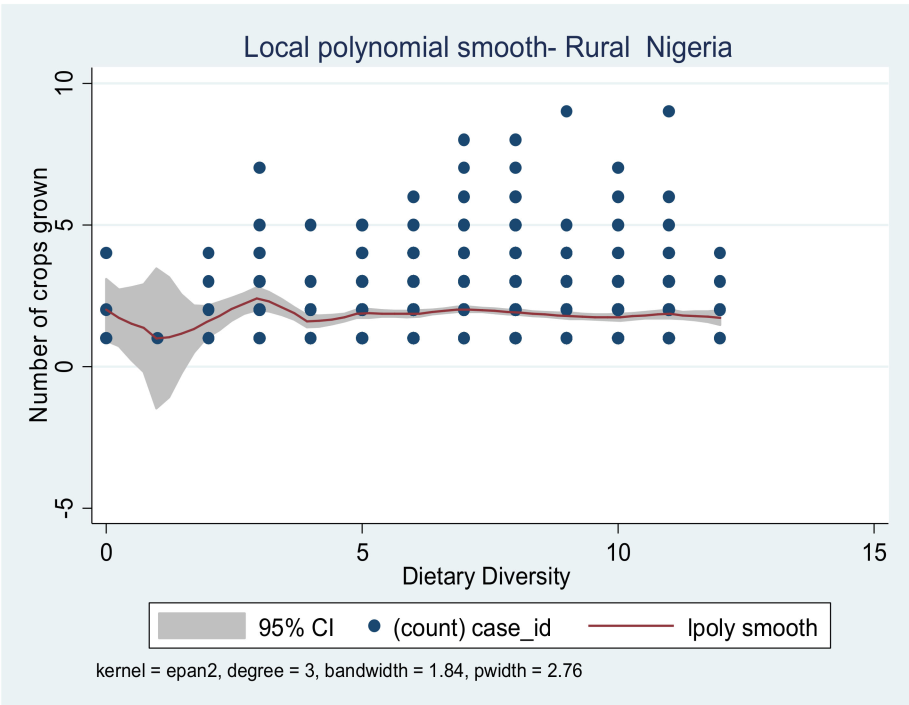

Figure 3. Plots of polynomial associations between crop diversity and dietary diversity: rural Nigeria.

4. Conclusions and Policy Options

The main results emanating from this study illustrate two alternative approaches (crops grown and agricultural revenue) to measuring the effect of agricultural on-farm production on household nutrition using dietary diversity. Usually, agricultural pathways to increase nutrition are likely to occur through two mechanisms, either through income effects or via the increased consumption of own produced foods. The findings reveal that on-farm production diversity is positively associated with dietary diversity in Nigeria in both approaches. Hence, on-farm crop diversification may help to improve household diets to some extent. However, the magnitude of the estimates suggests that the positive dietary effects of further diversifying on-farm production will be relatively small. With regard to rural and urban disparity, we found that crop diversification and agricultural revenue have a positive and significant relationship with dietary diversity in rural households, while an inverse relationship was recorded in the urban households. The findings further show that cereals are the most consumed food groups among the farming households compared to other food groups. In a consistent manner, food expenditure, asset ownership and regional dummies (precisely in the northern region) are the key factors among others in driving the types of food consumed by the households. Although these findings call for improved attention on diet diversity, it is equally important to emphasize the harmonizing roles of rural income improvement, especially through non-farm livelihood diversification (since the households under examination were predominantly rural) in tackling multiple nutritional deficiencies in Nigeria. In particular, relevant stakeholders should consider the nutritional status of households in the northern region, which has been plagued by serious security issues in recent years. Furthermore, since it was found that crop diversification is assumed to influence household diet diversification, efforts should be made on the policy front to prevent and cure severe malnutrition in Nigeria, so that the increase in agricultural intensification and biodiversity as a strategy to fight malnutrition in Nigeria should not take the place of malnutrition-reducing policies, but rather should be seen as complementary and supporting approaches, especially in northern and rural households. Having said that, one of the limitations of this study are the data used, which are slightly "outdated" and may not fully reflect the current realities due to time difference. In addition, we acknowledge that the use of agricultural revenue as a proxy for crop diversity may not be a best-fit variable. However, the findings emerging from this study could serve as useful background material for future research work, using more recent data and more appropriate variables.

Author Contributions: Conceptualization, I.O.A., A.I.O., G.M. and A.O.O.; methodology I.O.A., A.I.O.; resources, A.O.O., A.I.O. and I.O.A.; writing—original draft preparation, I.O.A. and A.I.O.; writing—review and editing, A.O.O. and G.M.; supervision, A.O.O. and G.M.; project administration, I.O.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no funding from any organization.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are available at this link: https://www.worldbank.org/en/programs/lsms (accessed on 15 May 2018).

Acknowledgments: We would like to thank the Editor of the journal and the three anonymous reviewers for their very helpful comments and suggestions, which were of great benefit to the current version. We would like to appreciate the comments received from the participants of the 2019 HORTISON Conference. Finally, we would like to express our appreciation to our respective institutes for providing us with an excellent environment in order to complete this research. Needless to say, the usual disclaimer applies.

Conflicts of Interest: The authors declare that there is no conflict of interest.

References

1. Arimond, M.; Ruel, M.T. Dietary diversity is associated with child nutritional status: Evidence from 11 demographic and health surveys. *J. Nutr.* **2004**, *134*, 2579–2585. [CrossRef] [PubMed]
2. Thompson, B.; Amoroso, L. *FAO's Approach to Nutrition-Sensitive Agricultural Development*; Food and Agriculture Organization: Rome, Italy; World Health Organization: Geneva, Switzerland, 2011.
3. Khondker, M.; Umehara, M.; Hayashi, H.; Omar, M.N.A.E.M. Agriculture, biology, and environment: Twenty first century challenges and opportunities. *Agron. J.* **2021**, *113*, 671–676. [CrossRef]
4. Fan, S.; Teng, P.; Chew, P.; Smith, G.; Copeland, L. Food system resilience and COVID-19–Lessons from the Asian experience. *Glob. Food Secur.* **2021**, *28*, 100501. [CrossRef]
5. World Health Organization. *The State of Food Security and Nutrition in the World 2020: Transforming Food Systems for Affordable Healthy Diets*; Food & Agriculture Organization: Rome, Italy, 2020; Volume 2020.
6. Bhattacharya, P.T.; Misra, S.R.; Hussain, M. Nutritional aspects of essential trace elements in oral health and disease: An extensive review. *Scientifica* **2016**, *2016*, 5464373. [CrossRef]
7. Lim, S.S.; Vos, T.; Flaxman, A.D.; Danaei, G.; Shibuya, K.; Adair-Rohani, H.; AlMazroa, M.A.; Amann, M.; Anderson, H.R.; Andrews, K.G. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the Global Burden of Disease Study 2010. *Lancet* **2012**, *380*, 2224–2260. [CrossRef] [PubMed]
8. Omotayo, A.O. Data on the agricultural household's dietary diversity and health in the South West geopolitical zone of Nigeria. *Data Brief* **2020**, *30*, 105413. [CrossRef] [PubMed]
9. Popkin, B.M.; Slining, M. New dynamics in global obesity facing low-and middle-income countries. *Obes. Rev.* **2013**, *14*, 11–20. [CrossRef] [PubMed]
10. Sibhatu, K.T.; Krishna, V.V.; Qaim, M. Production diversity and dietary diversity in smallholder farm households. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 10657–10662. [CrossRef]
11. Kennedy, G.; Moursi, M. *Dietary Diversity and Biofortification: Closer than You Think*; IFPRI: Washington, DC, USA, 2015.
12. Devi, S. Humanitarian need in 2022. *Lancet* **2022**, *399*, 132–133. [CrossRef]
13. Cassimon, D.; Fadare, O.; Mavrotas, G. Development finance, governance quality and their impact on food and nutrition security in Sub-Saharan Africa. *Rev. Dev. Financ.* **2021**, *11*, 1–17.
14. Cassimon, D.; Fadare, O.; Mavrotas, G. The combined effect of institutional quality and capital flows on food and nutrition security and undernourishment in Sub-Saharan Africa. *PLoS ONE* **2022**, *17*, e0275345. [CrossRef] [PubMed]
15. Ogunniyi, A.I.; Mavrotas, G.; Olagunju, K.O.; Fadare, O.; Adedoyin, R. Governance quality, remittances and their implications for food and nutrition security in Sub-Saharan Africa. *World Dev.* **2020**, *127*, 104752. [CrossRef]
16. Ben Hassen, T.; El Bilali, H. Impacts of the Russia-Ukraine war on global food security: Towards more sustainable and resilient food systems? *Foods* **2022**, *11*, 2301. [CrossRef]
17. Harvey, C.A.; Rakotobe, Z.L.; Rao, N.S.; Dave, R.; Razafimahatratra, H.; Rabarijohn, R.H.; Rajaofara, H.; MacKinnon, J.L. Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philos. Trans. R. Soc. B Biol. Sci.* **2014**, *369*, 20130089. [CrossRef]
18. Keding, G.B.; Schneider, K.; Jordan, I. Production and processing of foods as core aspects of nutrition-sensitive agriculture and sustainable diets. *Food Secur.* **2013**, *5*, 825–846. [CrossRef]
19. Mogge, M.; Sonntag, A. Without Land, No Crops-without Diversity, No Healthy and Sustainable Diets. In *Hidden Hunger: Strategies to Improve Nutrition Quality*; Karger Publishers: Basel, Switzerland, 2018; Volume 118, pp. 57–64.
20. Allen, S.; De Brauw, A. Nutrition sensitive value chains: Theory, progress, and open questions. *Glob. Food Secur.* **2018**, *16*, 22–28. [CrossRef]
21. Matshe, I. Boosting smallholder production for food security: Some approaches and evidence from studies in sub-Saharan Africa. *Agrekon* **2009**, *48*, 483–511. [CrossRef]
22. Crush, J.S.; Frayne, G.B. Urban food insecurity and the new international food security agenda. *Dev. South. Afr.* **2011**, *28*, 527–544. [CrossRef]
23. Pinstrup-Andersen, P. Agricultural research and policy for better health and nutrition in developing countries: A food systems approach. *Agric. Econ.* **2007**, *37*, 187–198. [CrossRef]
24. Palmioli, L.; Grando, S.; Di Iacovo, F.; Fastelli, L.; Galli, F.; Prosperi, P.; Rovai, M.; Brunori, G. Small farms' strategies between self-provision and socio-economic integration: Effects on food system capacity to provide food and nutrition security. *Local Environ.* **2020**, *25*, 43–56. [CrossRef]
25. Sibhatu, K.T.; Qaim, M. Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* **2018**, *77*, 1–18. [CrossRef]
26. Powell, B.; Thilsted, S.H.; Ickowitz, A.; Termote, C.; Sunderland, T.; Herforth, A. Improving diets with wild and cultivated biodiversity from across the landscape. *Food Secur.* **2015**, *7*, 535–554. [CrossRef]
27. Pellegrini, L.; Tasciotti, L. Crop diversification, dietary diversity and agricultural income: Empirical evidence from eight developing countries. *Can. J. Dev. Stud./Rev. Can. D'études Développement* **2014**, *35*, 211–227. [CrossRef]
28. Snapp, S.S.; Fisher, M. "Filling the maize basket" supports crop diversity and quality of household diet in Malawi. *Food Secur.* **2015**, *7*, 83–96. [CrossRef]

29. Frelat, R.; Lopez-Ridaura, S.; Giller, K.E.; Herrero, M.; Douxchamps, S.; Djurfeldt, A.A.; Erenstein, O.; Henderson, B.; Kassie, M.; Paul, B.K. Drivers of household food availability in sub-Saharan Africa based on big data from small farms. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 458–463. [CrossRef]
30. Qureshi, M.E.; Dixon, J.; Wood, M. Public policies for improving food and nutrition security at different scales. *Food Secur.* **2015**, *7*, 393–403. [CrossRef]
31. Benson, T.D. *Improving Nutrition as a Development Priority: Addressing Undernutrition within National Policy Processes in Sub-Saharan Africa*; International Food Policy Research Institute: Washington, DC, USA, 2008; Volume 156.
32. Waltner-Toews, D.; Lang, T. A new conceptual base for food and agricultural policy: The emerging model of links between agriculture, food, health, environment and society. *Glob. Chang. Hum. Health* **2000**, *1*, 116–130. [CrossRef]
33. Pingali, P. Agricultural policy and nutrition outcomes–getting beyond the preoccupation with staple grains. *Food Secur.* **2015**, *7*, 583–591. [CrossRef]
34. Khoury, C.K.; Bjorkman, A.D.; Dempewolf, H.; Ramirez-Villegas, J.; Guarino, L.; Jarvis, A.; Rieseberg, L.H.; Struik, P.C. Increasing homogeneity in global food supplies and the implications for food security. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 4001–4006. [CrossRef]
35. Jacobsen, S.-E.; Sørensen, M.; Pedersen, S.M.; Weiner, J. Feeding the world: Genetically modified crops versus agricultural biodiversity. *Agron. Sustain. Dev.* **2013**, *33*, 651–662. [CrossRef]
36. Nnadi, F.; Chikaire, J.; Echetama, J.; Ihenacho, R.; Umunnakwe, P.; Utazi, C. Agricultural insurance: A strategic tool for climate change adaptation in the agricultural sector. *Net, J. Agric. Sci.* **2013**, *1*, 1–9.
37. Daud, A.S.; Awotide, B.A.; Omotayo, A.O.; Omotoso, A.T.; Adeniyi, A.B. Effect of income diversification on household's income in rural Oyo State, Nigeria. *Acta Univ. Danubius. Acon.* **2018**, *14*, 155–167.
38. Omotoso, A.B.; Daud, S.A.; Okojie, L.; Omotayo, A.O. Rural infrastructure and production efficiency of food crop farmers: Implication for rural development in Nigeria. *Afr. J. Sci. Technol. Innov. Dev.* **2022**, *14*, 197–203. [CrossRef]
39. Eckhardt, C.L. *Micronutrient Malnutrition, Obesity, and Chronic Disease in Countries Undergoing the Nutrition Transition: Potential Links and Program/Policy Implications*; International Food Policy Research Institute: Washington, DC, USA, 2006.
40. M'Kaibi, F.K.; Steyn, N.P.; Ochola, S.; Du Plessis, L. Effects of agricultural biodiversity and seasonal rain on dietary adequacy and household food security in rural areas of Kenya. *BMC Public Health* **2015**, *15*, 1–11. [CrossRef]
41. Kerr, R.B.; Berti, P.R.; Shumba, L. Effects of a participatory agriculture and nutrition education project on child growth in northern Malawi. *Public Health Nutr.* **2011**, *14*, 1466–1472. [CrossRef]
42. Savy, M.; Martin-Prével, Y.; Traissac, P.; Eymard-Duvernay, S.; Delpeuch, F. Dietary diversity scores and nutritional status of women change during the seasonal food shortage in rural Burkina Faso. *J. Nutr.* **2006**, *136*, 2625–2632. [CrossRef]
43. Steyn, N.P.; Nel, J.H.; Nantel, G.; Kennedy, G.; Labadarios, D. Food variety and dietary diversity scores in children: Are they good indicators of dietary adequacy? *Public Health Nutr.* **2006**, *9*, 644–650. [CrossRef]
44. Herforth, A.; Ahmed, S. The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. *Food Secur.* **2015**, *7*, 505–520. [CrossRef]
45. Bowman, M.S.; Zilberman, D. Economic factors affecting diversified farming systems. *Ecol. Soc.* **2013**, *18*. [CrossRef]
46. Verger, E.O.; Dop, M.-C.; Martin-Prével, Y. Not all dietary diversity scores can legitimately be interpreted as proxies of diet quality. *Public Health Nutr.* **2017**, *20*, 2067–2068. [CrossRef]
47. Covic, N.; Hendriks, S. Introduction: The road to healthier diets and optimal nutrition. In *Achieving a Nutrition Revolution for Africa: The Road to Healthier Diets and Optimal Nutrition*; ReSAKSS Annual Trends and Outlook Report; The International Food Policy Research Institute: Washington, DC, USA, 2016; pp. 1–5.
48. Gashu, D.; Demment, M.W.; Stoecker, B.J. Challenges and opportunities to the African agriculture and food systems. *Afr. J. Food Agric. Nutr. Dev.* **2019**, *19*, 14190–14217. [CrossRef]
49. Raymond, J.; Kassim, N.; Rose, J.W.; Agaba, M. Context-specific food-based approach for ensuring nutrition security in developing countries: A review. *Int. J. Food Sci. Nutr.* **2018**, *69*, 410–416. [CrossRef] [PubMed]
50. IFPRI. *Global Nutrition Report*; IFPRI: Washington, DC, USA, 2015.
51. Ani, K.J.; Nnanwube, E.F.; Ojakorotu, V. Agriculture, oil-resource curse and conflict: An assessment of the Nigerian development quagmire. *Afr. Renaiss.* **2018**, *15*, 49–66.
52. Nchuchuwe, F.F.; Adejuwon, K.D. The challenges of agriculture and rural development in Africa: The case of Nigeria. *Int. J. Acad. Res. Progress. Educ. Dev.* **2012**, *1*, 45–61.
53. Akinyele, I.O. *Ensuring Food and Nutrition Security in Rural Nigeria: An Assessment of the Challenges, Information Needs, and Analytical Capacity*; IFPRI: Washington, DC, USA, 2009.
54. Atoloye, A.T.; Ogunba, B.O.; Samuel, F. Spatial pattern of household food insecurity and childhood malnutrition in Akinyele local government area, Nigeria. *Int. J. Health Sci.* **2015**, *3*, 235–250.
55. Matemilola, S. The challenges of food security in Nigeria. *Open Access Libr. J.* **2017**, *4*, 1. [CrossRef]
56. Thompson, B.; Meerman, J. Narrowing the nutrition gap: Investing in agriculture to improve dietary diversity. In Proceedings of the International Symposium on Food and Nutrition Security: Foodbased Approaches for Improving Diets and Raising Levels of Nutrition; FAO: Rome, Italy, 2010; pp. 7–9.
57. Pellegrini, L.; Tasciotti, L. Rural electrification now and then: Comparing contemporary challenges in developing countries to the USA's experience in retrospect. *Forum Dev. Stud.* **2013**, *40*, 153–176. [CrossRef]

58. Smale, D.A.; Burrows, M.T.; Moore, P.; O'Connor, N.; Hawkins, S.J. Threats and knowledge gaps for ecosystem services provided by kelp forests: A northeast A tlantic perspective. *Ecol. Evol.* **2013**, *3*, 4016–4038. [CrossRef]
59. Remans, R.; Wood, S.A.; Saha, N.; Anderman, T.L.; DeFries, R.S. Measuring nutritional diversity of national food supplies. *Glob. Food Secur.* **2014**, *3*, 174–182. [CrossRef]
60. Herforth, A.; Harris, J. *Understanding and Applying Primary Pathways and Principles*; IFPRI: Washington, DC, USA, 2014.
61. Jones, A.D.; Shrinivas, A.; Bezner-Kerr, R. Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. *Food Policy* **2014**, *46*, 1–12. [CrossRef]
62. Ochieng, J.; Afari-Sefa, V.; Lukumay, P.J.; Dubois, T. Determinants of dietary diversity and the potential role of men in improving household nutrition in Tanzania. *PLoS ONE* **2017**, *12*, e0189022. [CrossRef]
63. Rajendran, S.; Afari-Sefa, V.; Shee, A.; Bocher, T.; Bekunda, M.; Lukumay, P.J. Does crop diversity contribute to dietary diversity? Evidence from integration of vegetables into maize-based farming systems. *Agric. Food Secur.* **2017**, *6*, 1–13. [CrossRef]
64. Habtemariam, L.T.; Gornott, C.; Hoffmann, H.; Sieber, S. Farm production diversity and household dietary diversity: Panel data evidence from rural households in Tanzania. *Front. Sustain. Food Syst.* **2021**, *5*, 151. [CrossRef]
65. Kassie, M.; Fisher, M.; Muricho, G.; Diiro, G. Women's empowerment boosts the gains in dietary diversity from agricultural technology adoption in rural Kenya. *Food Policy* **2020**, *95*, 101957. [CrossRef]
66. Tsiboe, F.; Zereyesus, Y.A.; Osei, E. Non-farm work, food poverty, and nutrient availability in northern Ghana. *J. Rural. Stud.* **2016**, *47*, 97–107. [CrossRef]
67. Dzanku, F.M. Food security in rural sub-Saharan Africa: Exploring the nexus between gender, geography and off-farm employment. *World Dev.* **2019**, *113*, 26–43. [CrossRef]
68. Bellon, M.R.; Kotu, B.H.; Azzarri, C.; Caracciolo, F. To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Dev.* **2020**, *125*, 104682. [CrossRef]
69. Ogunniyi, A.; Omonona, B.; Abioye, O.; Olagunju, K. Impact of irrigation technology use on crop yield, crop income and household food security in Nigeria: A treatment effect approach. *AIMS Agric. Food* **2018**, *3*, 154–171.
70. Ruel, M.T.; Quisumbing, A.R.; Balagamwala, M. Nutrition-sensitive agriculture: What have we learned so far? *Glob. Food Secur.* **2018**, *17*, 128–153. [CrossRef]
71. Domènech, L. Improving irrigation access to combat food insecurity and undernutrition: A review. *Glob. Food Secur.* **2015**, *6*, 24–33. [CrossRef]
72. Mekonnen, D.A.; Talsma, E.F.; Trijsburg, L.; Linderhof, V.; Achterbosch, T.; Nijhuis, A.; Ruben, R.; Brouwer, I.D. Can household dietary diversity inform about nutrient adequacy? Lessons from a food systems analysis in Ethiopia. *Food Secur.* **2020**, *12*, 1367–1383. [CrossRef]
73. Timler, C.; Alvarez, S.; DeClerck, F.; Remans, R.; Raneri, J.; Carmona, N.E.; Mashingaidze, N.; Chatterjee, S.A.; Chiang, T.W.; Termote, C. Exploring solution spaces for nutrition-sensitive agriculture in Kenya and Vietnam. *Agric. Syst.* **2020**, *180*, 102774. [CrossRef]
74. Jones, A.D. Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low-and middle-income countries. *Nutr. Rev.* **2017**, *75*, 769–782. [CrossRef] [PubMed]
75. Zezza, A.; Tasciotti, L. Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. *Food Policy* **2010**, *35*, 265–273. [CrossRef]
76. Dillon, A.; McGee, K.; Oseni, G. Agricultural production, dietary diversity and climate variability. *J. Dev. Stud.* **2015**, *51*, 976–995. [CrossRef]
77. Mulmi, P.; Masters, W.A.; Ghosh, S.; Namirembe, G.; Rajbhandary, R.; Manohar, S.; Shrestha, B.; West, K.P.; Webb, P. Household food production is positively associated with dietary diversity and intake of nutrient-dense foods for older preschool children in poorer families: Results from a nationally-representative survey in Nepal. *PLoS ONE* **2017**, *12*, e0186765. [CrossRef] [PubMed]
78. Sibhatu, K.T.; Qaim, M. Farm production diversity and dietary quality: Linkages and measurement issues. *Food Secur.* **2018**, *10*, 47–59. [CrossRef]
79. Chiputwa, B.; Qaim, M. Sustainability standards, gender, and nutrition among smallholder farmers in Uganda. *J. Dev. Stud.* **2016**, *52*, 1241–1257. [CrossRef]
80. Fischer, E.; Qaim, M. Gender, agricultural commercialization, and collective action in Kenya. *Food Secur.* **2012**, *4*, 441–453. [CrossRef]
81. Babatunde, R.; Omotesho, O.; Sholotan, O. Factors influencing food security status of rural farming households in North Central Nigeria. *Agric. J.* **2007**, *2*, 351–357.
82. Fadare, O.; Amare, M.; Mavrotas, G.; Akerele, D.; Ogunniyi, A. Mother's nutrition-related knowledge and child nutrition outcomes: Empirical evidence from Nigeria. *PLoS ONE* **2019**, *14*, e0212775.
83. Amare, M.; Arndt, C.; Mahrt, K.; Mavrotas, G. Polygynous family structure and child undernutrition in Nigeria. *J. Dev. Stud.* **2021**, *57*, 1640–1661. [CrossRef]
84. Zezza, A.; Tasciotti, L. *Does Urban Agriculture Enhance Dietary Diversity? Empirical Evidence from a Sample of Developing Countries*; FAO: Rome, Italy, 2008.
85. Ogundari, K. Categorizing households into different food security states in Nigeria: The socio-economic and demographic determinants. *Agric. Food Econ.* **2017**, *5*, 1–20. [CrossRef]

86. Jones, B.A.; Madden, G.J.; Wengreen, H.J. The FIT Game: Preliminary evaluation of a gamification approach to increasing fruit and vegetable consumption in school. *Prev. Med.* **2014**, *68*, 76–79. [CrossRef] [PubMed]
87. Swindale, A.; Bilinsky, P. Development of a universally applicable household food insecurity measurement tool: Process, current status, and outstanding issues. *J. Nutr.* **2006**, *136*, 1449S–1452S. [CrossRef]
88. Kavitha, K.; Soumitra, P.; Padmaja, R. Understanding the linkages between crop diversity and household dietary diversity in the semi-arid regions of India. *Agric. Econ. Res. Rev.* **2016**, *29*, 129–137. [CrossRef]
89. Tesfaye, W.; Tirivayi, N. Crop diversity, household welfare and consumption smoothing under risk: Evidence from rural Uganda. *World Dev.* **2020**, *125*, 104686. [CrossRef]
90. Herforth, A. *Promotion of Traditional African Vegetables in Kenya and Tanzania: A Case Study of an Intervention Representing Emerging Imperatives in Global Nutrition*; Cornell University: Ithaca, NY, USA, 2010.
91. Hawksworth, D.L. *Biodiversity: Measurement and Estimation*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 1995; Volume 345.
92. Smale, S.T. Core promoters: Active contributors to combinatorial gene regulation. *Genes Dev.* **2001**, *15*, 2503–2508. [CrossRef]
93. Omotayo, A.O.; Aremu, A.O. Evaluation of factors influencing the inclusion of indigenous plants for food security among rural households in the North West Province of South Africa. *Sustainability* **2020**, *12*, 9562. [CrossRef]
94. Bravo-Ureta, B.E.; Greene, W.; Solís, D. Technical efficiency analysis correcting for biases from observed and unobserved variables: An application to a natural resource management project. *Empir. Econ.* **2012**, *43*, 55–72. [CrossRef]
95. Cameron, A.C.; Trivedi, P.K. *Regression Analysis of Count Data*; Cambridge University Press: Cambridge, UK, 2013; Volume 53.
96. Signorelli, S.; Haile, B.; Kotu, B. *Exploring the Agriculture-Nutrition Linkage in Northern Ghana*; IFPRI: Washington, DC, USA, 2017.
97. Musyoka, M.; Kavoi, M.M.; Omiti, J. Food consumption patterns and distributional welfare impact of import tariff reduction on cereals in Kenya. *Afr. J. Agric. Resour. Econ.* **2014**, *9*, 183–199.
98. Torres, M.J. *The Impact of Food Price Shocks on Consumption and Nutritional Patterns of Urban Mexican Households*; Working Papers; Econstor: Kiel, Germany, 2015.
99. Yawson, D.O.; Mulholland, B.J.; Ball, T.; Adu, M.O.; Mohan, S.; White, P.J. Effect of climate and agricultural land use changes on UK feed barley production and food security to the 2050s. *Land* **2017**, *6*, 74. [CrossRef]
100. Adebayo, O.; Olagunju, K.; Kabir, S.K.; Adeyemi, O. Social crisis, terrorism and food poverty dynamics: Evidence from Northern Nigeria. *Int. J. Econ. Financ. Issues* **2016**, *6*, 1865–1872.
101. Abubakar, I.R. Predictors of inequalities in land ownership among Nigerian households: Implications for sustainable development. *Land Use Policy* **2021**, *101*, 105194. [CrossRef]
102. Greene, W.H. *Econometric Analysis*; Pearson education Ltd.: London, UK, 2012.
103. Mannaf, M.; Uddin, M.T. Socioeconomic factors influencing food security status of miaze growing households in selected areas of Bogra district. *Bangladesh J. Agric. Econ.* **2012**, *35*, 177–187.
104. Esturk, O.; Oren, M.N. Impact of household socio-economic factors on food security: Case of Adana. *Pak. J. Nutr.* **2014**, *13*, 1–6. [CrossRef]
105. Koppmair, S.; Kassie, M.; Qaim, M. Farm production, market access and dietary diversity in Malawi. *Public Health Nutr.* **2017**, *20*, 325–335. [CrossRef]
106. Khattak, U.K.; Iqbal, S.P.; Ghazanfar, H. The role of parents' literacy in malnutrition of children under the age of five years in a semi-urban community of pakistan: A case-control study. *Cureus* **2017**, *9*, e1316. [CrossRef]
107. Lule, S.A.; Namara, B.; Akurut, H.; Muhangi, L.; Lubyayi, L.; Nampijja, M.; Akello, F.; Tumusiime, J.; Aujo, J.C.; Oduru, G. Are birthweight and postnatal weight gain in childhood associated with blood pressure in early adolescence? Results from a Ugandan birth cohort. *Int. J. Epidemiol.* **2019**, *48*, 148–156. [CrossRef]
108. Melku, M.; Takele, W.W.; Anlay, D.Z.; Ekubagewargies, D.T.; Getaneh, Z.; Abebe, M.; Abebe, Z. Male and undernourished children were at high risk of anemia in Ethiopia: A systematic review and meta-analysis. *Ital. J. Pediatr.* **2018**, *44*, 1–11. [CrossRef]
109. Wambogo, E.A.; Ghattas, H.; Leonard, K.L.; Sahyoun, N.R. Validity of the Food Insecurity Experience Scale (FIES) for use in Sub-Saharan Africa (SSA) and characteristics of food insecure individuals. *Curr. Dev. Nutr.* **2018**, *2*, nzy062. [CrossRef] [PubMed]