Agricultural Production Diversity and Market Access: Implications for Dietary Diversity among Smallholder Farm Households in Cameroon

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Abstract

Overnutrition, overweight, and obesity as consequences of nutrition transition are a growing concern of public policy in less developed countries, where it poses a triple burden even to rural areas battling with undernutrition and micronutrient deficiencies. The complex link between agriculture and nutritional outcomes has been well established. However, studies often overlook key socio-cultural dimensions of nutrition outcomes in the context of the nutrition transition and the increasing triple burden of malnutrition in rural agricultural communities. This study seeks to investigate the implications of agricultural production diversity on dietary diversity in rural smallholder farm households. We hypothesize that in addition to the contribution of production diversity and the mediating role of market access, socio-cultural factors have a significant influence on household dietary diversity and quality. Data was obtained from a cross-sectional survey of smallholder farm households in the Southwest Region, Cameroon, from 2018 to 2019. The effect of agricultural production diversity and better market access was estimated to be positive using both Generalised Poisson regression and Instrumental Variable two Stage Least Square or Instrumental Variable Poisson models. While better market access plays a positive and significant role in nutrition security and diet quality for smallholder farm households, we found that agricultural production diversity has a greater positive effect on diet outcomes than market access. Similarly, households with women empowerment indicators and better knowledge on nutrition were associated with better diet outcomes. We found a greater proportion of households with unfavourable attitudes relating to socio-cultural norms and perception. We posit that agricultural and food policies and investments should adopt an integrated approach that aligns with societal and cultural needs in promoting market access and encouraging more nutritious food choices to effectively and sustainably tackle challenges to poor nutrition. However, longitudinal studies are essential and will provide rigour on the role agricultural production diversity plays in the nutritional and health status of rural households in Cameroon.

Keywords: *Agricultural production diversity, dietary diversity, Market access, smallholder farm households, food consumption*

1. Introduction

Malnutrition linked to poor diet quality remains the leading cause of ill-health and death in less developed countries (Afshin et al., 2019). The Sustainable Development Goal (SDG) 2 emphasises to “end hunger, achieve food security and improved nutrition and promote sustainable agriculture by 2030” (FAO, 2013b; Gliessman, 2015; United Nations, 2017). In sub-Saharan Africa (SSA) smallholder farmers and households are disproportionately affected by the disease and economic burden associated with food insecurity and malnutrition, leading to significant losses of human capital and productivity (Hoddinott, 2016). Paradoxically, of the 2.5 billion people in emerging countries who depend on the agriculture sector for food and livelihood (FAO et al., 2017, Sekabira & Nalunga, 2020), 1.5 billion of them live in rural smallholder farmers’ households (FAO, 2012), where subsistence farm production is predominant (FAO, 2017). Annually, African economies incur malnutrition costs of 3 - 16 percent of GDP, along with substantial human capital losses (Hoddinott, 2017). In Cameroon, the annual economic cost of malnutrition is approximately 354 billion Central African Francs (CFA) (UNICEF, 2014). Addressing these challenges requires a multifaceted approach, where diet diversification is crucial in combating the triple burden of malnutrition (IFPRI, 2015).

Agriculture is essential for feeding the world’s population of over 7.7 billion people. Despite significant advancements in agricultural production, food and nutrition insecurity persist, particularly for smallholder farmers and households. (FAO, 2017; UN, 2019). The agricultural sector plays a key role in Cameroon’s economy, employing around 50 percent of the economically active population and contributing an estimated 22.3 percent to GDP (IFAD, 2015). Since 1999, the Government of Cameroon’s Agricultural Policy and Rural Sector Development Strategy has promoted agricultural growth to improve food security, farm income, and the livelihoods of vulnerable rural populations (Achancho, 2013). These policies have primarily assumed that increasing the production of selected biofortified crops such as maize, Irish potatoes, sweet potatoes, and cassava, and livestock like pigs and poultry, based on various agro-ecological zones, will result in lower food prices, improve access to food, and enhance nutrition. However, despite the abundance of food produced by agricultural communities, their diets remain monotonous and staple-based, with significant deficiencies in micronutrients. This issue is not unique to Cameroon; similar dietary patterns have been reported in other parts of Africa and Asia (FAO, 2018). These simplified diets, coupled with post-harvest losses of nutrient-rich vegetables and fruits, contribute to the stunting of children and leave smallholder farm households among the most malnourished populations in Cameroon (FAO, 2013a). The shift towards urban feeding styles, societal norms, cultural perceptions of body size, market conditions, and the information environment is driving a nutrition transition in Cameroon. This shift has led to the deterioration of traditional food systems in rural areas, as communities move from subsistence farming to a cash-based economy (Sneyd, 2014). This nutrition transition has resulted in a triple burden for rural areas, which now face undernutrition, micronutrient deficiencies, and growing non-communicable diseases (NCDs). Few studies have explored the sociocultural factors that influence diet outcomes during this transition. Despite progress in health and agricultural investments, food and nutrition insecurity issues persist as severe challenges for rural households. Studies on agriculture, nutrition, and health have rarely focused on small-scale farmers. There is limited literature examining the relationship between smallholder farm production diversity and household diet diversity in Cameroon.

Recently, attention has shifted from health to the agricultural sector, as it is best positioned to address crucial determinants of malnutrition, such as dietary diversity (De Schutter, 2012; Noack & Pouw, 2015; Headey & Hoddinott, 2016). Research and policy in agricultural systems suggest that diversified agriculture provides poor communities and households with access to a variety of foods, thereby improving the diversity and quality of diet (Herforth, 2011; Pingali, Ricketts, & Sahn, 2014). Furthermore, diversified agriculture is proposed as a solution to persistent malnutrition and for decreasing the vulnerabilities of these rural households to climate shocks (FAO, 2015). Agriculture-focused actions that are appropriately linked to nutrition can improve incomes, increase the consumption of nutritious foods, and enhance agricultural growth (Arimond et al., 2010). This is the fundamental assumption of nutrition-sensitive agriculture (NSA), an approach that promotes dietary diversity to reduce all forms of malnutrition and is recommended for state policy investments (FAO, 2017). The pathways through which agriculture contributes to nutritional outcomes are complex. Theoretical and empirical literature acknowledges the intricate linkages between agriculture and nutrition (Gillespie et al., 2012; Haddad et al., 2017; Hawkes, 2006; Herforth & Harris, 2014; Jones et al., 2014). One significant pathway is the "own-production pathway," where households produce food for their consumption. It is hypothesized that production choices directly improve the diversity and quality of food throughout the year (Behrman, 1997; LaFave & Thomas, 2014). The second pathway suggests that market access mediates these linkages. In another significant pathway, the level of a woman's involvement in production and consumption decisions influences the role of agriculture in nutritional outcomes for households.

The relationship between agriculture and nutrition extends beyond the agroecosystem, food market and the environment to include the sociocultural context of the household (Herforth & Harris, 2014). Smallholder farm households, like other consumers, are influenced by sociocultural factors in food consumption choices. These include knowledge and awareness of the nutritional value of different foods, beliefs about the health benefits of specific products, and their preferences for certain foods (Herforth, 2015). While shaping smallholder farm production choices for increased agricultural growth will improve food accessibility and availability, it may not always yield the expected nutritional outcomes, as sociocultural factors have a significant influence on decisions regarding consumption and nutrition (Fanzo, Hunter, Borelli, & Mattei, 2013). Empirical literature has largely emphasized the role of agricultural production and markets in diet diversity for the smallholder farm household. Even though the confounding effects of socio-demographic factors are often considered, we contend that the social dimension is frequently reduced to income and occupation (socio-economic), which undermines the socio-cultural factors related to food utilisation that contribute to poor nutrition outcomes. This is an important nuance that is largely missing in research and policy debates on agriculture and nutrition (Noack & Pouw, 2015b). Achieving improved nutrition requires attention not only to the availability of diverse and nutritious foods but also to the sociocultural norms and perceptions that determine nutrition and health outcomes.

The Cameroon Comprehensive Food Security and Vulnerability Analysis of 2017, reports that about 90 percent of the population of the Southwest region can be considered food secure (World Food Programme, 2017; Sneyd, 2013). A striking characteristic of the Southwest region of Cameroon is that more than 80 percent of the villages in this region depend on agriculture. Given the current trend of nutritional transition, investigating whether agricultural production policies translate to nutritional security for this agriculture-dominant, yet disproportionately nutrition-vulnerable population is a key motivation for this study. Mukete and Kato (2014) observed that the Fako Division of the Southwest region is characterized by significant heterogeneity, leading to diverse preferences for the production and consumption of specific food crops among both indigenous and non-indigenous communities. They also note that the supply and demand for certain foods within any locality in the study area are governed by the cultural background of the inhabitants about the concept of the traditional meal, structural biases and ideological perceptions around food. Therefore, it is essential to consider these sociocultural drivers of household food consumption patterns while examining the effects of agricultural production diversity and the supporting role of market access on household dietary diversity in this region of Cameroon. This study focuses on both the own-consumption and market access pathways through which agriculture influences nutrition. In examining the role of agricultural production diversity on diet outcomes, we look beyond socio-economic determinants to incorporate key sociocultural norms and perceptions including women's decision-making power in the household, knowledge of nutrition, diets and risk of overweight/obesity, food related perceptions and household preferences. We hypothesize that higher agricultural production diversity would lead to better food consumption patterns and diet outcomes for the smallholder farm households. We assume that although agricultural production largely contributes to farm households' consumption, sociocultural norms and perceptions significantly shape food consumption patterns, which have profound implications for nutrition outcomes in rural populations. Specifically, the study aims to 1) determine the effect of agricultural production diversity and market access on household diet outcomes in rural Cameroon; 2) examine whether market access mediates the effect of agricultural production diversity on household diet outcomes in rural Cameroon. Based on data obtained from a cross-section of smallholder farm households in rural Cameroon, we found that food group agricultural production diversity is low, crop–livestock production diversity is moderate, and household dietary diversity score is also moderate. Despite this moderate diversity, diet quality is low. This confirms that while the household dietary diversity scores assess the consumption of various food groups, they do not capture differences in the nutritional weights of those food groups. Food consumption scores consider both the frequency and nutritional weight of food intake to address the limitation that dietary diversity alone does not accurately reflect diet quality. Our empirical results show that agricultural production diversity and market access are positively associated with dietary outcomes in the rural smallholder farm households. Agricultural production diversity has a more significant effect on dietary diversity than market access does. We did not find any empirical significance in the interaction effect of market access on the link between agricultural production and dietary diversity outcomes. The woman's role in household decision-making and the head of household's level of knowledge in nutrition both correlate positively with diet diversity and quality in all regression estimations. Access to non-farm income is positively and significantly associated with household dietary diversity but not food consumption scores. The average income from the last farming season correlates positively with food consumption scores and not with household dietary diversity scores. Our findings confirm the heterogeneity of factors influencing the nonlinearity of the link between agriculture and nutrition. We contribute to the existing literature by highlighting the role of agricultural production diversity in dietary diversity in Cameroon. Additionally, we expand the understanding of the role of markets in diet outcomes across varying levels of agricultural production diversity among farm households. We also advance the evidence based on the potential effects of national agricultural policies on improving dietary diversity and nutrition security of rural farm households. We argue that sociocultural influences on diet outcomes have implications for agricultural and food policies, and therefore these policies should be paralleled to society and culture to tackle challenges to poor nutrition effectively and sustainably. We suggest that current policies and innovations should reconsider agricultural production diversity as part of integrated approaches that promote market access and encourage households to make more nutritious food choices, thereby upholding high-quality diets, reducing malnutrition-related social and economic costs, and improving the productivity of vulnerable farming populations. Examining these contextual factors at the farm-household level could inform nutrition-sensitive agricultural policies and programs for positive nutritional outcomes.

The following sections of the paper are organized as follows: Sections 2 and 3: Empirical evidence and Theoretical Framework, which provides a comprehensive review of the relevant literature on the agriculture-nutrition nexus, with a particular focus on the role of agricultural production diversity and market access in influencing dietary diversity. It also presents the theoretical framework guiding the study, drawing on the agricultural household model and other relevant theories.

Sections 4,5, and 6 focus on Data and Methodology and outline the research design, data collection methods, and analytical approaches used in the study. It details the sampling procedure, the construction of key variables, and the econometric models employed to estimate the effects of agricultural production diversity and market access on dietary outcomes. Sections 7 and 8 capture the Results and Discussion by presenting the empirical findings of the study, including descriptive statistics and econometric results. It discusses the implications of these findings in the context of existing literature and highlights the significance of agricultural production diversity and market access in shaping dietary diversity and diet quality among smallholder farm households. The final section summarizes the key findings and discusses their policy implications. It emphasizes the need for nutrition-sensitive agricultural policies that integrate socio-cultural factors, promote market access, and encourage diverse and healthy food choices to improve diet outcomes and address malnutrition in rural Cameroon

2. Empirical evidence

In developing countries, smallholder farmers produce at least 70% of the energy-rich foods required to address hunger (FAO, 2015). Despite their crucial role in the food system, they remain among the most malnourished and disadvantaged in terms of health outcomes linked to dietary diversity (IFPRI, 2016; Pingali et al., 2014). This paradox underscores the need to prioritize smallholders in agricultural innovations aimed at enhancing production, improving diets, and uplifting livelihoods (IFAD & UNEP, 2013). Dietary diversity—a reflection of a healthy diet—is defined as "the consumption of several different food groups or foods by a household or an individual over a distinct time frame" (Ruel, 2003; Pingali, et al., 2005). It is widely accepted that only diets that correlate with greater dietary diversity can effectively reduce malnutrition (Steyn & Mchiza, 2014; Muhammad-Lawal et al., 2017). Research has shown that rural households often consume diets high in empty calories to satisfy hunger, (Darmon & Drewnowski, 2015; Perignon et al., 2017) lacking adequate animal-source foods (Muhammed–Lawal et al., 2017). This pattern is closely linked to subsistence farming practices (FAO, 2015). Dietary diversity scores, which quantify diversity in diets, are significantly associated with nutritional and health outcomes. For example, in Mali and Burkina Faso, dietary diversity scores were positively related to women's mean adequacy ratio (Torheim et al., 2004) and their anthropometric outcomes(Savy et al., 2007). Similarly, dietary diversity scores have been found to have a significant positive relationship with children's nutrient adequacy and anthropometric outcomes in several other developing countries (Arimond & Ruel, 2004; Hirvonen, Hoddinott et al., 2017; Jones et al., 2014; Onyeneke et al., 2019). Studies in Nigeria (Muhammad-Lawal et al., 2017), Zimbabwe (Murendo et al., 2018)and Ethiopia (Hirvonen & Wolle, 2019) have linked household dietary diversity scores to household nutritional status.

Farm production diversity has the potential to improve food security and mitigate the effects of income inequalities, leading to better nutritional outcomes among smallholder households (Jones et al., 2014; The World Bank, 2008) and at the community level (Herforth, 2011; Pingali et al., 2014). Data from studies in Ghana, Kenya, Tanzania, Malawi, and Ethiopia have revealed a positive association between production diversity and nutrition outcomes in smallholder farmers' households (Hirvonen & Hoddinott, 2017; Jones et al., 2014; Romeo et al., 2016; Saaka et al., 2017; Sibhatu et al., 2015a), even when the effects of other explanatory variables and covariates linked to nutrition are controlled (Jones et al., 2014; Sibhatu et al., 2015). However, Koppmair (2016) and Sibhatu et al. (2015) found that further increasing production diversity may not be the most effective way to improve diets in smallholder farm households.

A growing number of studies argue that market access significantly influences the diets of smallholder farm households. (Berti, 2015; Jones et al., 2014; Koppmair, Kassie, & Qaim, 2017; Remans et al., 2015; Remans et al., 2019; Sibhatu & Qaim, 2017; Sekabira & Nalunga, 2020). Sibhatu et al. (2015), claim that market access is more important than production diversity in enhancing dietary diversity, based on the size of the coefficients of both explanatory variables. They argue that policies to improve market access should receive greater attention. Since smallholder farm households often buy more food than they produce, their access to a diverse and quality diet depends on income and consumer markets. This suggests the importance of an alternative pathway to the own-consumption model, even for subsistence-oriented farm households. Koppmair et. al. (2015), using data from Malawi, provide evidence that market food transactions (buying and selling) have a relatively larger impact on diet diversity than producing a more diverse set of foods. Conversely, Kissoly et al., (2018) observed that farm production diversity plays a lesser role in household food consumption diversity in contexts with better agro-ecological and market access features, such as in Tanzania. They argue that improving market access will not only enhance diets and address malnutrition but will also reduce poverty, which is at the center of malnutrition. (Remans et al. (2015) contend that improving market access may be challenging for many farming populations and rural settings and thus propose that maintaining production diversity is the most logical and strategic choice in some settings. This highlights the complexity of the agriculture-nutrition linkages, which requires a nuanced understanding.

The moderating effects of socio-cultural factors in the link between agricultural production diversity and dietary diversity have also been explored (Herforth & Ahmed, 2015). There is empirical evidence of an increasing trend of unhealthy food choices among agriculture-dominant communities in developing countries, often due to a lack of nutrition knowledge and misconceptions about healthy foods (Baral et al., 2021; Herforth, 2011; Kamga, 2013; Mirmiran et al., 2007; Murendo et al., 2018; Powell et al., 2015). Without adequate nutrition information or access to healthy food environments, consumers may opt for unhealthy diets driven by affordability, accessibility, and desirability. The change in consumer demand for African indigenous vegetables, resulting in increased production of these vegetables, has been documented in the literature (Muhanji et al., 2011; Murendo et al., 2018; Ngugi et al., 2006; Schippers, 2000; Singh et al., 2013). Using an instrumental variable approach, Hirvonen et al. (2017) found that greater dietary diversity among children was associated with better nutrition knowledge, particularly in areas with good market access. Similarly, Murendo et al. (2018), using negative binomial regression analysis, demonstrated the value of an integrated approach that complements the role of agricultural production diversity in dietary diversity. These studies highlight the potential of integrated approaches that educate, encourage, and improve access to markets for healthy diets. In another dimension, anthropological research from Cameroon by Cohen et al.(2018) and Cohen & Pasquet (2011), Senegal by (Duboz et al. (2017), and from Ghana by Duda et al.(2006, 2007) has revealed that obesity can be a deep-rooted status symbol embedded in cultural norms. A study in Botswana showed that in poorer communities, a "bigger female body may be considered good-looking and a sign of evolutionary fitness, with an increase in body fat equated with an increased potential to survive famine" (Kruger et al.,, 2020). Such anthropological local drivers of the social valorization of processed or high-calorie food and large body sizes could expose populations to obesity risk (Cohen *et al.,* 2015). In a related discourse, Akinpelu, Oyewole, and Adekanla, (2015), reported that among rural dwellers in Nigeria, a large proportion of participants could not accurately perceive their weight. These studies have unravelled the social and cultural processes that may contribute to the narrowing of the food plate at the household level and the food basket at the community level in rural Cameroon and other rural areas of sub-Saharan Africa (Noack and Poaw, 2015).

The social dynamics underlying the nutrition transition remain largely overlooked despite their potential to be addressed. Food and agricultural policy and research institutions continue to struggle with hypothesizing, measuring, and advancing programs that tackle the complexities of food and nutrition security in a socio-cultural context (FAO, 2012). The evolving landscape of diet-related chronic illnesses and the growing struggle with malnutrition across developing economies make it timely to understand the complex interrelatedness of the contextual characteristics of farms, agro-ecological zones, households, diets, and the socio-economic and cultural landscapes that shape household decisions around farm production and food consumption patterns (Arsenault et al., 2015; Bellon, et al., 2016; Ditzler et al., 2019; Estrada-Carmona et al., 2020; Haddad et al., 2017; Herforth & Ahmed, 2015; Remans et al., 2015). We contribute to the empirical literature by providing evidence on the social and cultural factors that enable the agriculture-nutrition nexus for better health outcomes in rural smallholder farm households. Research into agriculture-nutrition linkages often faces methodological challenges, including difficulties in establishing causality. The lack of agriculture-nutrition-health panel data across households often necessitates the use of cross-sectional data (Jones et al., 2014; Koppmair, Kassie & Qaim, 2017; Shively & Sununtnasuk, 2015), which requires rigorous methodologies to address heterogeneity and avoid biased estimates. However, concerns about heterogeneity are minimized in this study by including several control variables at the household and farm levels in our model. In addition to using OLS and Poisson estimators for robustness checks, this study applies an instrumental variable approach to account for the potential endogeneity of agricultural production diversity.

Demographic Health Surveys often capture data on diets but lack adequate information on agricultural production, limiting the availability of empirical evidence on agriculture-nutrition-health linkages, particularly in Cameroon. To address this limitation, we collect cross-sectional data on both production and consumption from the same households. Our study uses a household-level approach, which is increasingly recognized as essential for analyzing agricultural innovations (van Wijk et al., 2014). We infer the nutritional and health status of rural households using two measures of dietary diversity: the Household Dietary Diversity Score (HDDS) and the Household Food Consumption Score (FCS). The use of these two metrics allows us to capture the coexistence of undernutrition and overnutrition within households. The HDDS serves as a proxy for nutrient adequacy, assessing undernutrition-related risks, while the FCS, adapted from the WFP (2008), evaluates diet quality linked to overnutrition-related NCD risks at the household level.

3. The Conceptual Framework

The theoretical foundation of this study is rooted in the agricultural household model's assumption of utility maximization (Singh et al., 1986). In this model, the household operates both as a consumption unit, maximizing utility over consumption choices, and as a production unit, deciding how to allocate factors of production on the household farm. This framework also draws on the mutual dependence of agriculture and nutrition, a relationship extensively discussed in both theoretical and empirical literature (Gillespie et al., 2012; Herforth, 2015; Herforth & Harris, 2014; Jones et al., 2014; Ruel et al., 2017). The analysis seeks to understand whether a household's agricultural production decisions are separable from its food consumption preferences and resources. We conceptualize that agricultural production diversity is linked to dietary diversity through two pathways: In the own-production pathway, we hypothesize that agricultural production diversity correlates positively with household dietary diversity, especially in poor and rural settings. When households have limited market access or imperfect participation in markets, their production and consumption decisions become inseparable, leading to enhanced consumption of the food produced on the farm (Behrman, 1997; LaFave & Thomas, 2014). In this pathway, it is assumed that the household's production practices have the potential to directly improve the diversity and quality of food available throughout the year.

With the second pathway, the agricultural income – market effect pathway, agricultural production diversity is associated (positively or negatively) with dietary diversity through the purchase of foods when markets are functional. In this scenario, households can separate their production and consumption decisions when they have access to and can participate in markets. This access allows for a greater diversity of foods to be sold and purchased. In this pathway, the interaction between market functionality and the link between agricultural production diversity and dietary diversity adds complexity to this pathway. The agricultural household can generate income from selling diverse foods in markets, from wages earned through farm labor, non-farm employment, or income received as gifts. This income can then be used to purchase food, healthcare, education, and other household needs. As market access and participation opportunities increase, households might specialize in crops that are more marketable and profitable, choosing to purchase the foods they consume rather than producing them. This specialisation can lead to a decrease in agricultural production diversity, making the link between production diversity and dietary diversity less relevant. Meanwhile, the link between market access and dietary diversity becomes more significant.

Furthermore, the impact of both pathways on nutritional outcomes is influenced by enabling environment factors (Herforth & Harris, 2014), including trade opportunities, access to non-farm income, food–related socio-cultural norms, and preferences. Nutritional knowledge and other factors influence both the production and consumption decisions of the household. In this study, this conceptual model guides the analysis of how agricultural production influences consumption decisions and the nutritional status of smallholder farm households.

4. Data

The study uses cross-sectional data from smallholder farm households located in 12 villages spanning four subdivisions (Buea, Tiko, Muyuka, and West Coast) of Fako Division of Cameroon from a representative smallholder farm household survey obtained between October 2018 and May 2019 to encompass an agricultural production cycle or two harvesting seasons (September and May). The main population for our study is smallholder farmer households. We only consider rural households that primarily engage in agricultural activities because the study examines the relationship between agricultural production diversity and nutrition (dietary diversity).

Fako division is one of the five administrative units of the Southwest Region of Cameroon. This division is further divided into 5 Sub-Divisions which include Buea, Muyuka, Tiko, Limbe and West Coast/Idenau. Agriculture is the major economic activity in the Fako division. All the sub-divisions are of the same agroecological zone. According to village reports from the National Community Driven programme (PNDP) of 2017, farmers are involved in the cultivation of cocoa, tea, and palm oil. Plantains, bananas, cassava, cocoyam, tomatoes and vegetables are cultivated for subsistence. These types of food produced contribute to the overconsumption of starchy foods, palm oil and pork that characterize the typical feeding pattern of these communities. Farming practices are relatively less laborious due to the uniqueness of the soil type. The United Nations Environment Programme has long categorized the South West Region as one of the biodiversity hotspots of the country, amongst the South and East regions (Sneyd, 2014). The total number of farm households in the Southwest region is estimated at 141.000. As in most parts of the country, small farms dominate the types of farms in the region. The Regional Delegation of Agriculture and Rural Development, in Buea, report that about 45% of the farms in the region are between 0.5 to 1 hectare in size. A major feature of the villages is their limited resources such as land, skills and labor for farming **(World Bank's Rural Development Strategy, 2011).**

Table 1. Distribution of the samples in the Villages and Farm households

Sub – Division	Villages Selected	Population of Farm Households (N)*	Questionnaires Administered (n)
Buea	Lysoka	210	30
	Dibanda	322	50
	Tole	260	40
	Buea Total	**792**	**120**
West Coast	Bakingili	110	40
	Idenau Palm Estate	210	40
	Enyenge	134	40
	West Coast Total	**454**	**120**
Tiko	Misselle	490	60
	Mudeka	530	60
	Missaka	320	40
	Tiko Total	**1340**	**160**
Muyuka	Muyuka central	680	70
	Ekona	621	70
	Yoke	573	60
	Muyuka Total	**1874**	**200**
Total Population		**4460**	**500**

**Source = Field data (2018)*

A multi-stage sampling procedure was used to establish a sample of 556 smallholder farmers for the study. Firstly, the study area – Fako division is purposely selected among the (5) five divisions of the Southwest region as it produces the variety of food crops that is representative of the great variety of food produced in the region and is reported as food secured (Sneyd, 2014; WFP, 2017). In the first stage, four subdivisions (Buea, Tiko, Muyuka, and West Coast) out of five (including Limbe) were purposefully sampled because they are predominantly (65% – 82%) farming communities, as reported by the Regional Delegation of Agricultural and Rural Development, Buea.

In the second stage, in-depth discussions with the regional delegation and some agricultural officers established a list of villages from these sub-divisions with at least 80% farm households. This provided a sampling frame from which a maximum of three (3) villages per subdivision were randomly selected. Therefore, a total of twelve (12) villages were selected for the study. This stage prevented the study from randomly selecting villages with lesser involvement of households in smallholder agriculture. The third and final stage involved the simple random selection of smallholder farm households from the 12 villages chosen in the second stage. Based on a probability proportional (10%) to the approximated total of 4460 smallholder farm households estimated by the local quarter heads and community leaders in the 12 village (Table 1), a total of 556 small holder farm households were randomly sampled from the 12 villages for the study to anticipate effect size, loss of data, voluntary responses and for greater precision. Snowball sampling was adopted in some instances to meet the sample size for a village. To be an eligible household for the study, all persons in the household had to live under the same roof, share meals, and have farming as the primary source of livelihood. For our study, we consider only those who produce food crops and livestock either as monocrops, intercrops, or mixed farming on not more than one hectare of land.

An interviewer-administered structured questionnaire was used to collect the data in the randomly selected households. The survey team was comprised of trained enumerators. The survey questionnaire consisted of three parts: i) Household and farm characteristics, ii) knowledge and perceptions relating to diets, and attitudes towards diets and food culture, iii) Agricultural Production and iv) Food Consumption data. Our survey captures both household agricultural production and consumption data, which is often not the case with agricultural production surveys, which typically focus on the commodities produced by the household. Another innovation of our study is its attempt to exhaust and control socio-cultural influences on food consumption, which has been captured and analyzed narrowly in previous studies. Forty – two (42) households were removed from this study because of absence or refusal to respond to a quarter of the questions and they if reported producing cash crops such as cocoa and palm oil. A total of 494 SHF household responses (92% response rate) were received, which is considered an excellent rate for similar methodologies. A description of the variables used in the survey is found in Table 2. The authorization to carry out this study was obtained from the Regional Delegation of Public Health for the Southwest region (Ref: R11/ MINSANTE/SWR/RDPH/PS/558/770 of 25 October 2017) and the approval of the Regional Delegation of Agriculture and Rural Development for the Southwest Region.

5. Measurements

Measurements of Explanatory Variables

During the survey, households were asked to report the number of crop or livestock species categories they had produced on their farms during the last farming season, which we refer to as **Agricultural Production Diversity** in this study. Previous studies have often used a simple count of crop or livestock species produced on the farm or a combination of both (Jones et al., 2014; Sibhatu et al., 2015b) However, this measure does not fully capture production diversity from a dietary perspective (Koppmair et al., 2016). To address this, we utilized an agricultural production score, a method extensively employed in empirical studies ((Sibhatu & Qaim, 2018a; Kopmair et al., 2016;) which considers the dietary implications of production diversity. The Agricultural Production Diversity was constructed by using the same number of food groups as those used in dietary diversity measurements. If a farm household produced food from only one category, the score was set at one. If the household produced food from more than one category, the score increased accordingly, signifying greater agricultural production diversity. For this study, nine nutritional food groups (Swindale & Bilinsky, 2006) were considered: staples (cereals, tubers, roots), pulses (beans, nuts), vegetables, fruits, fisheries or livestock (seafood, meat, poultry, goats, pigs, guinea pigs), eggs, dairy products, oils, and sugar (including sugar products/honey/alcoholic beverages).

Markets play a critical role in shaping food consumption patterns, particularly in the sale of produce and the purchase of food in small quantities, such as fresh foods, vegetables, animal-source foods, and seafood—items not typically produced by smallholder farm households. In this study, Market Access was measured by walking time in minutes to the nearest consumer market, serving as a proxy for geographical market access. This measurement not only reflects the presence of nearby markets in a village but also the distance of households from these markets, a method frequently used in empirical studies investigating the role of markets in dietary diversity (Hoddinott & Yohannes, 2002; Jones et al., 2014; Qaim & Sibhatu, 2018; Sibhatu & Qaim, 2018b).

Measurement of Outcome Variable – Dietary Diversity

The food consumption data were obtained from a 7-day diet recall adapted from the Food Frequency Questionnaire (WHO, 2009) to assess the habitual farm household diet.

Household Dietary Diversity Score

The FAO (2011) has validated the use of the Household Dietary Diversity Score (HDDS) for low- and middle-income countries and recommends this tool for assessing changes in dietary diversity in agriculture-dependent populations (Sekabira & Nalunga, 2020; FAO, 2012; Arimond et al., 2010; Arimond & Ruel, 2004). The HDDS is recognized as an indicator of nutrient adequacy or nutrition security, particularly for women and children. It reflects the availability of foods, diet quality, and social behaviors around food. For each household, a maximum score of 12 was generated, based on the assumption that food items consumed across most households in West African countries, including Cameroon, could be conveniently categorized into 12 nutritional food groups (WFP, 2008; FAO, 2012). Each food group consumed over the past seven days was given one point, resulting in a maximum total score of 12 points per household if all food groups were consumed. Taruvinga et al. (2013) and O'Meara et al. (2019) categorized the total dietary diversity score for each household into three tertiles, following WHO-prescribed cut-offs (WHO, 2018): Low Dietary Diversity (0 –3), Medium Dietary Diversity (4 - 6) and High Dietary Diversity (7-12).

Table 2. Standard food groups and weights for food consumption Scores

	Food Items[1]	Food Groups	Weight	Justification[2]
1	Cereals/grains and cereals – made foods such as: Maize, rice, sorghum, millet, pasta, bread, and other cereals and related foods	Main Staples	1	Energy-dense food group - Overconsumption implicated in obesity and overweight. Less nutrient-rich foods Low protein content
2	Tubers and Roots Cassava, potatoes and sweet potatoes, yams, other tubers, plantains			
3	Beans, peas, seeds/groundnuts, cashew nuts, other nuts	Pulses	2	Energy-dense Low in micronutrients High protein content
4	Green and other vegetables and leaves	Vegetables	3	Low energy Rich in micronutrients Low protein
5	Fruits	Fruits	3	Low energy Rich in micronutrients Low protein
6	Fish and other seafood	Fish	1	Energy-dense food group - Overconsumption implicated in obesity and overweight. Rich in nutrient Rich in proteins
7	eggs			
8	Beef, goat, pork, poultry,	Meat		
9	Milk, yogurt, and another dairy	Milk	2	Rich in protein Low energy Rich in micronutrients
11	Sugar and sugar products (sweet alcoholic beverages)	Sugar	1	Energy-dense Poor in micronutrients No protein
12	Oils, fat, and butter	Oil	1	Energy-dense Low or poor in nutrients No protein
	Spices, tea, coffee, salt, small amounts of milk for tea	Condiments	0	Has no impact on the diet since taken in small quantities

[1] Informed by knowledge of the local food habits, as well as nutritional considerations for obesity/overweight.

[2] The principle guiding the determination of the weights is the energy density (from fats and carbohydrates), micronutrient and protein content

(Source: Author's compilation adapted from WFP, 2008)

Food Consumption Score

While the HDDS provides a snapshot of dietary diversity, it may not fully capture the consumption of micronutrients and other foods that contribute to the burden of chronic diseases such as diabetes and obesity. Therefore, a more robust classification of food groups is required (Ruel, 2003). We adopted a second indicator of dietary diversity, the Food Consumption Score (FCS), similar to an index validated by the World Food Programme (WFP, 2008) as described and used by O'Meara et al.(2019) and Onyeneke et al., 2019). The FCS is a composite score based on data about food groups and the frequency with which one or more household members consume them over the seven days preceding the survey. In this study, the FCS weighed each food group according to its nutritional contribution to ensuring a quality diet (WFP, 2008; Jones et al., 2014). The same food groups used in the HDDS were applied in calculating the FCS (Table 2). The FCS is a continuous variable, ranging from 16 (if a household consumes a food group only once a week) to 112 (if a household consumes each food group daily). Two standard thresholds were identified to classify households based on their food consumption patterns. It is expected that a rural household in Cameroon would minimally consume staples, vegetables, and oils daily, with an expected FCS of at most 35, calculated as frequency *weight of staples + frequency *weight of vegetables + frequency*weight of oils = 21 + 7 + 7 = 35. The second threshold is set at 56. Households with FCS between 36 and 55 are classified as having borderline diet quality, while those with scores above 56 are estimated to have acceptable/good diet quality or food consumption patterns. The classification of food consumption/quality profiles is as follows: Poor = ≤35; Borderline = 36–55; Acceptable = ≥56.

Other Covariates

In this study, we seek to expand the empirical evidence explaining the heterogeneity in the relationship between agricultural production diversity and nutrition outcomes. By incorporating additional covariates into our empirical strategy, we aim to assess how context-specific factors contribute to the non-linear association between agricultural diversity, market access, and dietary and nutritional outcomes. Our conceptual model hypothesizes that various contextual, sociocultural, and household characteristics may significantly influence these linkages, either positively or negatively. One key factor we consider is the ***age of the household head***, as previous studies suggest that older household heads may prioritize healthier diets for household members. We also include the level of education of the household head, measured in years of completed education, to determine if higher education levels correlate with the production or purchase of healthier foods, which in turn could positively impact diet quality. ***Knowledge of nutrition and awareness of overweight/obesity*** are important household-level factors influencing health outcomes and consumption behavior. We assess knowledge through awareness of healthy diets, understanding of food groups, and the benefits of balanced nutrition. Using silhouettes/images by Cohen et al. (2018), we evaluate participants' knowledge of overweight and obesity, as well as their understanding of its causes, risks, and prevention, as outlined in the FAO guidelines (FAO, 2010, 2016). We hypothesize that higher knowledge scores are positively associated with improved dietary outcomes.

Additionally, we examine the ***attitudes related to household food allocation and consumption practices, and food culture***, as these are hypothesized to affect nutrition outcomes positively. Specifically, we investigate how household food preferences and cultural influences impact dietary diversity scores. The ***gender of the household head*** is another variable of interest, as studies suggest that female-headed households often exhibit greater dietary diversity due to women's increased control over food preparation decisions (Njuki, Sanginga, & Kaaria, 2013; Kumar & Quisumbing, 2014). The greater involvement of women in household decision-making was assumed to have a positive effect on household diet outcomes. We include a ***Women's Decision-Making Power Index*** to assess the influence of women's participation in food preparation and allocation decisions on household diet outcomes. ***Household size***, defined as the number of people living together and sharing meals, is analyzed for its potential positive or negative effects on dietary diversity. In a larger household if most members are of working age, they may provide labor for greater agricultural production or if they are more children and or elderly dependents, it could affect food allocation. We also consider several indicators of wealth, including ***Average household income*** from farming, non-farm employment, and other sources, to understand their impact on dietary diversity. ***Having access to non-farm income*** through non-farm employment is expected to have either a positive or negative effect on household dietary diversity. ***Farm size,*** measured as the self-reported area of land in mm^2 used for crop cultivation or livestock keeping, is expected to influence subsistence or market-oriented production, and thus, on dietary diversity.

6. Empirical Models

Our conceptual model, along with frameworks such as those proposed by Herforth & Ahmed (2015) recognizes that external factors play a significant role in shaping agriculture-nutrition pathways, thereby influencing the nutritional and health outcomes of farm household members. This understanding justifies the empirical strategy of the study, which is estimated by the regression equation (1) at the smallholder farm household level. It models the primary pathways of nutrition outcomes, specifically dietary diversity as a function of agricultural production diversity, markets, and a set of covariates established in the literature.

$$DD_i = \beta_1 + \beta_2 \mathrm{APD_i} + \beta_3 APD_i\, Markets_i + \beta_4 Markets_i + \cdots \beta_n \mathrm{X_{in}} + \varepsilon_i \quad i = 1, 2 \ldots .\ n \quad (1)$$

Modelling the Effects of Agricultural Production Diversity on Dietary Diversity

In this study, we model the effects of agricultural production diversity, $\boldsymbol{APD_i}$ on dietary diversity, $\boldsymbol{DD_i}$ using two measures: Household Dietary Diversity score (HDDS) and Food Consumption Score (FCS). The $\boldsymbol{DD_i}$ is the dietary diversity indicator of the i^{th} household and the dependent variable. HDDS is a count variable that takes only non–negative integer values, while FCS is continuous data. $\boldsymbol{\beta_1}$ is the constant term. The coefficient, $\boldsymbol{\beta_2}$ for $\boldsymbol{APD_i}$, represents the effect of agricultural production diversity $\boldsymbol{APD_i}$ on dietary diversity. A positive estimate of β_2 indicates that increased agricultural production diversity contributes to greater dietary diversity and improved nutrition security. The sign of the coefficient,$\boldsymbol{\beta_2}$, does not differ with the use of the FCS indicator. We estimate that agricultural production diversity is the key explanatory variable for both nutritional outcome measures, when other variables are controlled. $\boldsymbol{\beta_n}$ represents a vector of coefficients for additional observed household, and farm characteristics included in the analysis.

Assessing the Role of Markets in the link between Agricultural Production Diversity and on Dietary Diversity

Smallholder farm households are typically situated in areas with varying degrees of market infrastructure. Many of these households sell a portion of their produce in local markets, which offer a greater variety of foods than what any single farm household can produce (Arimond & Ruel, 2004).

To estimate the effects of market access on dietary diversity, we include a market access variable, $\boldsymbol{Markets_i}$ in our regression model. Specifically, we examine the interaction between agricultural production diversity and market access by incorporating $Markets_i$ as an interaction term, $\boldsymbol{APD_i\, Markets_i}$ in the standard equation. The coefficient $\boldsymbol{\beta_2, \beta_3}$ represents the effect of $\boldsymbol{APD_i}$ with and without the interaction with $Markets_i$ respectively and $\boldsymbol{\beta_4}$ captures the independent effect of market access on dietary diversity. We control several covariates to account for the potential confounding sociocultural, economic and demographic characteristics of households that may be correlated with both agricultural production diversity and dietary diversity. In our estimation, they are captured in the vector $\boldsymbol{X_{in}}$, which includes household characteristics (such as education and age of the household head, female headship, household size, average household income in natural logarithm, access to non -farm income, distance to nearby markets, women's power and decision-making index, score of knowledge, food culture and attitudes towards diets) s well as farm characteristics (such as farm operation size in natural logarithm). The error term, $\boldsymbol{\varepsilon_i}$ is assumed to be normally distributed, capturing all other unobserved factors specific to the i^{th} small holder farm household.

Addressing Potential Endogeneity

The decision to diversify food group production within a farm household may be influenced by factors that also affect food consumption outcomes. Consequently, in addition to the observed factors accounted for in our model (as outlined in equation 1), there may be unobserved factors that correlate with both dietary outcomes—specifically, Household Dietary Diversity Scores (HDDS) and Food Consumption Scores (FCS). Moreover, if agricultural production diversity and market access are measured with some degree of error, our estimates of their effects may be biased. Measurement errors, especially when they are randomly distributed with a mean of zero, typically lead to downward-biased estimates (Deaton & Muellbauer, 1980). Additionally, the effect of agricultural production diversity on HDDS and FCS is mediated through a system of simultaneous equations. In this system, agricultural production diversity acts as the dependent variable in the first equation (equation 2), which then feeds into the second equation (equation 1) to influence dietary outcomes (HDDS and FCS). This simultaneity introduces a correlation between the error term and the endogenous variable, raising concerns about potential simultaneity or selection bias between the production equation (2) and the diet outcomes in equation (1). Addressing these issues is critical to ensuring the validity and reliability of our findings.

$$APD_i = \kappa_1 + \kappa_2 Y_i + \varepsilon_i \qquad i = 1, 2....n \qquad (2)$$

Where omitted variables and simultaneity or selection bias are present, estimating equation (1) without correction would result in biased estimates, potentially leading to an under- or overestimation of the effect of agricultural production diversity in our regression models. Therefore, addressing endogeneity concerns is crucial when estimating equation (1). The standard estimation methods, such as Poisson regression and Ordinary Least Squares (OLS), which are typically used based on the count and continuous nature of the outcome variables, would yield biased and inconsistent results under these conditions. To mitigate potential endogeneity, we employ an instrumental variable (IV) approach, which allows for the estimation of coefficients that are free from endogeneity-related bias (Angrist & Pischke, 2019; Rupa, et l.,2019). The empirical literature has highlighted the problem of endogeneity in the relationship between agricultural production diversity and dietary diversity, but shows it can be addressed with an IV strategy (Hirvonen and Hoddinott 2017; Sibhatu and Qiam 2018; Zanello et al., 2019. Hirvonen et al., 2017).

The IV 2SLS model can be specified in a system of equations as follows.

$$\widetilde{\mathrm{APD}}_i = \kappa_1 + \kappa_2 Z_i + \cdots .... \kappa_{ni} X_{ni} + \mu\varepsilon_i \qquad i = 1, 2, ...n \qquad (3)$$

$$DD_i = \lambda_1 + \lambda_2 \widetilde{APD}_i + \lambda_{ni} X_{ni} + \varepsilon_i \qquad i = 1,2,....n \qquad (4)$$

Where $\boldsymbol{DD_i}$ represents indicators of dietary diversity measures for the smallholder farm household $\boldsymbol{i}$, $\boldsymbol{\kappa_0}$, $\boldsymbol{\kappa_1}$, $\boldsymbol{\kappa_{ni}}$, $\boldsymbol{\lambda_0}$, $\boldsymbol{\lambda_1}$, $\boldsymbol{\lambda_{ni}}$, are unknown parameter estimates of interest, $\boldsymbol{X_{ni}}$ are a vector of unknown exogenous regressors or household and farm characteristics hypothesized to be correlated with household dietary diversity scores and Food consumption scores, $\widetilde{\mathbf{APD_i}}$ is the predicted values of the number of food groups produced by the smallholder farm household. $\mathbf{APD}_i$ is the production diversity that is potentially endogenous in the dietary diversity model. Z_i is a vector of instruments for agricultural production diversity in the i^{th} household while ε_i and μ_i are the error terms assumed to be independent and identically distributed in the model.

Previous studies in Africa have utilized rainfall, average temperatures, and soil characteristics as valid instruments for agricultural production diversity (Hirvonen & Hoddinott 2017;(Zanello et al., 2019,). However, these factors are not suitable instruments in our study because all study sites are located within the same agro-ecological zone, resulting in similar agro-climatic conditions such as rainfall, temperature, and elevation, as well as minimal variation in agrobiodiversity. Following theoretical discussions and empirical studies on instrumental variables (IV) related to agricultural diversification and livelihoods (Zanello et al., 2019), we identify landownership (as a proxy for wealth), use of pesticides (UoP) and agricultural extension visits (AEV) as possible instruments for agricultural production diversity and its influence on dietary diversity.

In agricultural sciences, land ownership is often associated with the wealth levels of small-farm households. To account for its potential effects on agricultural production diversity and dietary outcomes, we include land ownership as a covariate in equation (2). This approach also enhances its performance as an instrument. The use of pesticides is recognized in agricultural policy and programs for its role in reducing yield loss due to pests and maximizing productivity, particularly in scenarios where available land, water, and other resources are limited (Oerke, 2006, 2007)*,* Given that the use of pesticides is a strong predictor of agricultural production diversity and lacks direct theoretical and empirical links to dietary diversity, we propose it as an instrument. Access to agricultural extension services is a key determinant of farm diversity in agricultural-dependent economies, as it increases productivity and helps reduce food insecurity. While agricultural extension visits could theoretically influence dietary diversity through indirect channels like nutritional education, we consider it a viable instrument due to its strong association with agricultural production diversity.

To verify the appropriateness of our IV approach in addressing endogeneity, we conducted three statistical diagnostics on the Two-Stage Least Squares (2SLS) regression model. The results, presented in Table 4, include, i) Test for the relevance criterion: This test assesses whether the instruments are strong predictors of the endogenous variable. The first stage of the 2SLS regressions reveals that, after controlling for household socio-economic and demographic factors, as well as farm characteristics, land ownership does not significantly correlate with agricultural production diversity *(Coefficient = 0.22, p > 0.05).* However, agricultural production diversity is significantly predicted by the use of pesticides and agricultural extension visits. The Sanderson-Windmeijer F-test for excluded instruments confirms that these two agricultural innovations and services explain a substantial portion of the variance in agricultural production diversity. Specifically, smallholder farmers who use pesticides and receive visits from agricultural extension officers are more likely to increase their agricultural production diversity.

Table 3: Diagnostics Tests for Instrumental Variable Regression

Test	**HDDS (Model 1)**	**FCS (Model 2)**
Agricultural Production Diversity		
Use of Pesticides	0.369(0.000)	0.369(0.000)
Agricultural Extensions Visits	0.878(0.000)	0.878(0.000)
F – test (Sanderson–Windmeijer F–test) of excluded instrument	58.12(0.000)	58.12(0.000)
Chi-squared test with the Anderson canonical correlation Statistics	96.31(0.000)	96.31(0.000)

Sargan Statistic (Chi squared)	6.24 (0.0125)	13.729 (0.0002)
Wu – Hausman (Chi –squared test) –Endogeneity test	1.674 (0.195)	5.863 (0.0155)
Controls ***(without Market Access)***	Yes	Yes
2nd Stage regression		
Agricultural Production Diversity	0.351 (0.037)	3.185(0.003)
Agricultural Production Diversity		
Use of Pesticides	0.41 (0.000)	0.410 (0.000)
Agricultural Extensions Visits	0.855 (0.000)	0.855 (0.000)
F – test (Sanderson – Windmeijer F test) of excluded instrument	59.91 (0.000)	59.91 (0.000)
Chi –squared test with the Anderson canonical correlation Statistics	98.84 (0.000)	98.84 (0.000)
Sargan Statistic (Chi squared)	2.704 (0.100)	5.669 (0.0173)
Wu – Hausman (Chi –squared test)	1.158 (0.282)	4.511 (0.034)
Controls ***(with Market Access)***	Yes	Yes
2nd Stage regression		
Agricultural Production Diversity	0.356 (0.029)	3.208 (0.001)
Market Access	-2.14 (0.00)	-2.26 (0.000)

Source: Authors

P-value in parenthesis

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ii) Secondly, we exclude the use of pesticides and agricultural extension visits from the prediction of dietary diversity in the second stage of 2SLS regression because of the significant Sargan – Hansen statistics. This confirms that the selection of the Instrumental Variables is empirically grounded. iii) Third, the Wu –Hausman test for endogeneity for the household dietary diversity score model is not significant, therefore, endogeneity is not biasing the estimate of the effect of agricultural production diversity on Household Dietary Diversity Score, and it is empirically valid to rely on the results obtained with Poisson regression. Table 4 also shows that the Wu–Hausman test for endogeneity in the food consumption score model is significant, implying that agricultural production diversity is endogenous to dietary diversity when the food consumption score metric is used. The Instrumental Variable regression is necessary to correct the resulting bias in the OLS estimate of the effect of agricultural production diversity on FCS.

The second criterion for the validity of our Instrumental Variable strategy is that for instruments to be good instruments, they must not correlate with our outcome variable (household dietary diversity score/food consumption score) except through the agricultural production diversity pathway. We theoretically suspect that agricultural extension visits may be correlated with some other factors (such as nutrition knowledge, which could affect purchasing behavior and influence HDDS or FCS through market pathways. Based on this analysis, we concluded that agricultural extension visits do not meet the criteria for a good instrument and have thus excluded it from our estimations. As a result, the use of pesticides remains the only instrument employed in further analysis. To identify the cross-sectional explanation of dietary diversity by agricultural production diversity, we use both the Poisson and 2SLS regression models to address the possible endogeneity of our key explanatory variables – Agricultural Production Diversity and Market Access, as presented in equation (1).

7. Results

Descriptive results

Table 4 presents the variables of the sample households used in the empirical analysis, focusing on: i) levels of agricultural production diversity, and ii) household dietary outcomes by common sources of food. A total of 494 smallholder farm households were surveyed, of which 59.7% are headed by females. The mean household income from the last farming season (spanning four months) is 45,811 Francs CFA (Communaute Financiere Africaine), which is approximately 79.06 US dollars. The survey assessed the overall nutrition knowledge and awareness of overweight/obesity among household heads, utilizing a 9-point scale. On average, households scored 4.1, indicating below-average knowledge of nutritional principles. We also surveyed attitudes towards diets and food culture, using the household as a proxy measure of socio-cultural norms and preferences linked to food consumption. Households exhibited neutral attitudes, with scores of 14.7 out of 30 points and 24.9 out of 55 points, respectively, for diet practices and food culture. This neutrality suggests that households neither strongly adhere to nor reject common dietary practices in the study area. However, when recategorizing the Likert scale responses, the results indicate that, on average, households hold unfavourable attitudes towards diet and food culture. The level of women's involvement in decision-making regarding food production and consumption is slightly above average within the sample, as reflected by an index score of 5.6 out of 9. Households reported an average walking time of 34.9 (±36.6) minutes to the local market and 153.9 (±108.3) minutes to the district market. Finally, the average land area used for food production by these households is approximately 0.2 hectares.

Table 4. Definition and Summary Statistics of variables (N=494)

Variables	Definition	Mean (SD)
***Outcome Variable*-Dietary Diversity (DD)**: Different food groups consumed by households in the previous 7 – day period		
1. Household DD Score (HDDS)	Count of food groups (out of 10) consumed in the previous 7 days - Pooled sample	7.69(1.54)
	HDDS from own production	1.68(0.07)
	HDDS from purchases (markets)	4.66(1.79)
	HDDS from both its own production and purchases	0.60(0.78)
2. Food consumption score (FCS)	Composite score of food groups multiplied by frequency at which they are consumed in the previous 7-day period – Pooled Sample	24.1(8.4)
	FCS from own production	6.75(5.81)
	FCS from purchases (markets)	19.04(7.87)
	FCS from both own production and purchases	2.57(4.49)
Explanatory Variable		
Agricultural production diversity (APD)	Number of food groups from crops and livestock species categories produced in the last agricultural season	2.1 (0.88)
Market Access -	Walking distance to the nearest local market (minutes)	34.9(36.6)
	Walking distance to district market (minutes)	153.9(108.3)
Covariates		
Farm operation size (m^2)	Total land used in cultivating or keeping livestock in the last agricultural season	1869 (2213.4)
Age household head	Age of household head (years)	43.6(11)
Female headship	Gender of head of household is Female (%)	59.7
Education of the head of household	Number of years in formal education (Maximum of 17 years)	9.3(3.6)
Household size	Number of people lliving inthe household	6.3(2.6)
Average household income	Income from last farming season (Francs CFA)	45,811(10,309)

Women's Power/Decision-making index	Index of the woman's level of decision –making for household food production, preparation and consumption (range 1 – 7)	5.6(0.97)
Non-farm income	Household has access to non-farm income = 1; 0 = otherwise (%)	48
Score of knowledge on nutrition	Overall score of knowledge on nutrition (total score of 9 points)	4.09(1.7)
Food culture attitudes	Score of food culture attitudes (total score of 30)	14.7(3.84)
Attitudes towards diets	Score of attitudes towards diets (total score of 55)	24.9 (4.14)

Source: Authors, based on survey data (2018 – 2019)

Distribution of Dietary Diversity Indicators in the Smallholder Farm Household

In this study, the household dietary diversity score and food consumption scores are used as indicators of dietary diversity. Information about foods consumed in the household over the preceding 7-day period was provided by the primary female decision-maker or the person responsible for meal preparation. Table 5 reveals that the mean household dietary diversity score within the study sample is 7.69 (±1.54), indicating that, on average, households consumed 7.69 different food groups. Notably, 25.1% of households reported consuming this number of food groups. Furthermore, the data confirm that during the recall period, most households (71.5%) exhibited moderate dietary diversity, falling within the medium dietary diversity tertile, which corresponds to the consumption of 4 to 6 food groups per week. Table 5 also presents the distribution of households in terms of diet quality, guided by the WHO (2012) definition of a healthy/quality diet and adapted from the WFP standards for classifying households' diets based on the macronutrient–sensitive Food Consumption Score (WFP, 2008). The mean food consumption score (macronutrient-sensitive FCS[3]) is 24.1(±8.4). When applying cut-off points modified to assess the diet-related risk of non-communicable diseases (NCDs), it was found that three-quarters of the households (77.9%) are exposed to diets of inadequate quality. This inadequate dietary quality poses a long-term risk of diet-related NCDs, especially if other preventive measures, such as physical activity, are not present in these households. Alarmingly, only 0.8% of households consume what can be classified as a healthy diet.

Table 5. Household Food Access and Food Consumption Patterns

Levels of Quality and Quantity of Household Food Access	Percent	Standard Error	95% Confidence Interval
Food Consumption Score Categories			
Poor	77.9	1.8	74.0 - 81.3
Borderline	21.2	1.8	17.8 - 25.0
Acceptable	0.8	0.4	0.3 - 2.1
Household Dietary Diversity Score (no. of food groups consumed)			
3	0.2	0.2	0.0 - 01.4
4	0.2	0.2	0.0 - 1.4
5	5.8	1.0	04.1 - 8.3
6	17.0	1.6	13.9 - 20.6
7	23.4	1.9	19.9 - 27.4
8	25.1	1.9	21.4 - 29.1
9	15.5	1.6	12.6 - 19.0

[3] This is opposed to the micronutrient -sensitive indicators initially proposed by WFP in 2008. We adapt this micronutrient – sensitive approach to assess food consumption patterns and relate them to exposure to NCDs.

10	8.1	1.2	5.9 - 10.8
11	3.8	0.8	2.4 - 5.9
12	0.6	0.3	0.2 - 1.9
Household Dietary Diversity Score (level of food group consumption)			
Less than 4 food groups	0.4	0.29	0.1 - 1.6
Between 4 and 6 food groups	71.5	2.04	67.3 - 75.3
More than 6 food groups consumed	28.1	2.03	24.3 - 32.4

Source: Authors calculation based on survey data (2018 – 2019)

In summary, although a significant proportion of the smallholder farm households (71.5%) in the study area consume 4 to 6 food groups within a 7-day period, the majority have food consumption patterns characterized by inadequate quality and less healthy diets. In the context of agricultural production, the variety of food groups produced by households during the last farming season is referred to in this study as agricultural production diversity. Households that choose to diversify their agricultural production are termed "production diversifiers," while those that opt not to diversify are labelled "non-production diversifiers." Table 6 shows that, on average, households produced approximately six crop-livestock species, five crop species, and foods from 2.1 food groups during the past farming season. There is no significant difference in production diversity measures across the subdivisions studied. Out of the ten possible categories of food groups that smallholder farmers can produce, we find that farm households identified as production diversifiers consume a mean of 7.77 food groups within the 7 days preceding the survey. In contrast, non-production diversifiers consume a mean of 7.47 food groups during the same period.

Table 6. Measures of Agricultural production diversity by the Subdivisions

Subdivision	The proportion of Households with APD(SE)	Crop species Count	Crop – livestock species Count	Food group Diversity Score
Idenau (West Coast)	0.71(0.041)	5.39(1.7)	5.7(1.8)	2.15(0.92)
Tiko	0.71(0.043)	5.25(1.4)	5.5(1.6)	2.07(0.89)
Buea	0.69(0.044)	5.44(1.7)	5.67(1.8)	2.04(0.86)
Muyuka	0.74(0.035)	5.42(1.58)	5.74(1.74)	2.13(0.86)
Overall	0.72(0.020)	5.38(1.61)	5.66(1.73)	2.10(0.88)
	(F = 0.292. P = 0.831)	(F = 0.299. P = 0.826)	(F = 0.429. P = 0.732)	(F = 0.413. P = 0.744)

Standard Deviation in Parenthesis. F= F statistic; P = P-value for the significant difference between study sites
Source: Author's calculation

Agricultural Production Diversity and Dietary Diversity Indicators

The t-test results indicate a significant mean difference in the number of food groups consumed between the two categories of households. Specifically, households that diversify their agricultural production (production diversifiers) have a significantly higher mean food consumption score related to overnutrition, with a score of 29.55, compared to 27.38 for non-diversified households. Furthermore, the higher mean food consumption score associated with undernutrition among diversified farm households suggests that non-diversified farm households consume fewer micronutrient-rich foods than their diversified counterparts. Interestingly, a smaller proportion of food consumed came from households' own production (14.5%), while a larger proportion was sourced from the market (43.5%). The observed distribution of dietary diversity indicators among production diversifiers and non-production diversifiers supports the hypothesis of this study, suggesting a positive association between agricultural production diversity and dietary diversity.

Sources of Food Groups Consumed by Household Members

Table 6 provides detailed information on the consumption and sources of various food groups during the 7-day recall period. Nearly all households reported consuming tubers and fats/oils, with 99.5% and 99.8% of households, respectively, having consumed these food groups during the recall period. Cereals, primarily maize and rice, were consumed by 95.1% of households. Three-quarters of the households reported consuming vegetables, legumes, and seafood (78.1%, 70.4%, and 78.7%, respectively). The consumption of milk, dairy products, eggs, and sugar is relatively low in this setting.

Table 7. Comparison of Mean Values of Diet Diversity Indicators by Agricultural Production Choice

Dietary Diversity Indicator	Total Mean (SD)	Agricultural Production Choice of Household n = 494		Mean Difference*
		No production diversity (1 food group produced) n= 140	*Production diversity (>1 food group produced) n = 354*	
Household dietary diversity score (HDDS)	7.69 (1.54)	7.47 (1.51)	7.77 (1.53)	-0.303**
HDDS from own production only (HDDSOP)	1.51 (0.89)	0.95 (0.96)	1.74 (0.87)	-0.787***
HDDS from purchased food only (HDDSPM)	4.66 (1.79)	5.57 (1.73)	4.29 (1.68)	1.27***
Food consumption score related to over nutrition (FCS- Ov)	28.93 (28.09)	27.38 (9.21)	29.55 (9.51)	-2.17**
Food consumption score related to under nutrition (FCS- Un)	33.83 (12.09)	32.17 (11.95)	34.49 (12.10)	-2.31*
Food consumption score related to Over nutrition from own production only (FCS-OvOP)	6.75 (5.81)	4.97 (4.87)	7.45 (9.01)	-2.48***
Food consumption score related to Over nutrition from purchased food only (FCS-OvPM)	19.03 (7.86)	21.09 (0.73)	18.22 (7.41)	2.87***

Source: Authors

**t-test compares means between non –diversified and diversified farm households, SD in parenthesis. Bonferroni post –hoc test was used to identify significant mean differences among groups*

Additionally, a slightly below-average proportion of households (46.8%) reported consuming meat, including beef, pork, and poultry. A significant number of households sourced their vegetables, tubers, and roots from their own production. The food consumption data (Table 8) reveals that, on average, 64.1% of households consumed foods across various food categories within the week preceding the survey. The proportions of consumption varied widely, ranging from 26.1% for fruits to 99.8% for oils, particularly palm oil. The higher mean dietary diversity scores from purchased foods, along with the greater proportion of food groups consumed from purchased sources compared to those from own production, underscore the critical role that markets play in contributing to dietary diversity among households in the study sites.

Table 8. Food groups consumed by households in the 7–day period preceding the survey and the sources

Food group	Examples of food	Overall	Main source (%)

Consumed		(%)	Own Production	Purchased	Both
Cereals	*White rice, maize, wheat products including white bread and pasta*	95.1	32.2	48.4	15
White tubers and roots	*Cassava and its products, plantains (cooking bananas), white yams, white potatoes, cocoyam*	99.5	58.9	25.7	14.6
Vegetables[1]	*Tomatoes, dark leafy vegetables, okra, onions, eggplant*	78.1	45.1	12.8	21.5
Fruits[2]	*Ripe bananas, watermelon, citrus fruits, pineapple, soursop, mangos, papaya*	26.1	6.3	18.0	1.4
Meat[3]	*Chicken, pork, beef*	46.8	4.9	38.5	3.4
Eggs	*Chicken eggs*	29.4	3.2	26.1	0
Legumes, nuts, pulses	*Beans, groundnuts, pumpkin seeds, soya beans*	70.4	8.9	59.9	2.2
Seafood	*Fresh and smoked fish, dried prawns*	78.7	0	78.3	0
Milk and dairy	*Powdered milk, yoghurt*	23.2	0	23.1	0
Fats and oils	*Palm oil (raw or red processed, factory processed*	99.8	12.3	86.0	1.4
Sugars and other sweet beverages	*Tea,/coffee with sugar, pastries, sweet drinks, biscuits, cakes, chocolate bread spread*	29.6	0	28.5	0.8
Spices and other condiments	*Salt, ginger, garlic, pepper, non-timber forest spices, herbs*	92.3	4.0	77.1	11.3
	Mean		14.7	43.5	6.0

Source: Authors

[1] The vegetable food group is a combination of vitamin A-rich vegetables and tubers, dark green leafy vegetables, and other vegetables.

[2]The fruit group is a combination of vitamin A-rich fruits and other fruits.

[3]The meat group is a combination of organ meat and flesh meat.

Econometric Results

The association between Agricultural Production Diversity and Household Food Consumption Outcomes

Our study hypothesizes that higher agricultural production diversity leads to improved food consumption patterns and dietary outcomes. To test this hypothesis, we estimate two versions of the model outlined in equation (1) to examine the association between agricultural production diversity and two key indicators of household diet outcomes. The household dietary diversity score (HDDS), ranging from 1 to 12, is estimated using the Poisson estimator (Saffari, Adnan, & Greene, 2012). We apply the auxiliary regression test (Cameron, 2013) to assess the equidispersion assumption and find evidence of underdispersion in the HDDS data, as indicated by an α coefficient of -0.09. Consequently, we model the relationship between agricultural production diversity and HDDS using the generalized Poisson estimator, following the approach of Koppmair et al., (2017). The estimated coefficients and marginal effects (ME) of agricultural production diversity on dietary diversity are presented in Table 8, with all estimations using robust standard errors (RSE). For robustness checks, we conduct goodness-of-fit chi-square tests for the HDDS to evaluate whether the Poisson model is appropriate (Cameron, 2013). For the dietary diversity indicator related to diet quality, namely the food consumption score (FCS), we apply an Ordinary Least Squares (OLS) approach to equation (1). Previous literature has commonly used OLS techniques to estimate the relationship between dietary diversity and explanatory variables when dietary diversity is treated as a continuous variable (Jones et al., 2014). OLS assumptions, including uncorrelated and homoscedastic errors, are maintained to ensure that OLS remains the best linear unbiased estimator. All models are estimated using RSE to account for heteroskedasticity (Saffari, Adnan, & Greene, 2012; Sibhatu et al., 2015). To assess multicollinearity, we calculated the variance inflation factor (VIF) for each independent variable. The VIF values did not indicate any multicollinearity concerns, with an average VIF of 2.16. All models are adjusted for relevant covariates.

The Association between Agricultural Production Diversity and Dietary Diversity

We first examine whether agricultural production diversity, which is defined as the number of food groups produced by households based on crop species and livestock categories—determines the dietary diversity of smallholder farm households, excluding covariates. In the first version of the model (Model I), we use HDDS, while in the second version (Model II), we use FCS, as shown in Table 9. Both indicators reflect household food consumption patterns and dietary outcomes. Agricultural production diversity is positively and significantly associated with overall dietary diversity scores ($HDDS_{TOT}$ and $FCS_{TOT)}$ in the absence or covariates. We first examine whether agricultural production diversity, defined as the number of food groups based on crop species and livestock categories produced by households, determines the dietary diversity of smallholder farm households, excluding covariates. In the first version of the model (Model I), we use HDDS, while in the second version (Model II), we use FCS, as shown in Table 9. Both indicators reflect household food consumption patterns and dietary outcomes. Agricultural production diversity is positively and significantly associated with overall dietary diversity scores.

The relationship between Agricultural Production Diversity and Dietary Diversity in the food consumption pathways

The relationship between agricultural production diversity and dietary diversity is complex, as households obtain food from both subsistence production and market purchases. Our analysis shows that agricultural production diversity is positively associated with diet outcomes through the own-production pathway ($HDDS_{OP}$ & FCS_{OP}). The partial marginal effect of agricultural production diversity through the own-production pathway (0.361) is positive. It exceeds the total effect of agricultural production diversity on dietary diversity (0.19), as shown in Table 9. Conversely, agricultural production diversity is negatively associated with diet outcomes linked solely to the market-income pathway ($HDDS_{MI}$ & FCS_{MI}) (Table 9). Specifically, an additional food group produced on the farm is associated with a 0.52 decrease in the number of food groups purchased by the household for consumption. Similarly, the food consumption score from market-purchased foods decreases by 1.02 points with each additional food group produced on the farm. This suggests that increased agricultural production diversity may reduce reliance on market purchases, thereby impacting dietary diversity through the market pathway.

Table 9. Association between Agricultural Production diversity and dietary diversity in SHF Households

	Household Dietary Diversity Score (HDDS)			**Food Consumption Score (FCS)**		
	$HDDS_{TOT}$ (Model I)	**$HDDS_{OP}$**	**$HDDS_{MI}$**	**FCS_{TOT} (Model II)**	**FCS_{OP}**	**FCS_{MI}**
Number of food group produced (APD)	0.026**	0.238***	-0.112***	1.37***	0.89	-1.021**
(RSE)	*(0.011)*	(0.028)	*(0.019)*	*(0.488)*	*(0.287)*	*(0.418)*

Marginal Effects (ME) *APD*	0.197**	0.361***	-0.523	-	-	-
SE of ME	*(0.081)*	(0.047)	*(0.09)*	-	-	-
Model Intercept	1.98***	-1.09	1.77***	26.1***	4.86***	21.18***
(RSE)	*(0.024)*	*(0.069)*	*(0.042)*	(1.08)	(0.623)	(0.097)
Chi square	5.9**	64.47***	33.35***			
F - statistics	-	-	-	7.8***	9.77***	5.96**
Pseudo R/R-squared	0.036	0.025	0.011	0.0163	0.0186	0.0131
No. of Observations	*494*	494	494	494	494	494
α estimates of equidispersion test	-0.091***	0.193	0.193***	-	-	-
SE	*0.002*	*0.022*	*0.022*	-	-	-

*Based on Equidispersion results, the models for HDDS from the own – production pathway (**$HDDS_{OP}$**) and income pathway (**$HDDS_{IM}$**) were estimated with Negative binomial regression meanwhile the model for the overall HDDS (**$HDDS_{TOT)}$** was estimated with the generalized Poisson estimator. **P<0.05, ***P<0.01. See tables 5.1 and 5.2 for extensive details on the results*

The Effect of Agricultural Production Diversity on Nutrition security and food consumption patterns of Smallholder farm households in the Fako Division of Cameroon

The Impact of Agricultural Production Diversity on Dietary Diversity Indicators

This study seeks to address the question: What is the effect of agricultural production diversity on dietary diversity (nutrition security) and food consumption patterns (diet quality) among smallholder farm households? Our findings demonstrate that agricultural production diversity has a positive and significant effect on household dietary diversity scores, independent of the explanatory or confounding influence of market access. The marginal effect of production diversity on household dietary diversity is relatively small (0.22; $p < 0.05$), indicating that a 22% probability exists that increasing the production of an additional food group on the household farm will result in the household consuming one additional food group. Furthermore, production diversity is significantly correlated with the food consumption score at the 1% level (Coefficient = 11.56; $p < 0.001$) in the IV 2SLS model specified. An increase in agricultural production diversity by one food group is associated with an 11.56-point increase in the household food consumption score. In both estimations, all covariates are fully controlled (Table 10). Our results suggest that the marginal effect of agricultural production diversity on household dietary diversity remains consistent even when other factors that significantly influence consumption decisions are accounted for in the estimations (ME of 0.22; Coefficient = 0.029), compared to when these factors are not controlled (ME of 0.19; Coefficient = 0.026). This consistency implies that the primary effect of agricultural production diversity on dietary diversity is robust, even when additional influencing factors are included (and does not suffer from endogeneity bias). Conversely, the effect of agricultural production diversity on food consumption scores is significantly higher when potential covariates are controlled (11.56) compared to when these factors are not controlled (1.37). This serves as a robustness check, confirming the exogenous nature of production diversity when diet outcomes are measured by the number of food groups consumed, and its endogeneity when diet outcomes are assessed using weighted scores of foods consumed. Our analysis suggests that measuring dietary diversity through food consumption scores could introduce sources of bias when estimating the effects of agricultural production diversity on dietary diversity. In an additional robustness check using the OLS estimator, we find that the estimated coefficients of agricultural production diversity on food consumption scores are lower (1.729) than those obtained with the IV-OLS regression (7.79). This indicates that failing to control endogeneity leads to lower-bound estimates, potentially underestimating the true impact of agricultural production diversity on dietary outcomes.

Examining the Role of Markets in the Diet Outcomes of Smallholder Farm Households

In our study, we measure market access as the walking time to the nearby local market where the farm household will buy or sell food. As shown in equation (7), As outlined in equation (7), we analyze the role of markets in enabling the production, sale, and purchase of food in influencing household dietary diversity by incorporating market access as an additional explanatory variable. We hypothesize that agricultural production diversity will positively affect dietary diversity, while limited market access will have a negative impact on dietary diversity. As shown in Table 3, our preferred models accept the null hypothesis that production diversity is exogenous to household dietary diversity scores and endogenous to food consumption scores. In Table 10, the estimated coefficients for walking time to the nearest local market are negative and significant in both the Poisson and IV OLS models. This implies that as the distance to markets increases (i.e., households live farther away), their dietary diversity scores decrease. Specifically, an increase in walking time to the local market by 15 minutes is associated with a 20% probability that a household consumes one less food group. Conversely, reducing the walking time to the market by 15 minutes has a more negligible positive effect on dietary diversity compared to increasing farm production diversity by one additional food group (a 20% versus 24.9% probability of increasing dietary diversity, respectively). Additionally, a 15-minute decrease in walking time to the market increases household food consumption scores by 2.37 points, while the production of one additional food group on the farm increases the score by 7.96 points. Our findings suggest that while better market access significantly contributes to nutrition security and diet quality among smallholder households, agricultural production diversity has a greater positive impact on dietary outcomes.

We further explore the role of markets by interacting market access with agricultural production diversity in additional regression estimations, as described in equation (1). We hypothesize that with improved market access, households may prioritize farming for increased income and purchase a more diverse array of foods from the market. Our objective is to determine whether the effect of agricultural production diversity on diet outcomes depends on the household's level of market access. As validated by the IV strategy in Table 3, we use two instruments to control for the endogeneity of the two endogenous variables—agricultural production diversity and the interaction term agricultural production diversity*market access—on food consumption scores. Even with the interaction models, the coefficient for agricultural production diversity remains positive and significant. The marginal effects of agricultural production diversity on household dietary diversity scores increased to 0.34, and the food consumption scores increased to 8.51 points, as shown in Table 11. However, the interaction term between market access and agricultural production diversity shows a negative, though insignificant, coefficient. This suggests that with longer walking times to markets, agricultural production has a positive effect on dietary diversity, even though it lacks statistical significance in our study. Therefore, in areas with poor market access, increasing agricultural production diversity may be crucial for improving diet outcomes, though this effect was not statistically significant in our sample. Overall, our data suggests that the relationship between dietary diversity and agricultural production diversity is consistent across all levels of market access for smallholder farm households in the study area. However, poor access to consumer markets contributes to lower diet outcome scores, regardless of the role of agricultural production diversity.

Other Factors associated with Household diet outcomes

There are other factors strongly associated with household dietary diversity scores and food consumption scores. In all three estimations, as shown in tables 10 and 11, households have higher scores of both diet outcomes if they are female-headed, the woman in the household has a greater power or decision-making role. The overall nutrition knowledge of the household head and the household's access to non-farm income are positively and significantly associated with household dietary diversity scores. However, these factors do not show a significant association with food consumption scores. The score of food culture and diet attitudes is negatively associated with dietary diversity scores in all estimations, albeit insignificantly. This suggests that households with lower scores in these areas—indicating more favourable food culture attitudes—tend to have higher dietary diversity scores. Similarly, the score of attitudes towards diets is positively associated with dietary diversity scores, though this association is statistically insignificant. This implies that households with favorable attitudes toward diets and food culture are likely to experience better diet outcomes. Our analysis confirms that socio-cultural, economic, and demographic factors significantly influence the diet outcomes of smallholder farm households. These factors contribute meaningfully to the overall effect of agricultural production diversity and market access on dietary diversity.

8. Discussion

Malnutrition continues to exert a profound human and economic toll globally, particularly in sub-Saharan Africa, where it contributes to significant health expenditures and productivity losses. Currently, more than one in three people suffer from diet-related malnutrition, and if current trends persist, this number could rise to one in two. In Cameroon, the MICS 2014 survey revealed that 32% of the population suffers from chronic malnutrition, with 13% experiencing severe forms. The adult population in Cameroon faces a substantial malnutrition burden, with 44.4% of women of reproductive age affected by anemia, 6.9% of women suffering from diabetes (compared to 6.5% of men), and obesity affecting 16.4% of women and 6.1% of men.

The agricultural sector plays a crucial role in combating malnutrition, particularly among smallholder farmers and households who are disproportionately vulnerable to malnutrition indicators and are key players in food production. Enhancing dietary diversity and quality is essential for addressing malnutrition and improving the overall well-being of the poorest segments of the population. There is a growing consensus among the food and agricultural research, practice, and policy communities that agriculture must become more nutrition sensitive. Leading debates and technical solutions focus on enhancing dietary diversification among smallholder farm households by increasing agricultural production diversity at the farm level. However, recent studies have emphasized that the role of markets should not be underestimated in efforts to enhance dietary diversity and improve the nutritional status of smallholder farm households and the broader population.

Empirical evidence underscores the importance of dietary diversity in addressing the triple burden of malnutrition: undernutrition (inadequate intake of calories and proteins), micronutrient deficiencies, and overnutrition (excess energy intake leading to overweight and obesity). To our knowledge, previous studies examining the association between agricultural production diversity, market access, and household dietary diversity in resource-poor communities in Cameroon are lacking. This study appears to be the first to investigate the predictors of household dietary diversity among smallholder farm households in Cameroon. Our research examines the cross-sectional relationship between agricultural production diversity and two key indicators of dietary diversity—household dietary diversity score (HDDS) and food consumption score (FCS)—among smallholder farm households in the Fako Division of Cameroon, conducted between October 2018 and May 2019.

Descriptive Results

Distribution of Dietary Diversity Indicators in the Smallholder Farm Household

In this study, the household dietary diversity score and food consumption scores reflect nutrition security and diet quality of the smallholder farm household, respectively. Both dietary diversity indicators are useful for application with communities of the same agro-ecological zone, assumed to have similar dietary patterns (Kennedy et al., 2010). Most smallholder farm households (71.5%) in our sample consumed at least four different food categories or groups in the seven days before the survey. These households, categorized as having medium household dietary diversity, meet the WHO recommendation of consuming a minimum of four nutrient-rich food groups to ensure optimal micronutrient intake. This suggests that, on average, a significant proportion of smallholder farm households have diets that are nutrient adequate. Previous studies have reported high dietary diversity in rural food-producing communities (Ayenew et al., 2018; Kissoly, Faße, & Grote, 2018; O'Meara, Williams, Hickes, & Brown, 2019; Sibhatu & Qaim, 2018). However, some studies conducted in remote Papua New Guinea by Goris, Zomerdijk, & Temple (2017) and Kiribati Eme et al.(2019) in Asia have found that a majority of households did not consume at least 4 food groups, indicating low household dietary diversity. The mean household dietary diversity score in our study was 7.7, which is slightly lower than the mean score of 8.7 reported for central Uganda (Whitney et al., 2018) and similar to the mean score of 7.5 found in western Uganda by Sekabira et al. (2017). However, it is much lower than the mean score of 11.4 observed at the country level in Kenya (Sibhatu et al., 2015). Literature on dietary diversity in Cameroon is limited, but it is important to note that seasonal variations can influence food production, dietary diversity, and quality among smallholder farm households (Herforth & Harris, 2014). In our study, we do not expect significant seasonal variations to affect food consumption patterns. This is because we did not measure agricultural production diversity in terms of crop species diversity, whose production and consumption are seasonal in the study settings. However, further research is needed to confirm this assumption. It is important to note that a higher dietary diversity score is not always synonymous with good diet quality, particularly when more food groups with empty calories are consumed. In this study, we attempt to classify dietary diversity by using an additional indicator to reflect the quality of household diets. The conventional FCS (WFP, 2008) is micronutrient sensitive. We found that between October 2018 and May 2019, 77.9% of smallholder farm households in the study area had "poor" food consumption scores, while 21.2% had "borderline" scores, reflecting inadequate diet quality according to the adapted WFP classification. Despite an average of 7.7 food groups being consumed by households, cereal, tuber, and oil consumption predominated in both frequency and quantity. This indicates that over 95% of households consume more foods with empty calories compared to diverse, nutrient-rich food groups. In summary, while a significant proportion of households have, on average, diverse diets, a greater proportion exhibit food consumption patterns that are of inadequate quality or less healthy. The interpretation of the food consumption scores suggests that diets are characterized by a higher frequency of high-calorie food consumption and a lower frequency of fruit and vegetable consumption (Table 1). The HDDS and FCS statistics for rural smallholder farm households in this study are similar to those presented by WFP (2017) following the Comprehensive Food Security Vulnerability Assessment in Cameroon. Our study confirms that in smallholder farming communities, which often represent the poorest populations in developing countries, poor diet quality is common. Diets are predominantly based on starchy staples (Rathnayake et al., 2012; Ruel, 2002), and include only a limited amount of animal foods and seasonal vegetables and fruits (Arimond & Ruel, 2004; Herforth & Harris, 2014).

Overall, the dietary diversity indicators in our study suggest that while smallholder farm households may have average access to food, they frequently consume energy-dense foods and fewer micronutrient-rich foods. The fact that the food consumption score metric places households below the threshold for adequate or good diet quality, despite the average to high consumption of diverse foods, reflects the dampening effect of food consumption frequency on relative dietary diversity. Equally, this could mean that farmers' consumption choices are driven by the goal to address chronic hunger in households rather than “hidden” hunger. It is well established that increased consumption of fruits, vegetables, and legumes is linked to a lower risk of obesity, diabetes, cancer, and other cardiovascular diseases (Gibson, Wardle, & Watts, 1998; Key, 2011). Conversely, several studies have demonstrated both direct and indirect links between the consumption of unhealthy diets—those dominated by fats and refined carbohydrates—and the prevalence of overweight, obesity, and hypertension (Gulliford, Mahabir, & Rocke, 2003; Lakka & Bouchard, 2005; Cecchini et al., 2010; Kimani-Murage, 2013; Oladimeji et al., 2014). A long-standing consensus holds that overweight and obesity may result from limited food availability, which can lead to the consumption of obesity-promoting foods. Alaimo and colleagues (2001) further supported this paradox by demonstrating a relationship between low family income, food insufficiency, and overweight. Overweight and obesity may be attributed to overeating when food becomes available or to metabolic changes that hinder the efficient use of energy.

Table 10: The effects of Agricultural Production Diversity on Dietary Diversity Indicators

Explanatory Variables	**Model 2 Without Market Access**				**Model 3 With Market Access**			
	Household Dietary Diversity Score (HDDS) Poisson		**Household Food Consumption Score (FCS) IV OLS**		**Household Dietary Diversity Score (HDDS) Poisson**		**Household Food Consumption Score (FCS) IV OLS**	
	Coefficient	***RSE***	***Coefficient***	***RSE***	***Coefficient***	***RSE***	***Coefficient***	***RSE***
Agricultural Production Diversity (counts)	0.029**	*0.011*	11.43***	*3.161*	0.032***	*0.011*	7.79***	*2.38*
Female Household head	0.038**	*0.017*	3.083***	*1.12*	0.031**	*0.017*	3.06***	*0.96*
Age of household head (years)	0.001	*0.001*	-0285	*0.353*	0.001	*0.001*	-0.284	*0.274*
Age of household head (years)-squared	0.00001	*0.0001*	0.0014	*0.144*	0.00002	*0.0001*	0.002	*0.003*
Education of household head (years)	0.001	*0.002*	-0.125	*0.161*	0.001	*0.002*	-0.09	*0.13*
Household Size (No.)	-0.002	*0.003*	-0.387*	*0.212*	-0.001	*0.003*	-0.13	*0.18*
Log average income of last farming season	-0.074	*0.048*	-24.62***	*7.037*	-0.064	*0.049*	-15.45***	*5.27*
Having non –farm income(yes)	0.045***	*0.017*	1.55	*1.056*	0.040**	*0.016*	0.83	*0.87*
Level of access to nearby local market (categories of 15 minutes of walking time)	-	-	-	-	-0.026***	*0.006*	-2.37***	*0.31*
Women Power/Decision-making index	0.073***	*0.008*	2.62***	*0.502*	0.071***	*0.008*	2.40***	*0.44*
Overall score on knowledge on nutrition	0.013***	*0.005*	0.390	*0.300*	0.011**	*0.005*	0.25	*0.25*
Score of food culture attitudes	-0.002	*0.002*	-0.190	*0.143*	-0.002	*0.002*	-0.16	*0.10*
Score of attitudes towards diets	0.002	*0.002*	0.038	*0.132*	0.002	*0.002*	0.03	*0.11*
Log Farm operation size (m^3)	0.005	*0.019*	0.445	*1.245*	-0.005	*0.019*	-0.56	*1.08*
Residuals	0.032	*0.029*			2.206***	*0.516*		
Model Intercept	2.223***	*0.518*	266.94***	*70.77*	0.027	*0.029*	183.56***	*53. 49*
Marginal Effects of Agricultural Production Diversity (counts)	0.22**	*0.085*	-	-	0.24***	*0.083*	-	-
Marginal Effects of Level of access to nearby local market	-	-	-	-	-0.20***	*0.041*		
Number of Households	*494*		*494*		*494*		*494*	
R -squared / Centered R-squared Pseudo R-squared/	*0.0138*		-		*0.0178*		*0.0381*	
Pearson goodness of fit (Prob>Ch2)	*122.49(1.0)*				*117.53(1.0)*			
Log pseudolikelihood	*-1019.7*				*-1017.1584*			
Wald chi2	*132.42****		*60.41****		*186.21****		*144.69****	
First Stage Regression of Production Diversity								
Instrument: Use of Pesticides (UoP)			*0.336****	*0.672*				
Under-identification test: *Anderson canon. corr. LM statistic(P-value)*			*24.32(0.000)*					
Weak – identification test: Stock – Togo (2005)								
Sanderson-Windmeijer multivariate F test of excluded instruments (P – value):			*24.90(0.000)*					
Over – identification test: *Sargan Chi – square Statistic (P-value)*						*0.0000*		
Endogeneity test: *Wu –Hausman Chi –square (p- value*					*19.99(0.000)*			

*Coefficients of estimates with the robust standard errors (RSE) are shown in corresponding columns. *, **, *** denotes statistically significant estimates at the 10%, 5% and 1% level respectively*

Table 11: The Role of Markets on Agricultural Production Diversity on Dietary Diversity Indicators

Explanatory Variables	Model 2 with Interaction Term			
	Household Dietary Diversity Score (HDDS) Poisson		Household Food Consumption Score (FCS) IV OLS	
	Coeff	*RSE*	*Coeff*	*RSE*
Production Diversity (counts)	0.044**	*0.022*	8.507*	5.078
Access to the nearby local market (5 increasing categories of 15 minutes of walking time)	-0.017	*0.017*	-1.938	3.252
Production Diversity *Level of access to the nearby local market	-0.004	*0.007*	-0.192	1.454
Gender of Household head (female)	0.031**	*0.017*	2.970***	1.019
Age of household head (years)	0.001	*0.001*	-0.121**	0.058
Education of household head (years)	0.001	*0.002*	-0.088	0.132
Household Size (No.)	-0.001	*0.003*	-0.133	0.179
Log Average income of last season	-0.066	*0.049*	-16.014***	5.486
Having non –farm income(yes/no)	0.040**	*0.016*	0.846	0.885
Women Power/Decision-making index	0.071***	*0.008*	2.377***	0.480
Overall score on knowledge on nutrition	0.011**	*0.005*	0.238	0.264
Score of food culture attitudes	-0.002	*0.002*	-0.161	0.105
Score of attitudes towards diets	0.003	*0.002*	0.029	0.112
Log Farm operation size (m^3)	-0.005	*0.019*	-0.569	1.077
Model Intercept	2.217	*0.518*	8.507	5.078
Marginal Effects of Agricultural Production Diversity	0.339**	*0.165*		
Marginal Effects of Level of access to nearby local market	-0.126	*0.126*		
Number of Households			*494*	
F			*9.20****	
R -squared / Centered R-squared			*0.0254*	
Dispersion (1/df) Pearson statistic				
Pearson goodness of fit(Prob>Ch2)				
Log pseudolikelihood		*-1017.1*		
Wald chi2		*187.66*		
Pseudo R2		*0.0163*		
First Stage Regression of Production Diversity				
Instrument: Use of Pesticides (UoP)				
Under-identification test: *Anderson canon. corr. LM statistic(P-value)*			*23.652****	
Weak – identification test: Stock – Togo (2005)				
Cragg-Donald Wald F (Minimum Eigenvalue) statistic				
Critical value 10% max IV size				
Over – identification test: *Sargan Chi – square Statistic (P-value)*			*0.000*	
Endogeneity test: *Durbin - (Score Wu –Hausman Chi –square (p-value)*			*5.0663(0.0248)*	

The nature of Agricultural Production Diversity

In our sample of 494 households, the smallholder farm households produced an average of 2.1 food groups (ranging from 1 to 4). This average number of crops or livestock categories produced is relatively low compared to the average number of food groups consumed. Similar observations have been made in rural Uganda (Sibhatu et al., 2016), Tanzania (Kissoly et al., 2018), and Zimbabwe (Murendo et al.,2018). This could partly be explained by the fact that in smallholder farming systems in Africa, there is typically greater emphasis on and support to produce a wide variety of food species rather than a diverse range of food groups/categories. The number of different crop species tends to be high, while the diversity of food groups remains low (Sibhatu, 2015). Smallholders often choose to diversify the production of crop and livestock species as a risk mitigation strategy (Kissoly et al., 2018). Given that a household in our study consumes an average of 7.7 food groups within seven days but only produces 2 food groups, it is evident that a significant portion of a diverse diet must be sourced from the market. This discrepancy highlights that in this context, there is less emphasis on food group production diversity and a greater focus on species diversity, which may not align with nutritional goals.

Empirical Results

The number of food groups produced from crop and livestock species categories by households has a significantly positive effect on dietary diversity outcomes—both the household dietary diversity score (HDDS) and food consumption score (FCS) are positively influenced. However, the magnitude of this effect is small. Our findings align with several studies conducted in sub-Saharan Africa (Koppmair et al., 2016; Sibhatu et al., 2015; Kissoly et al., 2018; O'Meara et al., 2019; Sekabira & Nalunga, 2020). In our study, increasing agricultural production diversity by one food group is associated with only a 0.22 increase in the number of food groups consumed by the household. This implies that farms would need to produce five additional food groups to increase the consumption of each food group by just one. Jones (2018) reports that the mean marginal effects of agricultural production diversity on dietary diversity are generally minimal (0.062), regardless of the indicator used for production diversity. It is important to note that the effect sizes mentioned in Jones' review and other studies (Sibhatu et al., 2016; Bellon et al., 2016) focused on the effect of crop or livestock species production and were smaller (0.009 to 0.062) than the effect sizes observed by Koppmair et al. (2018) and in our study (0.12 and 0.22, respectively), which both focused on food group production. These analyses suggest that the effect on dietary diversity is somewhat larger when production diversity is measured at the food group level rather than at the crop or livestock species level. Our study shows that while better market access plays a significant positive role in nutrition security and diet quality for smallholder farm households, agricultural production diversity has an even greater positive effect on dietary outcomes. These results are expected, given that these smallholder farm households are primarily subsistence-oriented in their agricultural production, like the majority of rural households in Cameroon.

Furthermore, our study seeks to understand how agricultural production diversity is associated with food consumption patterns that may reduce the diet-related risk of non-communicable diseases (NCDs) in smallholder farm households. Using the food consumption score as a proxy for diet quality, our findings reveal that producing an additional food group on the farm is associated with an increased probability of consuming diets that lower the risk of NCDs. It is well established that increased consumption of fruits, vegetables, and legumes is linked to a lower risk of obesity, diabetes, cancer, and other cardiovascular diseases (Gibson et al., 1998; Key, 2011). Table 7 shows that households consume a combination of fewer food groups produced on the farm (mean = 1.51) and more food groups purchased from the markets (mean = 4.66). Our study concurs with the finding that despite their subsistence orientation, smallholders often purchase more than half of all foods consumed from the market (Jones, 2017; Sibhatu & Qaim, 2017; Bellon et al., 2015). This observation suggests that the market pathway and own-production pathway have a mutual effect on the dietary outcomes of households. Therefore, agricultural production is crucial for household diets through the market pathway, as households with limited food group diversity from their production are likely to purchase foods to achieve higher-value, nutritious diets beyond starchy staples (Sibhatu & Qaim, 2018). The negative effect of longer walking times to nearby consumer markets on diet outcomes observed in our study suggests that households with less access to consumer markets rely more on their own production for dietary diversity and less on market purchases. Our results align partially with other studies, which have found that market access can directly influence dietary diversity, although those studies often report that the effects of market access are larger than those of agricultural production diversity (Hirvonen & Hoddinott, 2017; Jones, 2017; Koppmair et al., 2017; Sibhatu et al., 2015; Jones et al., 2014; Pellegrini et al., 2014; Keding et al., 2012). We assessed the mediating role of the market in the relationship between production and consumption by hypothesizing that the positive association between agricultural production diversity and diet outcomes would be less pronounced in households with greater market access. However, this trend was not observed in our study, which contrasts with findings from previous research (Hirvonen & Hoddinott, 2017; Jones, 2017; Koppmair et al., 2017; Sibhatu et al., 2015; Jones et al., 2014; Pellegrini et al., 2014; Keding et al., 2012). In our study, the positive association between agricultural production diversity and dietary diversity or diet quality remained consistent across households, irrespective of market access. This finding of no evidence for effect modification by market access is consistent with the literature from Jones et al. (2014). Our findings are plausible given that households in the rural Southwest region of Cameroon are predominantly subsistence agricultural households living in the context of poorly functioning markets. While these households are considered subsistence farmers, they are not closed systems. Consistent with existing evidence that nutritional outcomes are influenced by factors beyond the agroecosystem and food market environment, we analyzed the role of wealth, economic status, and other significant factors that could proxy for the role of socio-cultural norms and perceptions on food consumption. Our results reveal that female-headed households tend to have better dietary outcomes. Similarly, households where women have greater involvement in decision-making regarding food allocation, preparation, and other household decisions also experience better diet outcomes. Additionally, we observed that better nutrition knowledge among household heads contributes to improved diet outcomes. Although our study does not establish statistical significance for the negative effect of unfavorable diet and food culture attitudes on diet outcomes, our analyses indicate that a substantial number of smallholder farm households hold unfavorable socio-cultural norms and preferences regarding food. The relevance of assessing the implications of agricultural and dietary diversity on nutritional outcomes is crucial given the current context of the triple burden of malnutrition in communities across sub-Saharan Africa, including Cameroon. Managing diseases related to malnutrition is expensive, with most healthcare costs borne by patients without health insurance, leading to significant lifelong out-of-pocket expenses and further impoverishment. These economic burdens undermine efforts to reduce poverty and promote economic growth among the rural poor. Mortality and morbidity from malnutrition can lead to decreased labor force participation and reduced productivity among smallholder farmers. The emergence of NCDs exacerbates inequities, as the economic impact of NCDs is disproportionately greater among poor and vulnerable households, such as farming households (Engelgau, Karan, & Mahal, 2012). For smallholder farmers living on less than a dollar a day, this could mean the potential loss of earnings equivalent to two months of living expenses. In developing countries, the burden of NCDs and associated risk factors is increasingly shifting towards the poorer segments of the population (UNICEF/WHO/World Bank Group, 2019). Overall, the growing prevalence of NCDs among agricultural producers will ultimately limit the contribution of agriculture to the national Gross Domestic Product.

Limitations

We note that although a cross-sectional survey is time-saving and cost-effective, using cross-sectional data to estimate dietary diversity requires attention, as one-time data collection on foods consumed may not reflect the actual pattern of food consumption in a household. This is a potential gap that lends an area of caution in further research. Mindful of this limitation, a longer recall period of 7 days instead of 24 hours was employed to provide a better reflection of the pattern of food consumption by the household. In another dimension, establishing the implications of agricultural production diversity on dietary diversity, including its quality, with cross-sectional data requires a thought-through rigorous methodology. Although we have used cross-sectional data to establish effects and attempted to find instruments with some rigour, the instrumental variable regression estimates of effects are valid based on the suitability of these instruments. We agree that panel or time series data obtained through repeated surveys would be ideal in future research for estimating the effects of agricultural production diversity on the nutritional outcomes of smallholder farm households in Cameroon.

Our study uses the household dietary diversity score to measure the number of various food groups consumed. This metric can reveal high dietary diversity (7 – 12 food groups) in a 7-day food consumption pattern of a household that is characterized by consumption of large quantities of only 2-3 food groups and the consumption of minimal quantities of a greater number of food groups. Therefore, this measure of diet outcomes does not capture the frequency and weights of various food groups consumed, which can be less meaningful in characterizing the quality of diets linked to health outcomes. Our dataset lacks sufficient consumption or food expenditure data to address the issue. We adopted a second metric – FCS- to address diet quality. To an extent, the use of the FCS minimises the bias this limitation can introduce to the conclusion and discussion of our study.

Lastly, we acknowledge the significance of market participation on diet outcomes for the farm households, which our study fails to capture in the estimations. We assume that market access and participation logically have the same implications on diet. Even with these possible limitations, our study provides relevant empirical insights into the complex link between agricultural production diversity and household diet outcomes.

Conclusion and Policy Implications

The fundamental assumption of nutrition-sensitive agriculture (NSA) is that diversified agricultural production can significantly improve diet diversity, especially in poor communities and households. This approach is widely recommended for state policy investments aimed at reducing all forms of malnutrition. However, for sustained nutritional outcomes, it is crucial to recognize the complex linkages between agriculture and nutrition, which extend beyond agricultural production and market environments. These linkages include the socio-cultural context of households and communities, which influences food consumption choices. These choices are shaped by factors such as the level of knowledge and awareness of the nutritional value of various foods, as well as socio-cultural beliefs, preferences, and norms regarding certain foods. Our study, conducted in the Fako Division of Cameroon, highlights that while increasing smallholder farm production can improve food accessibility and availability, it may not always yield the expected nutritional outcomes in terms of dietary diversity and quality. Although socio-demographic factors are often considered in various effect estimations, significant socio-cultural factors related to food utilisation, which contribute to poor nutrition outcomes, are often overlooked. Utilizing cross-sectional data collected from smallholder farm households between October 2018 and May 2019, this paper begins to fill the gap in research and policy debates by examining the effect of agricultural production on household dietary diversity and food consumption. Additionally, we investigate the potential association of household knowledge of nutrition and socio-cultural norms or preferences on nutrition indicators that influence health outcomes in rural settings.

We analysed data from a sample of 494 rural smallholder farm households across four subdivisions within the same agroecological context in Cameroon. Two indicators of dietary diversity—household dietary diversity scores (HDDS) and food consumption scores (FCS) were used to assess the significance of agricultural production diversity (measured by the number of crop and livestock species categories produced in the last farming season) and market access (measured by walking time to the nearby local market) on diet outcomes. We employed instrumental variable regression to address the endogeneity of agricultural production diversity in relation to diet outcomes, as measured by the FCS. We used a Poisson estimator for the HDDS metric. Our comprehensive dataset allowed us to control a rich set of household economic, wealth, demographic, and socio-cultural variables. Specifically, we examined the nature of diets and analysed the effect of agricultural production diversity and market access on dietary diversity. Our study shows that agricultural production diversity is positively associated with dietary diversity and diet quality for smallholder farm households. However, market access also significantly explains variations in dietary diversity among these households. We found a correlation between knowledge of nutrition and attitudes related to food culture and diets, particularly regarding dietary diversity. Our regression analysis highlights that the effect of agricultural production diversity on smallholder farm households' dietary diversity is relatively small, with an estimated marginal effect of 0.24. This implies that smallholder farmers would need to produce 4.2 additional food groups to increase dietary diversity by one food group. The effect of improving agricultural production diversity by one food group is somewhat larger than the effect of improving market access by reducing walking time to the nearby market by 15 minutes.

In examining FCS as a measure of diet-related disease risk, we find that smallholder farm households are exposed to inadequate diets, which could place them at risk for diet-related non-communicable diseases (NCDs) over time, especially if preventive strategies like physical activity are lacking. Our findings corroborate this analysis, showing that higher levels of agricultural production diversity correlate with an increased likelihood of consuming better diets. Moreover, our results indicate that while access to markets is crucial for improving diet outcomes, the level of market access does not significantly modify the effect of agricultural production diversity on dietary diversity. Despite the positive role of agricultural production diversity and market access in enhancing dietary diversity and food consumption outcomes, our findings reveal patterns of inadequate diet quality. These patterns are characterised by a high frequency of consuming high-calorie foods and a lower frequency of consuming fruits and vegetables, even with average to high consumption of diverse foods. This reflects the dampening effect of food consumption frequency on relative dietary diversity. Additionally, we find that socio-demographic factors and proxy indicators of household nutrition-related knowledge, norms, and preferences are significantly associated with diet outcomes. Given that households in rural southwest Cameroon are predominantly subsistence agricultural households living in the context of poorly functioning markets, our findings are plausible. Diverse preferences, structural biases, and ideological perceptions around food influence these households.

Our study underscores the need for agricultural investments and policies to be more nutrition sensitive. Promoting food group production diversity is a sustainable approach to enhancing dietary diversity and reducing poverty among agricultural households. However, the question remains: How effective and sustainable is agricultural production diversity in improving nutrition and health outcomes?
We note that the goal of agricultural production diversity in subsistence settings is not to obstruct market integration and development, which brings economic benefits. Our study highlights the essential role of markets in providing access to diverse and healthy diets. Markets are crucial for supplying food that is not locally available or can be more efficiently produced elsewhere. More diverse production destined for markets can have indirect effects on diets beyond the individual producing households. Markets provide cash and increase incomes, which can benefit households. However, it is important to recognize that increased income may not necessarily lead to better nutritional outcomes, as higher incomes could result in higher non-food expenditures. Therefore, caution is needed when promoting market integration solely for income generation, as it may not directly translate into improved nutritional outcomes.

In settings with limited access to consumer markets, a high food price-to-wage ratio, especially for nutrient-rich foods, can restrict access. In contrast, highly processed, nutrient-poor foods may dominate the markets. Diversifying into nutrient-dense foods may offer greater benefits than specialization or intensification of agriculture. Agricultural specialization could lead to a loss of nutritionally important foods, such as fruits and vegetables, from these production systems. This would negatively impact their availability and price, with dietary implications for the rural poor. Promoting the specialization of less perishable foods, such as staples, becomes costly in settings with limited market infrastructure, like the area studied, where the flow of nutrient-rich foods from other regions is restricted. In such contexts, agricultural production diversity ensures that perishable foods critical for diet diversity and quality are readily available and accessible for consumption.

Given the emerging landscape of diet-related chronic illnesses and the persistent challenge of malnutrition, critical consideration should be given to policies that guide smallholder farmers in developing contexts, like Cameroon, from diverse traditional agrarian systems to less diverse, high-input intensive agriculture, favouring single crops, staples, or cash crops. This evolution, compounded by socio-cultural norms and perceptions at both the household and community levels, has led to unintended consequences for local diets. Sustainable approaches are necessary if this transition is to be pursued as the only option for poverty alleviation in rural areas.

Based on our findings, we offer three policy recommendations that encourage governments, agricultural and food research, and policy institutions to move beyond siloed approaches to agricultural, economic, and social policies. We suggest i) Nutrition-sensitive policies should not only promote improvements on the supply side (agricultural production diversity) but also on the demand side (farm household knowledge, attitudes, and practices, as well as purchasing power). ii) Policies that strengthen participation and access to markets will not only improve income but also reduce poverty and enhance diet outcomes. Iii) Social policies and investments should focus on enhancing nutrition knowledge through both formal and informal learning channels to encourage healthy food choices and diets, even amidst prevailing cultural norms and perceptions.

In summary, agricultural and food policies and investments should adopt an integrated approach that aligns with societal and cultural contexts to effectively and sustainably address the challenges of poor nutrition. In both policy and practice, agricultural production diversity should be part of an integrated strategy that promotes market access and encourages more nutritious food choices. This approach will help uphold healthy diets, reduce malnutrition-related social and economic costs, and improve the productivity of vulnerable farming populations.

9. References

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To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

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