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Subsistence Production, Markets, and Dietary Diversity in the Kenyan Small Farm Sector

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Abstract

Undernutrition and low dietary quality remain widespread problems especially among smallholder farmers in sub-Saharan Africa. Hence, the question as to how smallholder systems can be made more nutrition-sensitive is of particular relevance for research and policy. Recent studies analysed whether increasing farm production diversity may help to improve nutrition and found a positive but small effect on dietary diversity. The underlying mechanisms were not examined in detail. This paper tests the hypothesis that the effect of farm diversity on nutrition is small because production diversity is positively associated with dietary diversity from subsistence but negatively associated with dietary diversity from the market. This hypothesis is confirmed with data from Kenya, using different indicators of production diversity and dietary diversity scores at household and individuals levels. The results underline the important role of markets for smallholder diets and nutrition. Hence, strengthening markets and improving market access should be a key strategy to make smallholder systems more nutrition-sensitive.

Keywords: Nutrition-sensitive agriculture, malnutrition, food security, smallholder farmers, Africa

JEL classification: I15, O12, Q12

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1. Introduction

Undernutrition is a widespread problem in many developing countries. While the proportion of undernourished people declined significantly during the last few decades, the number of people with insufficient access to food remains high and even increased recently in sub-Saharan Africa (FAO, 2018). Beyond food quantity, dietary quality and diversity are important for healthy nutrition, especially with a view to micronutrient sufficiency. Undernutrition and micronutrient malnutrition remain the leading risk factors for child mortality and other serious health issues in Africa (Gödecke *et al*., 2018; IFPRI, 2017).

Many of the people affected by undernutrition and micronutrient malnutrition are smallholder farmers. Hence, the question as to how smallholder systems can be made more nutrition-sensitive has received considerable attention in the recent literature (Ruel *et al*., 2018; Carletto *et al*., 2015). One common recommendation is to increase farm production diversity (Fanzo *et al*., 2013). As smallholder households typically consume large proportions of what they produce at home, higher production diversity may also lead to higher dietary diversity. Indeed, several recent studies found a positive relationship between farm production diversity and dietary diversity in the small farm sector of different developing countries (Ecker, 2018; Hirvonen and Hoddinott 2017; Koppmair *et al*., 2017; Bellon *et al*., 2016; Romeo *et al*., 2016; Sibhatu *et al*., 2015; Jones *et al*., 2014). However, the effect of production diversity on dietary diversity was found to be small in many cases, which could mean that introducing additional species may not be the most effective strategy to improve nutrition in smallholder households. A few authors argued that the small effects might be due to measurement issues and that the picture could change if other indicators were used (Verger *et al*., 2017; Berti, 2015), but recent reviews showed that the mean effects remain small even with alternative indicators of production diversity and diets (Sibhatu and Qaim, 2018a, 2018b).

Here, we hypothesize that the association between farm production diversity and dietary diversity is small because production diversity may have a positive effect on diets through the subsistence pathway, which is often counteracted, however, by a negative effect through the market pathway. Even though smallholder farmers tend to be subsistence-oriented, a sizeable share of their diets is typically also obtained from the market (Sibhatu and Qaim, 2017; Frelat *et al*., 2016; GLOPAN, 2016; Luckett *et al*., 2015). Increasing farm production diversity can lead to a substitution of subsistence for food market purchases, so that the total effect on dietary diversity may be reduced. While the important role of markets for smallholder diets was highlighted in previous research

(Koppmair *et al.*, 2017; Barrett, 2008), we are not aware of studies that explicitly differentiated between subsistence and market pathways. We address this research gap with data from farm households in Western Kenya.

In particular, we examine the association between farm production diversity and dietary diversity as a whole and then extend the analysis by separately looking at dietary diversity from subsistence and dietary diversity from the market. This analysis can help to better understand the underlying mechanisms and develop effective strategies towards making smallholder systems more nutrition-sensitive. We also test the robustness of the results by using various indicators of production diversity and dietary diversity with household-level and individual-level data for women and children. Farms in Western Kenya are predominantly small and subsistence-oriented, which is typical for sub-Saharan Africa. Hence, the results may offer some broader lessons also beyond the concrete empirical setting.

2. Conceptual Framework

The available literature on farm production diversity and dietary diversity has implicitly assumed a direct link between these two variables by estimating regression models of the following type:

$$DD = \alpha_0 + \alpha_1 PD + \varepsilon \quad (1)$$

where *DD* is an indicator of dietary diversity, *PD* is an indicator of farm production diversity, and ε is a random error term. However, in reality the relationship is less direct because households obtain their food from different sources, including subsistence production and market purchases.[1] Hence, overall dietary diversity is a function of dietary diversity from subsistence and dietary diversity from the market, as shown in Figure 1.

Figure 1 about here

Farm production diversity has a direct effect on dietary diversity from subsistence, which is expected to be positive. But farm production diversity may also affect dietary diversity from the market, and this partial effect may be negative. Up to a certain extent, a negative partial effect may simply be due to dietary substitution: if a household produces certain food items itself, there may be no need to obtain the same foods also from the market. However, increasing farm production diversity may also affect household income and thus the ability to buy food in the market (Dzanku and Mawunyo, 2018). If production diversification is a response to market incentives, household

[1] Other sources can include the collection of wild foods, gifts, and transfers, but subsistence production and market purchases are generally the most important ones (Sibhatu and Qaim, 2017).

income may rise, which could lead to higher dietary diversity through the market pathway. For instance, Hirvonen and Headey (2018) showed that rural households in Ethiopia are more likely to grow vegetables in home gardens when they are located close to the market, probably because market closeness allows these households to also sell some of the vegetables produced. Similarly, Bellon *et al*. (2016) found that better market opportunities were associated with higher levels of farm diversification in one region in Benin. More typically, however, the opposite is true: farms with poor market access are more diversified and subsistence-oriented (de Janvry *et al*., 1991). While farm diversification can be an effective mechanism to reduce risk, diversifying beyond optimal levels can be associated with income losses due to foregone benefits from specialization (Sibhatu and Qaim, 2018b). Such income losses may imply lower economic ability of households to buy food diversity from the market.

Against this background, we hypothesize that farm production diversity is positively associated with dietary diversity from subsistence (DD_{sub}), but negatively associated with dietary diversity from the market (DD_{mar}). This hypothesis is tested using the following regression models:

$$DD_{sub} = \beta_0 + \beta_1 PD + \varepsilon \quad (2)$$

$$DD_{mar} = \gamma_0 + \gamma_1 PD + \varepsilon \quad (3)$$

where β_1 is expected to be positive, and γ_1 is expected to be negative. A negative γ_1 might also explain why the combined effect of production diversity on total dietary diversity (DD_{tot}) is often smaller than expected. These partial effects were not analysed in previous research. We will use equation (1) to estimate the combined effect and equations (2) and (3) to estimate the partial effects, with and without additional control variables included.

3. Materials and Methods

3.1 Household Survey

Data for this study were collected from farm households in the counties of Kisii and Nyamira in Western Kenya through a survey that was implemented in November and December 2016. Kisii and Nyamira are characterized by high population density, very small farm sizes, and favourable agricultural potential. With over 1000 mm of annual rainfall spread over two extended rainy seasons, agricultural production takes place all the year around. As a result, there is relatively little seasonal variation in production and consumption, which is advantageous for our analysis, because data were only collected during a two-months period. In spite of the favourable agricultural conditions, over 50% of the smallholder farm households in Kisii and Nyamira live below the poverty line (Ogutu and Qaim, 2018). Undernutrition is also widespread in the study region. According to official statistics, 25% of the children in Kisii and Nyamira are affected by stunting (low height-for-age), the most common indicator of child undernutrition (KNBS, 2014).

To get a representative sample of farm households in the absence of recent census data, we exploited the fact that the majority of rural households in the study area are organized in common interest groups (CIGs), such as farmer groups, church groups, or self-help groups. These common interest groups are registered with the Ministry of Social Services. Based on the Ministry list of CIGs and with the help of Africa Harvest, a local non-governmental organization active in the region, we identified the existing CIGs in Kisii and Nyamira and randomly sampled 48 groups that were spread over 8 different sub-counties. In each of these 48 CIGs, we randomly selected 15-20 households (depending on group size), resulting in a total sample of 757 farm households.

The selected households were personally interviewed with a structured questionnaire that was carefully designed and pre-tested. The interviews were conducted in local languages by trained enumerators, who were supervised by the researchers. The questionnaire included sections on farm production characteristics, other household economic activities, general socioeconomic conditions, and consumption. Food consumption at the household level was captured through a 7-day recall. In addition, individual food intakes were captured with a 24-hour dietary recall. Dietary recalls for children were answered by the mother or another caretaker of each child.

3.2 Measurement of Dietary Diversity

We compute three types of dietary diversity scores, as shown in Table 1. Dietary diversity scores count the number of different food groups consumed over a certain period of time and are widely used indicators of food access and dietary quality. Various studies showed that dietary diversity scores are significantly correlated with more comprehensive measures of diets and nutrition (Fongar *et al.*, 2018; Headey and Ecker, 2013; Arimond and Ruel, 2004). The first score that we use is the household dietary diversity score (HDDS) with a total of 12 food groups (FAO, 2011). We calculate the HDDS based on data from the 7-day food consumption recall.

HDDS is a good proxy of food security, but not necessarily of dietary quality (Verger *et al.*, 2017). Dietary quality is better captured with individual-level data. Therefore, the other two scores are calculated at the individual level for women and children aged 6-59 months, using the 24-hour dietary recall data. Women and children are of particular interest, because they are typically most affected by undernutrition and micronutrient malnutrition (IFPRI, 2017). For women, we calculate the Women's Dietary Diversity Score (WDDS) using 9 food groups (FAO, 2011). For children, we calculate a Child Dietary Diversity Score (CDDS), using the 7 food groups recommended by WHO (2008) for assessing minimum dietary diversity of small children. The food group classifications for all three scores are shown in Table 1.

Table 1 about here

All three dietary diversity scores are first calculated taking into account all foods consumed by households and individuals, regardless of the particular food source. In a second step, we re-calculate two additional versions of all three dietary diversity scores by (i) only considering the foods consumed from subsistence production ($HDDS_{sub}$, $WDDS_{sub}$, $CDDS_{sub}$) and (ii) only considering the foods consumed from the market ($HDDS_{mar}$, $WDDS_{mar}$, $CDDS_{mar}$). Note that the total dietary diversity scores are not necessarily the sum of the scores from the two sources, because certain food groups may be obtained from subsistence and from markets (or other sources) simultaneously.

3.3 Measurement of Farm Production Diversity

Farm production diversity can be measured in different ways. One common approach is to simply count the different crop and animal species produced by the farm household (Sibhatu *et al.*, 2015; Jones *et al.*, 2014. We use such a species count as one measure of farm production diversity. However, this simple count also includes non-food cash crops that cannot contribute to dietary diversity through the subsistence pathway. Moreover, different crop species that belong to the same food group – such as different types of cereals – may not add to diets when these are assessed with dietary diversity scores (Berti, 2015). Therefore, we calculate production diversity scores that count the number of different food groups produced, using the same food group classification as for the HDDS. Production diversity scores were also calculated and used in other recent research analysing the association between production diversity and dietary diversity (Sibhatu and Qaim, 2018b; Hirvonen and Hoddinott, 2017; Koppmair *et al.*, 2017).

3.4 Measurement of Other Key Variables

In some of the regression model specifications we use control variables that may also affect dietary diversity and may possibly be correlated with farm production diversity. Control variables include farm size, household size, gender, age, and education of the household head, education of the spouse, and distance to markets. We differentiate between two types of markets, namely the main agricultural markets, which are typically located in the next bigger town, and the village market. For the child dietary diversity models we also control for the age of the individual child.

Household income is also expected to influence dietary diversity, but much of the income in sample households is derived from farming, and farm income is directly affected by farm production patterns and production diversity (Sibhatu and Qaim, 2018b). Hence, controlling for farm income would bias the estimates of farm production diversity. Instead we control for off-farm income sources, which may also influence dietary diversity. As off-farm income is typically earned by individual household members, we differentiate between off-farm activities of the household head and the spouse, which may also reveal interesting gender patterns. Finally, we control for farmers' social networks through a variable that counts the number of other persons within the CIG that the farmer interacts with on topics related to food and agriculture. These informal social networks are an important channel for the flow of agricultural and nutrition information in rural Kenya (Jäckering *et al.*, 2018).

3.5 Regression Estimators

As explained in section 2, we estimate the models shown in equations (1) to (3) to analyse the association between farm production diversity and dietary diversity. In these models, the dependent variables are dietary diversity scores, which are count variables. Count data models are typically estimated with a Poisson estimator (Greene, 2007). The standard Poisson estimator assumes equi-dispersion in the data, implying that the variance of the outcome variable is equal to its mean. We tested the equi-dispersion assumption in our data and found that the variance of all dietary diversity scores is significantly lower than the mean, indicating the presence of under-dispersion. Against this background, instead of the standard Poisson estimator we use the generalized Poisson model, which is more suitable to analyse under-dispersed data (Harris and Young, 2012). We use the generalized Poisson estimates to calculate marginal effects for all variables, which are more straightforward to interpret.

4. Results

4.1 Descriptive Statistics

Descriptive statistics for the main variables used in this study are shown in Table 2. The farms are small in size and quite diverse in their production patterns. On average, farms produce 13.4 different crop and livestock species, including maize, sorghum, millet, beans, bananas, different types of vegetables, as well as cash crops such as tea, coffee, and sugarcane. Many households also keep sheep, goats, chicken, and sometimes cattle. The average production diversity score is 5.8, meaning that households produce more than five different food groups on their farms.

Table 2 about here

The lower part of Table 2 shows the different dietary diversity scores. The HDDS is larger than the WDDS and the CDDS, which is plausible for three reasons. First, the HDDS includes a larger number of food groups than the other two scores. Second, the HDDS considers the foods consumed by all household members, whereas the WDDS and CDDS only include the foods consumed by individual women and children. Third, for the calculation of HDDS we used data from the 7-day food recall, meaning that all foods consumed over a 7-day period were considered, whereas the WDDS and CDDS were calculated using 24-hour recall data.

Households obtain a larger part of their food diversity from the market than from subsistence production (Table 2). This is in line with recent results from other African contexts (Hirvonen and Hoddinott, 2017; Sibhatu and Qaim, 2017). The picture is somewhat different for the WDDS and CDDS disaggregation, where subsistence and market sources both account for about half of total dietary diversity. The larger role of markets for HDDS is due to the fact that the HDDS also includes food groups such as oils and fats, sweets, and other processed foods that are only purchased in the market. Interesting to note is that the average number of food groups produced on the farms is larger than the number of food groups consumed from subsistence. Seasonality may potentially play a role here, because the HDDS only considers foods consumed during the last 7 days. On the other hand, there are also certain foods that farms produce and sell without consuming them on a regular basis. This is especially true for certain types of vegetables, but also for eggs and other animal products. For instance, 80% of the sample households produce eggs, while only 34% of them consumed eggs from their own farm during the 7-day recall period.

In Table 3, we compare more specifically which of the food groups are produced by many farm households and what shares of total consumption are obtained from subsistence and from the market.[2] Almost all households produce cereals, especially maize, but at the same time almost all households also purchase cereal products from the market. Around 40% of all cereal foods consumed in the farm households were obtained from the market, which often involves semi-processed products such as maize and wheat flour. Similarly, almost all households grow

[2] For some of the food groups, the subsistence and market shares do not add up to 100%, because small quantities are also obtained from other sources, such as collection of wild foods, gifts, and transfers. However, subsistence and markets account for over 95% of the quantities consumed in most cases.

vegetables and fruits, but the majority also buy items from these food groups in the market. For instance, a household may grow kale and bananas, but may buy other fruits and vegetables such as tomatoes and papaya. This means that most households specialize in producing certain species rather than trying to produce everything that they would like to consume. Most of the roots and tubers, meat, fish, and highly processed food products are obtained from the market, as one would expect.

Table 3 about here

In Table 4, we subdivide the total sample into two subsamples of equal size according to their level of commercialization, using the proportion of farm output sold as the distinguishing variable. More commercialized households have higher HDDS and WDDS than less commercialized households (Table 4). Interesting to note is that farm commercialization seems to be more strongly associated with dietary diversity from subsistence than with dietary diversity from the market, underlining the complex relationships between production, consumption, and market participation. For CDDS, no significant differences can be observed between more and less commercialized households.

Table 4 about here

4.2 Estimation Results

Table 5 presents the estimation results of the models explained in equations (1) to (3) with only farm production diversity included as explanatory variables. For each model, we estimate two versions; first, using the simple species count as the production diversity indicator, and second, using the production diversity score. We start the interpretation by looking at the association of these variables with household-level dietary diversity, presented in the upper part of Table 5. Farm production diversity is positively associated with total HDDS, but the magnitude of the association is relatively small. The marginal effect of 0.047 suggests that each additional species produced on the farm is associated with a 0.047 increase in the number of food groups consumed. In other words, households would have to produce more than 20 additional species in order to increase HDDS by one food group. The association is larger when the production diversity score is used, as demonstrated in previous research (Sibhatu and Qaim, 2018a). But the marginal effect remains relatively small: the value of 0.22 implies that more than four additional food groups would have to be produced in order to increase HDDS by one food group.

Table 5 about here

The results for $HDDS_{sub}$ and $HDDS_{mar}$ in Table 5 reveal the pathways that were outlined in the conceptual framework and confirm the main hypothesis of this study: farm production diversity is positively associated with dietary diversity from subsistence, but negatively associated with dietary diversity from the market. As expected the partial effects through the subsistence pathway are larger than the total effects. Interesting to note, however, is that even when the production diversity score is used, the effect on dietary diversity from subsistence remains significantly smaller than one (0.64). Hence, the production of one additional food group on the farm does not necessarily mean that this additional food group would also be consumed by the farm household. This is in line with the above-mentioned finding that certain foods are produced primarily for the market and not consumed by the farm households on a regular basis.

The middle and lower parts of Table 5 show the results with individual-level dietary diversity scores as dependent variables. For women, the results are similar to what we found at the household level: farm production diversity is positively associated with dietary diversity from subsistence but negatively associated with dietary diversity from the market. The combined effect is positive and relatively small. The marginal effects on WDDS are smaller than those on HDDS in absolute terms, which is due to the smaller number of food groups considered in calculating the WDDS. For children, we also find positive and negative partial effects of production diversity on dietary diversity from subsistence and from the market, respectively. But as both partial effects are similar in absolute magnitudes, they balance out so that the combined effects are not significantly different from zero. We conclude that using individual-level instead of household-level data to assess dietary diversity does not change the main results considerably.

In Tables 6 to 8, we show results of the same type of model estimations for HDDS, WDDS, and CDDS, but with other control variables included.[3] The first observation is that the estimates for farm production diversity are not much affected by the inclusion of other control variables, which underlines the robustness of the results discussed above. Beyond this robustness check, some of the control variables are also of interest in their own right, as they help to better understand dietary diversity outcomes. Farm size is positively associated with HDDS (Table 6), which is unsurprising given that farm size is a common indicator of household wealth. The effect of farm size is particularly channelled through the subsistence pathway (Table 6). Interestingly, the combined effect of farm size on dietary diversity is not significant for women (Table 7), and is even negative for children (Table 8).

Table 6 about here

[3] The numbers of observations in the model estimates in Tables 6-8 are slightly smaller than in Table 5, which is due to missing values for some of the control variables.

Table 7 about here

Table 8 about here

Male household head is positively associated with household and individual dietary diversity. This effect is mainly driven by households with male household heads having larger incomes on average. Female-headed households are often those where the male household head died or left, which tends to reduce the income-earning opportunities for the rest of the family. Education of the household head and the spouse has positive marginal effects in several of the models. Diets are not only determined by income but also by nutrition knowledge, and nutrition knowledge tends to increase with rising educational levels. The important role of knowledge and access to information is also stressed by the positive marginal effects of the social network indicator. Informal social networks can play an important role for the spread of agricultural and nutrition information in rural areas of Africa (Jäckering *et al*., 2018).

Other interesting results relate to off-farm employment of the spouse, who is usually the wife of the male household head. Off-farm employment of the spouse is positively associated with total HDDS and WDDS (Tables 6 and 7). The effect of spouse employment on dietary diversity from subsistence is negative, which is probably related to the fact that spouses with off-farm employment have less time to spend on the farm. However, this negative effect is overcompensated by a larger positive effect on dietary diversity from the market. Female spouses with off-farm employment often have more freedom to decide what to buy, which contributes to female empowerment. And research shows that female-controlled income has more positive effects on dietary quality and nutrition than male-controlled income (Chege *et al.*, 2015; Hoddinott and Haddad, 1995).

Distance to the main agricultural market has insignificant effects in most of the models, but the effect on WDDS in Table 7 is negative and significant, as one would expect. Distance to the village market has positive marginal effects on dietary diversity in some of the models, which is particularly channelled through the subsistence pathway. This is plausible, since households with limited market access are often more oriented towards subsistence production (Hirvonen and Hoddinott, 2017; de Janvry *et al*., 1991).

5. Conclusion

Smallholder farmers in sub-Saharan Africa remain one of the groups that are most affected by undernutrition and low dietary quality. Hence, there is an urgent need to make smallholder production systems more nutrition-sensitive. Several recent studies analysed whether further increasing farm production diversity might be a useful strategy to improve diets and nutrition. Most of these studies identified a positive relationship between production diversity and dietary diversity, even though the average magnitude of the effect was found to be small. Reasons for the small effect were hardly examined in detail, a research gap that we addressed in this paper with data from smallholder farmers in Western Kenya.

Farm production can affect smallholder diets through different pathways, especially the subsistence pathway and the market pathway. We tested the hypothesis that farm production diversity is positively associated with dietary diversity from subsistence and negatively associated with dietary diversity from the market. This hypothesis was confirmed, using various indicators of production diversity and dietary diversity, also after controlling for possible confounding factors. In addition to household-level dietary diversity scores, we also calculated individual-level dietary diversity scores for women and children with the same overall conclusions. To some extent, the negative partial effect through the market pathway can be explained by a simple substitution of own-produced foods for foods purchased in the market. However, high farm production diversity and a focus on subsistence can also be associated with foregone benefits from specialization. Furthermore, high levels of farm diversity bind household labour to the farm, reducing opportunities for off-farm employment. Thus, farm diversification may be associated with lower household income and lower economic ability to purchase food diversity from the market. In any case, the negative partial effect through the market pathway counteracts the positive effect through the subsistence pathway, so that the combined overall effect of production diversity on dietary diversity is small.

The results underline the important role of markers for the diets of smallholder farmers, even in subsistence-oriented settings. Overall, about half of all the foods consumed in sample households were purchased in the market. While the role of food sources varies by food group, for 9 out of the 12 food groups used to calculate household dietary diversity scores the market-derived quantities were found to be 30% or more. These numbers are in line with previous studies carried out in other parts of sub-Saharan Africa (Hirvonen and Hoddinott, 2017; Koppmair *et al*., 2017; Sibhatu and Qaim, 2017; GLOPAN, 2016).

One important policy implication is that promoting farm diversification may not be the most effective strategy to improve diets and nutrition in smallholder farm households. African smallholder farms are often quite diverse anyway. Further diversification may foster subsistence and reduce the opportunities to participate in markets as sellers and buyers. Strengthening markets and improving market access for smallholders seems to be a more promising strategy. This does not mean that certain forms of production diversification may not be useful in particular contexts. But, unless markets are completely absent, diversification should build on market incentives rather than focusing on subsistence alone.

The results presented here on the different pathways refer to farm households in Western Kenya. However, the situation in Western Kenya is quite typical for the African small farm sector, so that the general findings may also apply to other contexts. Of course, follow up research in different settings will be very useful to better understand the complex linkages between agricultural production patterns, markets, diets, and nutrition in smallholder farm households.

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Figures and Tables

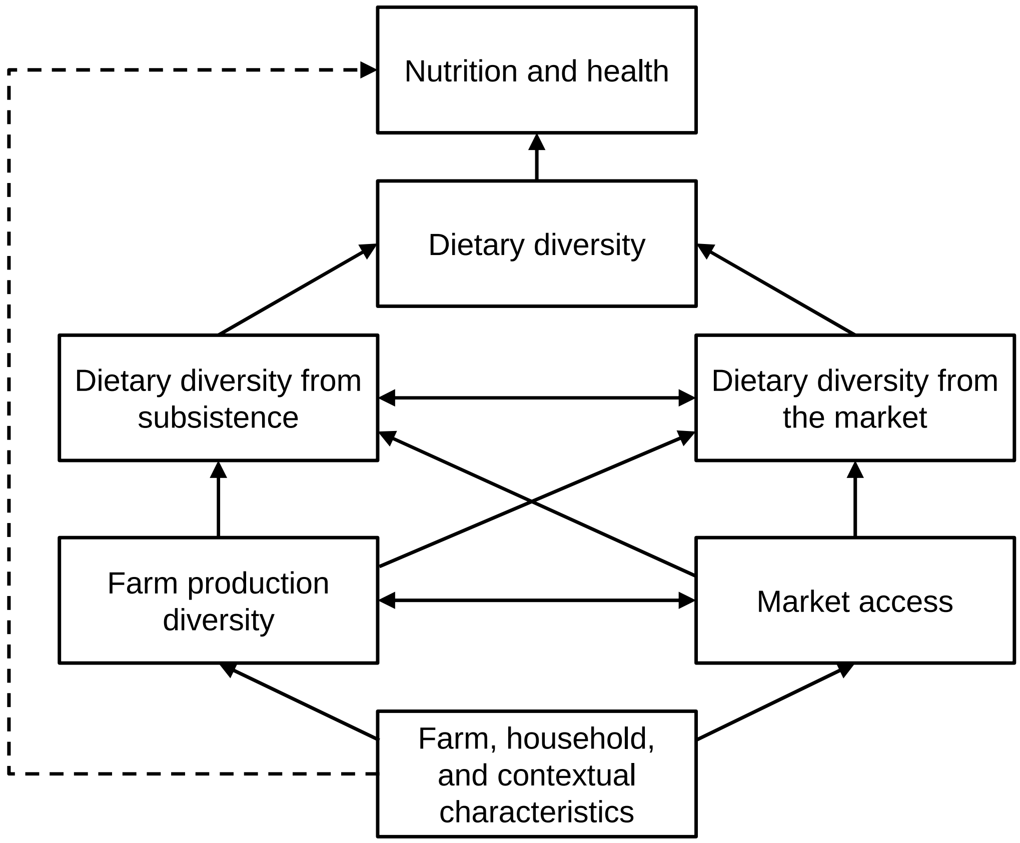

Figure 1: Links between farm production diversity and dietary diversity through subsistence and market pathways

Table 1: Food group classification for different dietary diversity scores

Number	Household dietary diversity score (HDDS)	Women's dietary diversity score (WDDS)	Child dietary diversity score (CDDS)
1	Cereals	Starchy staples	Grains, roots, and tubers
2	White roots and tubers	Dark green leafy vegetables	Legumes and nuts
3	Vegetables	Other vitamin A rich fruits and vegetables	Dairy products (milk, yogurt, cheese)
4	Fruits	Other fruits and vegetables	Flesh foods (meat, fish, poultry, and liver/organ meats)
5	Meat	Organ meat	Eggs
6	Eggs	Meat and fish	Vitamin A rich fruits and vegetables
7	Fish	Eggs	Other fruits and vegetables
8	Legumes, nuts, and seeds	Legumes, nuts, and seeds	
9	Milk	Milk and milk products	
10	Oils and fat		
11	Sugar and sweets		
12	Spices, condiments, beverages		

Table 2: Descriptive statistics for key variables (N=757)

Variable	Description	Mean	SD
Socioeconomic characteristics			
Farm size	Land area owned (acres)	1.45	1.19
Household size	Number of household members	5.49	2.04
Male head	Household head is male (dummy)	0.76	0.43
Age head	Age of household head in years	50.31	12.43
Education head	Years of education of household head	8.74	3.60
Education spouse	Years of education of spouse	8.12	8.12
Off-farm employment head	Household head has off-farm employment (dummy)	0.33	0.47
Off-farm employment spouse	Spouse has off-farm employment (dummy)	0.12	0.32
Distance village market	Distance to closest village market (km)	1.90	2.02
Distance agricultural market	Distance to closest agricultural market (km)	4.45	4.18
Social network	Number of people farmer shares information with	6.54	4.36
Farm production diversity			
Species count	Number of crop and animal species produced	13.37	3.74
Crop count	Count of crop species grown on farm	11.31	3.41
Animal count	Count of animal species kept on farm	2.06	1.13
Production diversity score	Number of food groups produced	5.81	1.07
Dietary diversity			
HDDS	Household dietary diversity score	9.72	1.31
$HDDS_{sub}$	HDDS from subsistence	4.75	1.58
$HDDS_{mar}$	HDDS from the market	7.37	1.55
WDDS	Women's dietary diversity score	4.17	0.82
$WDDS_{sub}$	WDDS from subsistence	2.86	1.36
$WDDS_{mar}$	WDDS from the market	2.31	1.06
CDDS	Child dietary diversity score	4.13	0.73
$CDDS_{sub}$	CDDS from subsistence	2.95	1.28
$CDDS_{mar}$	CDDS from the market	2.34	1.05

Table 3: Food group production and consumption from different sources

	Households producing (%)	Household consumption		
		Total quantity (kg)	From subsistence (%)	From the market (%)
Cereals	97	4.19 (4.78)	53	40
Roots and tubers	16	3.50 (3.36)	21	68
Vegetables	98	3.04 (4.07)	65	30
Fruits	95	10.27 (10.24)	61	31
Meat	97	1.04 (0.87)	31	68
Eggs	80	5.82 (4.06)	75	24
Fish	0.4	0.64 (0.58)	2	92
Legumes, nuts, seeds	31	1.4 (1.44)	78	19
Milk/milk products	67	6.8 (5.83)	77	22
Oils and fats	0	0.7 (0.46)	0	99
Sugar and sweets	0	1.44 (0.84)	0	97
Spices, condiments, beverages	0	0.29 (0.27)	0	97

Notes: Consumption refers to mean quantity consumed by sample households over a 7-day recall period with standard deviations shown in parentheses. For fruits and eggs, quantity is measured in terms of pieces consumed.

Table 4: Dietary diversity scores in more and less commercialized households

	Less commercialized		More commercialized	
	Mean score	SD	Mean score	SD
HDDS	9.58	1.36	9.85**	1.24
$HDDS_{sub}$	4.50	1.59	4.99***	1.53
$HDDS_{mar}$	7.28	1.55	7.46	1.56
WDDS	4.12	0.83	4.23*	0.79
$WDDS_{sub}$	2.71	1.35	3.01**	1.35
$WDDS_{mar}$	2.33	1.11	2.29	1.02
CDDS	4.19	0.74	4.07	0.72
$CDDS_{sub}$	2.90	1.25	2.99	1.32
$CDDS_{mar}$	2.36	1.10	2.32	1.01

Notes: The total sample was subdivided into two groups of equal size according to the proportion of farm produce sold. *, **, *** Mean values of more commercialized households are significantly larger than mean value of less commercialized households at the 10%, 5%, and 1% level, respectively.

Table 5: Association between farm production diversity and dietary diversity

	Total dietary diversity	Dietary diversity from subsistence	Dietary diversity from the market
Household	*HDDS*	$HDDS_{sub}$	$HDDS_{mar}$
Farm diversity (species count)	0.047*** (0.012)	0.146*** (0.015)	-0.035** (0.015)
Farm diversity (production diversity score)	0.220*** (0.041)	0.644*** (0.047)	-0.191*** (0.048)
Number of observations	757	757	757
Women	*WDDS*	$WDDS_{sub}$	$WDDS_{mar}$
Farm diversity (species count)	0.023*** (0.009)	0.095*** (0.014)	-0.024* (0.013)
Farm diversity (Production diversity score)	0.106*** (0.041)	0.470*** (0.048)	-0.134*** (0.042)
Number of observations	597	597	597
Children	*CDDS*	$CDDS_{sub}$	$CDDS_{mar}$
Farm diversity (species)	-0.020 (0.014)	0.067*** (0.020)	-0.077*** (0.016)
Farm diversity (Production diversity score)	0.078 (0.051)	0.444*** (0.083)	-0.280*** (0.070)
Number of observations	205	205	205

Notes: Marginal effects of generalized Poisson models are shown with robust standard errors in parentheses. Marginal effects for species count and production diversity score were obtained with separate models.

*, **, *** Statistically significant at the 10%, 5%, and 1% level, respectively.

Table 6: Association between farm production diversity and household dietary diversity with other control variables included

	HDDS	$HDDS_{sub}$	$HDDS_{mar}$
Farm diversity (species count)	0.044*** (0.013)	0.124*** (0.015)	-0.024* (0.015)
Farm size (acres)	0.081** (0.034)	0.137*** (0.043)	-0.004 (0.046)
Household size	0.035 (0.023)	0.002 (0.025)	0.043 (0.028)
Male head (dummy)	0.317*** (0.113)	0.407*** (0.125)	0.179 (0.139)
Age head (years)	-0.005 (0.004)	0.008* (0.005)	-0.011** (0.005)
Education head (years)	-0.014 (0.017)	0.003 (0.020)	-0.019 (0.024)
Education spouse (years)	0.025 (0.019)	0.065*** (0.022)	0.013 (0.026)
Off-farm employment head (dummy)	0.060 (0.100)	-0.045 (0.118)	0.109* (0.129)
Off-farm employment spouse (dummy)	0.275** (0.129)	-0.289* (0.160)	0.794*** (0.185)
Distance agricultural market (km)	0.011 (0.010)	0.002 (0.013)	0.007 (0.012)
Distance village market (km)	0.040** (0.020)	0.079*** (0.028)	0.010 (0.026)
Social network (number of people)	0.022** (0.010)	0.028*** (0.010)	0.003 (0.012)
Number of observations	718	718	718

Notes: Marginal effects of generalized Poisson models are shown with robust standard errors in parentheses.

*, **, *** Statistically significant at the 10%, 5%, and 1% level, respectively.

Table 7: Association between farm production diversity and women's dietary diversity with other control variables included

	WDDS	$WDDS_{sub}$	$WDDS_{mar}$
Farm diversity (species count)	0.027*** (0.009)	0.077*** (0.015)	-0.012 (0.012)
Farm size (acres)	0.013 (0.033)	0.078** (0.041)	-0.090*** (0.036)
Household size	0.031* (0.018)	-0.018 (0.028)	0.026 (0.022)
Male head	0.164* (0.085)	0.222* (0.128)	0.117* (0.098)
Age head (years)	-0.005* (0.003)	0.002 (0.005)	-0.006 (0.004)
Education head (years)	0.003 (0.012)	0.006 (0.020)	-0.003 (0.017)
Education spouse (years)	0.009 (0.014)	0.051** (0.020)	-0.021 (0.018)
Off-farm employment head (dummy)	-0.051 (0.076)	-0.034 (0.113)	0.607 (0.098)
Off-farm employment spouse (dummy)	0.234* (0.120)	-0.443*** (0.173)	0.607*** (0.158)
Distance agricultural market (km)	-0.020** (0.009)	-0.002 (0.013)	-0.010 (0.011)
Distance village market (km)	0.051*** (0.020)	0.053** (0.025)	0.016 (0.022)
Social network (number of people)	0.010 (0.009)	0.022** (0.010)	-0.006 (0.009)
Number of observations	583	583	583

Notes: Marginal effects of generalized Poisson models are shown with robust standard errors in parentheses.
*, **, *** Statistically significant at the 10%, 5%, and 1% level, respectively.

Table 8: Association between farm production diversity and child dietary diversity with other control variables included

	CDDS	$CDDS_{sub}$	$CDDS_{mar}$
Farm diversity (species count)	-0.022 (0.015)	0.050** (0.021)	-0.065*** (0.017)
Farm size (acres)	-0.059* (0.034)	0.032 (0.049)	-0.053 (0.052)
Household size	-0.022 (0.027)	-0.047 (0.044)	0.010 (0.038)
Age child (months)	0.011*** (0.004)	0.007 (0.007)	-0.001 (0.005)
Male head	0.361*** (0.121)	0.334* (0.182)	0.147 (0.160)
Age head (years)	0.006 (0.005)	0.009 (0.007)	-0.006 (0.006)
Education head (years)	0.036* (0.020)	0.055** (0.026)	0.020 (0.025)
Education spouse (years)	0.011 (0.023)	-0.002 (0.030)	0.002 (0.026)
Off-farm employment head (dummy)	-0.132 (0.123)	-0.423** (0.180)	0.028 (0.155)
Off-farm employment spouse (dummy)	0.109 (0.182)	-0.051 (0.308)	0.203 (0.237)
Distance agricultural market (km)	-0.008 (0.012)	-0.005 (0.016)	-0.019 (0.015)
Distance village market (km)	0.014 (0.022)	0.079** (0.034)	0.024 (0.030)
Social network (number of people)	0.003 (0.012)	0.037** (0.016)	-0.019 (0.014)
Number of observations	193	193	193

Notes: Marginal effects of generalized Poisson models are shown with robust standard errors in parentheses.
*, **, *** Statistically significant at the 10%, 5%, and 1% level, respectively.