Production diversity and dietary diversity in smallholder subsistence- and market-oriented farming households in rural Paraguay

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Introduction: On-farm production diversification is perceived as a promising strategy to improve dietary quality and diversity of smallholder farming households.

Objective: Determine the association between on-farm production diversity (PD) and quality of household diets in smallholder farming households in rural Paraguay and assess hypothesized mechanisms for this association via both subsistence- and market-oriented pathways.

Materials and Methods: Analysis of representative sample of households from the Household Survey of Income and Expenditures 2011-12 (final analytical sample included 1,247 rural households). A household diet diversity score (DDS) and daily *apparent* per adult equivalent intake of energy, protein, iron, vitamin A, and zinc were calculated from 7-day household food expenditure data. On-farm production diversity (PD) was calculated from plot-level data on all crops cultivated during the period under study. Multivariate regression techniques were used to assess the association of PD with household diet quality and diversity.

Results: On-farm PD was positively associated with DDS as well as daily intake per adult equivalent of energy, protein, iron, vitamin A, and zinc. Total area cultivated by the household was consistently positively associated with DDS, although the effect was relatively small. Household food expenditures amplified the effect of agricultural biodiversity on DDS; yet, the more diversified the household, the less diversified the food it purchased.

Conclusions: Promoting on-farm PD may be a valuable strategy for simultaneously supporting enhanced diet quality and diversity in rural Paraguay.

Keywords: agricultural biodiversity, diet diversity, diet quality, income, Latin America

Introduction

Dietary diversity has long been recognized to be a key component of healthy diets (Ruel 2003). There are a number of studies linking dietary diversity to people's nutritional status (Arimond 2010, Moursi et al. 2008, Ruel 2003, Steyn et al. 2006), suggesting that dietary diversity may reflect higher dietary quality and greater likelihood of meeting daily energy and nutrient requirements (Arimond and Ruel 2004).

To the extent that increasing dietary diversity represents an important strategy to improve and support human health and nutrition, the agricultural production also needs to be diversified. However, as most developed countries undergo dramatic changes in diets, with clear movement away from staple grains towards a more diversified diet higher in meats, dairy products, fats, sugar, fruit and vegetables, there is a "growing disconnect between agricultural policy and contemporary nutritional challenges… as staple grain fundamentalism has constrained the ability of agricultural policies to achieve positive nutritional outcomes" (Pingali 2015).

Poorly developed markets for non-staples mean that the lack of dietary diversity is particularly severe among poor populations in the developing countries, where diets are mainly based on starchy staples and often include few or no animal products and only seasonal fruits and vegetables (Arimond and Ruel 2004).

In Paraguay, as in most of the Latin American countries, majority of the poor population reside in rural areas. Given that agriculture and food production represent the single most important source of income for the low-income households in these rural areas (World Bank 2014), it has been suggested that a useful approach to improving dietary diversity in rural areas could be by diversifying production on these smallholder farming households (Pellegrini and Tasciotti 2014, Powell 2015, and Remans et al. 2011).[1]

A growing empirical literature has explicitly examined the relationship between agricultural (production) biodiversity and dietary diversity (Jones et al. 2014, Jones 2017, Sibhatu et al. 2015). However, while these studies generally find a positive relationship between the two, they are also careful to make generalized or simplifying conclusions about the hypothesized mechanisms linking agricultural biodiversity with dietary diversity (Jones 2017, Sibhatu et al. 2015).

Indeed, the extent to which these linkages operate simultaneously is not always clear. For example, producing a variety of foods (or even increasing the production diversity) may reduce households' need to buy diversified foods. On the other hand, selling part of their produce in the market may increase households' income to the extent that they can buy food diversity; in this case, further production diversification may actually reduce household income due to foregone benefits from specialization (Sibhatu et al. 2015).

The aim of this study was to verify the association between agricultural biodiversity and the quality and diversity of household diets in Paraguayan rural households using data from a nationally representative household survey. Our hypothesis was that the farm agricultural diversity was positively associated with household dietary diversity and a greater intake of micronutrients. We also analyzed whether household's production diversity affects its food purchase behavior.

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[1] In addition to poor market conditions, the deterioration of natural resources, loss of soil fertility, and the absence of essential public goods and services also contribute to rural poverty in the region.

Methodology

Study Population

Data for this study were obtained from the National Income and Expenditure Survey of 2011-12 (EIG 2011-12), carried out between August 2011 and July 2012 by the General Directorate of Statistics, Surveys and Censuses (DGEEC). This was a nationally and sub-nationally representative national household survey that used a two-stage stratified household design.[2]

The survey examined a total of 5,417 households, of which 3,446 resided in urban areas and 1,971 resided in urban areas. Retaining only the households that engaged in agricultural activities during the 12 months prior to taking the survey produced an analytic sample of 1,297 rural households.

Measurement of Dietary Diversity

The primary outcome variables were household dietary diversity and household's daily intake of energy, proteins, and micronutrients (vitamin A, iron, and zinc). The high prevalence of deficiencies in these micronutrients and their important adverse consequences on mortality, morbidity and disability, especially in low- and middle-income countries, have been shown to result in a substantial disease burden (Black 2014).

The corresponding dietary outcomes were calculated by aggregating the quantity of food purchased or self-produced by the household over the previous 7 days. Quantities of food items acquired with a non-weekly frequency (e.g. every day, once a week, monthly, et cet.) were transformed into their weekly (7-day) equivalents. Food items that the household received from another household, from a social protection or nutrition program, as a gift from church or a non-profit institution, or that any member of the household took from the business were not considered in the analysis.[3]

A household diet diversity score (DDS) was obtained on the basis of 10 food groups, otherwise equivalent to those that constitute the Minimum Dietary Diversity for Women (MDD-W) indicator (FAO and FHI 2016). They included 1) starchy staple foods (grains, white roots and tubers, and mandioca), 2) pulses (beans, peas and lentils), 3) nuts and seeds, 4) dairy, 5) flesh foods (meat, poultry, fish) 6) eggs, 7) vitamin A–rich dark green leafy vegetables, 8) other vitamin A–rich fruits and vegetables, 9) other vegetables, and 10) other fruits. The MDD-W indicator was shown to have a stronger relationship to micronutrient adequacy than similar dietary diversity indicators with different groupings (Martin-Prével et al. 2015). Food groups that may reflect economic access to food and/or that have been shown to contribute little to the micronutrient density of the diet (e.g., sugar, honey, oils and fats) – although generally part of the household dietary diversity scores

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[2] The survey was representative at the area (rural and urban) level. The EIG 2011-12 dataset is publicly available from the DGEEC's website.

[3] Food items that either member of the household took from a business account, food items that the household received from another household, and food items received by the household from a social protection or nutrition program, or as a gift from church or a non-profit institution, altogether account for about 6 % of total food items in the sample.

(Swindale and Bilinsky 2006) – were not included in the DDS (Arimond et al. 2010). All food acquisition data were converted into standard units of weight (grams).[4]

The data on energy, protein and micronutrient contents of food items were primarily obtained from two sources: Argentina Food Composition Tables (CENEXA 1995) and Central American Food Composition Tables (INCAP and OPS 2012). Composition data for food items (or equivalents thereof) that were not listed in either of these two sources were estimated based on the data from the USDA National Nutrient Database for Standard Reference (USDA 2018). Vitamin A was measured in μg (micrograms) of retinol activity equivalent (RAE), and iron and zinc in milligrams (mg).

The household (apparent) consumption data were converted to daily quantities consumed and were used to calculate daily energy and nutrient intake per adult equivalent based on calorie needs estimates for specific sex and age groups provided by the Institute of Medicine (IOM 2002).[5]

Measurement of On-Farm Production Diversity

Two distinct indicators of production diversity were calculated: crop species richness (CSR) and crop nutritional functional richness (CNFR). CSR was calculated as the number of crop and livestock species produced on a farm. In total, 62 different crop species and 4 general (catch-all) crop groups were cultivated across rural households during the 2011–12 period.[6] Crop nutritional functional richness was calculated to match the 10 food groups included in the DDS. Measuring the dietary diversity and the production diversity on the same scales has been recommended as a possibly preferred approach to evaluating the relationship between the two (Berti 2015). When calculating the CNFR, cereals, roots and tubers were categorized to correspond directly to the ‘‘starchy staple foods’’ group of the DDS. In addition to crops cultivated, household’s current livestock ownership (any number of farm animals), and household’s production of eggs or milk (any production over the previous 3 months) contributed to crop nutritional functional richness in line with the ‘‘flesh foods,’’ ‘‘eggs,’’ and ‘‘dairy’’ categories of the DDS, respectively. The concept of functional diversity as a means of quantifying diet diversity – analogous to approaches to quantifying biological diversity in ecology (Petchey 2002) – has been previously applied to nutritional functional groups by Remans et al. (2011) and Jones (2016).

As a robustness check, we used two alternative measures of agricultural biodiversity: Simpson index and food crop production richness (FCPR). The Simpson index is defined simply as one minus the sum of squared shares of total crop area planted to each unique variety (Meng et al.

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[4] In some instances, grams of juice needed to converted into milliliters of juice. In that case, we used an average juice density of 1.048 g/cm^3.

[5] Sedentary level of physical activity was assumed; daily calorie needs estimates for the sedentary physical activity level (by age and sex) are provided in Table A3. in the Appendix. These estimates are based on the Estimated Energy Requirements (EER) equations, using reference heights (average) and reference weights (healthy) for each age-sex group. For adults, the reference man is 5 feet 10 inches tall and weighs 154 pounds; the reference woman is 5 feet 4 inches tall and weighs 126 pounds. For children and adolescents, reference height and weight vary (IOM 2002).

[6] The four catch-all groups include Assorted Vegetables, Other Vegetables, Other Temporary Crops, and Other Permanent Crops. For the purpose of the analysis, each catch-all group is considered as a separate “species”.

1999).[7] The FCPR was obtained as a simple, unweighted count of only the food crop species produced on a farm (Sibhatu et al. 2015).

Statistical Analyses

To analyze the relationship between production diversity and dietary diversity we use regression models of the following form:

$$DD_i = \beta_0 + \beta_1 ABD_i + \beta_2 \boldsymbol{X}_i + \beta_3 \boldsymbol{Y}_i + \beta_4 (ABD_i \times \boldsymbol{Y}_i) + \varepsilon_i,$$

where DD_i denotes the dietary diversity and ABD_i an indicator of agricultural biodiversity of household *i*. A positive and significant estimate for β_1 implies that higher production diversity is associated with higher dietary diversity.[8] $\boldsymbol{X}_i$ denotes a vector of socio-economic and demographic characteristics of household i (including household size, sex and age of head of household, education level of female head of household or spouse of male head of household, mother's education, and household's income quintile) as well as household *i*'s department. $\boldsymbol{Y}_i$ denotes a set of production and market activity indicators, including total land area cultivated (in ha), total quantity of crops harvested (in kilograms), proportion of harvest sold, total quantity sold (in multiples of 100,000 of Paraguayan Guaranies), and total food expenditures over the previous 7 days. Finally, an interaction term is included to account for the multiplicative relation between agricultural biodiversity and proportion of harvest sold.

We used a Poisson estimator procedure for model estimation.[9] In this case, the coefficient estimates can be interpreted as semi-elasticities. That is, a coefficient estimate indicates the percentage change in the dietary diversity score resulting from a one-unit change in the explanatory variable.

To analyze the relationship between production diversity and micronutrient adequacy, we use the same model as above but with either the daily intake per adult equivalent of energy, protein, iron, vitamin A, or zinc as dependent variables. In this case, we use an ordinary least squares model for model estimation.

In addition to estimating the models described above, further analyses were carried out to elucidate the links between the agricultural biodiversity and diet quality and diversity, including the relationship between production of crops or products from specific food groups and dietary diversity, and the relationship between agricultural biodiversity and the dietary diversity only with respect to the food purchased in the market (Sibhatu et al. 2015).

Results

The analysis of household data shows that the average size of household was 4.35 persons, with one in four households headed by a female, and an average age of household head being 50.2 years (Table 1).

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[7] In other words, the Simpson index is equal to one minus the Herfindahl index that is used in the industrial economics literature on market shares (Hartell 1996, Pardey et al. 1996).

[8] A squared term for agricultural biodiversity was included in initial models to test whether the relationship was linear; however, in most cases, the coefficient estimates were not significant and were therefore not included in the final models.

[9] We used Stata's `svy: poisson` command to account for the survey design.

Table 1. Household Characteristics

	Mean	SE	[95% Conf. Int.]	
Household size, n	4.38	0.08	4.22	4.53
Female head of household (yes/no)	0.25	0.02	0.21	0.28
Age of head of household (years)	50.21	0.69	48.84	51.58
Women with more than 1 years of education[1]	87.72	1.10	85.54	89.90
Income quintiles (Q1-Q5)[2]				
Lowest (Q1)	19.06			
Low (Q2)	18.83			
Middle (Q3)	20.03			
High (Q4)	20.32			
Highest (Q5)	21.76			

1) Only heads of households or spouses of heads of households. 2) Shows Percentage of households in each income quintile.

The average size of the land area cultivated by rural households was 7.2 ha. The average production diversity (measured by crop species richness) was 5.83, with starchy staples and other vegetables representing the most common crops produced by rural households (81.8% and 60.6%, resp.) (Table 2). On average, rural households sold 20.7% of their harvest.

Table 2. Agricultural characteristics

	Mean	SE	[95% Conf. Int.]	
CSR: Crop species richness	5.83	0.19	5.46	6.21
CNFR: Crop nutritional functional richness	4.81	0.09	4.63	5.00
Land area cultivated (annual crops), ha	7.21	2.23	2.82	11.61
Amount of harvest, kg	21,072.6	5.617.5	9,980.7	32,164.5
Value of sold harvest (Guaranies x 100,000)	156.7	58.9	40.4	272.9
Proportion of harvest sold	20.7	1.5	17.9	23.6
Production of any crops from specified food group				
Starchy staple foods	81.8	2.1	77.7	85.8
Beans and peas	50.5	2.4	45.8	55.1
Nuts and seeds	27.1	2.4	22.5	31.8
Vitamin A-rich dark green leafy vegetables	3.6	0.7	2.2	5.0
Other vitamin A-rich fruits and vegetables	25.0	1.9	21.3	28.7
Other vegetables	60.6	2.6	55.5	65.7
Other fruits	28.4	2.6	23.3	33.5
Ownership of any stock (annual)	92.2	1.3	89.6	94.8
Households that produced milk in the previous 12m	34.2	1.9	30.4	38.0
Households that produced eggs in the previous 12m	77.8	1.7	74.4	81.2

Detailed statistics on household dietary intake show that the average dietary diversity score was 6.4 food groups, with more than two in every three households consuming six or more food groups and about one in four households consuming eight and more food groups (Table 3). The dietary diversity score based on purchased food items only was 4.1. The daily energy intake per adult equivalent shows that almost 9 out of every 10 calories consumed (89%) came from only three food groups: starchy staples (68%), flesh foods (12%), and milk (9%). In terms of food expenditures, most were spent on flesh foods (46%).

It remains to be noted that the dietary diversity score was correlated with daily intake per adult equivalent of energy (*r* = 0.33), protein (*r* = 0.35), iron (*r* = 0.32), zinc (*r* = 0.35), and vitamin A (*r* = 0.14), where *r* denotes Pearson product-moment correlation coefficient.

Table 3. Household dietary intake and household food expenditures

	Mean	SE	[95% Conf. Int.]	
Household Dietary Intake				
DDS[1]	6.39	0.07	6.25	6.53
% of ouseholds consuming ≥ 6 groups	71.5	1.6	68.2	74.7
% of households consuming ≥ 8 groups	27.8	1.7	24.5	31.2
% of households consuming all 10 groups	0.8	0.3	0.2	1.4
DDS (Purchased Food Only)[2]	4.08	0.09	3.90	4.26
Daily energy intake per adult equivalent (kcal)	2,774.7	56.7	2,662.8	2,886.6
Daily protein intake per adult equivalent (g)	96.0	2.2	91.6	100.4
Daily vitamin A intake per adult equivalent (g)	814.7	56.1	704.0	925.4
Daily iron intake per adult equivalent (μg RAE)	19.6	0.6	18.5	20.7
Daily zinc intake per adult equivalent (mg)	12.3	0.3	11.7	12.8
Daily energy intake per adult equivalent by food group (kcal)				
Starchy staple foods	1,887.0	46.0	1,796.1	1,977.9
Beans and peas	60.0	4.7	50.6	69.3
Nuts and seeds	38.8	6.6	25.8	51.7
Dairy	262.2	12.2	238.1	286.4
Flesh foods	330.1	11.8	306.7	353.5
Eggs	59.4	2.8	53.9	64.8
Vitamin A-rich dark green leafy vegetables	2.5	0.2	2.0	3.0
Other vitamin A-rich fruits and vegetables	9.3	1.0	7.3	11.2
Other vegetables	36.9	1.4	34.1	39.7
Other fruits	88.6	6.6	75.6	101.6
Proportion of food consumed from purchases (in %)	42.5	1.8	41.0	46.0
Proportion of food consumed from own production (in %)	57.7	1.6	54.6	60.8
Household Food Expenditures (previous 7 days) (Gs.)				
All Foods	122,039	5,102	111,965	132,112
Starchy staple foods	34,136	1,390	31,392	36,879
Beans and peas	1,540	226	1,093	1,986
Nuts and seeds	872	232	413	1,331
Dairy	17,653	1,437	14,816	20,490
Flesh foods	55,851	2,114	51,677	60,025
Eggs	1,619	185	1,254	1,984
Vitamin A-rich dark green leafy vegetables	252	62	129	374
Other vitamin A-rich fruits and vegetables	3,369	330	2,717	4,021
Other vegetables	15,372	582	14,223	16,522
Other fruits	7,581	833	5,936	9,226

1) Based on household (apparent) consumption over the previous 7 days.

2) Based on household (apparent) consumption of purchased food items over the previous 7 days.

Association Between Production Diversity and Dietary Diversity

Table 4. shows results of regression models where dietary diversity is used as a dependent variable and agricultural biodiversity (crop species richness, or CSR, and crop nutritional functional richness, CNFR) as an explanatory variable.[10] Results from unadjusted regressions show that agricultural biodiversity was positively associated with dietary diversity, although the effect was relatively small; producing one additional crop or livestock species lead to a 2.3% increase in the number of food groups consumed in case of CSR and a 5.0% increase in the number of food groups consumed in case CNFR.

Including a vector of household's socio-economic and demographic characteristics and production and market activity indicators resulted in a marginal increase in the magnitude of the positive association between agricultural biodiversity and dietary diversity. The dietary diversity was also significantly associated with total area cultivated by household, proportion of harvest sold by household and food expenditures made by household over the previous 7 days, both in case of CSR and CNFR. In particular, the proportion of harvest sold reduced while the total area cultivated and food expenditures further amplified the effect of agricultural biodiversity on dietary diversity. No clear association was found between the income quintiles and dietary diversity.

Table 4. Household dietary intake and household food expenditures

	Crop Species Richness (CSR)			Crop Nutr. Funct'l Richness (CNFR)		
	DDS	DDS	Energy	DDS	DDS	Energy
ACB	0.023***	0.026***	103.1***	0.050***	0.060***	218.5***
HH Size		0.002	-310.4***		0.000	-314.6***
Female Head of HH		0.005	103.3		0.012	127.6
Age of Head of HH		-0.001**	-2.232		-0.002***	-3.005
Mother's Educ. (No Educ.)		0.051*	140.69		0.050**	140.0
Income Quintile						
Income Quintile 2		0.018	-46.12		0.011	-68.91
Income Quintile 3		0.051**	-28.02		0.034	-90.04
Income Quintile 4		0.046*	-25.14		0.031	-84.90
Income Quintile 5		-0.006	-454.1***		-0.019	-504.9***
Total Area Cultivated		0.001**	0.942		0.001***	1.39
Total Qty Harvested		0.000	0.000		0.000	0.001
Prop. of Harvest Sold		-0.070**	-239.7*		-0.053*	-144.1
Total Qty Sold (Gs.)		-0.000*	-0.069		-0.000**	-0.123
Food Expenditures 7d		0.098***	842.8***		0.108***	875.8***
Model Intercept	1.717***	1.605***	2,218.7***	1.609***	1.481***	1,788.6***
No. of observations	1,297	1,193	1,193	1,297	1,193	1,193

***, ** and * indicate the statistical significance of the partial regression coefficients at 1%, 5%, and 10% levels, respectively. Dietary diversity (DDS) CSR and CNFR models estimated using Poisson estimator and Energy SCR and CNFR models estimated using OLS. Source: Authors' calculations.

Results of regression models where the daily energy intake per adult equivalent was used in place of dietary diversity as a dependent variable show that greater agricultural biodiversity was also

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[10] Full regression results are available in Tables B1 and B2 in the Appendix.

positively associated with greater daily energy intake per adult equivalent. The CSR was significantly associated with greater micronutrient intake, including greater daily intakes of proteins (3.34, p<0.001), iron (0.54, p<0.001), zinc (0.49, p<0.001), and vitamin A (28.5, p<0.001) (Appendix: Table B6). Additional results show similar significant associations between CNFR and greater energy and micronutrient intake per adult equivalent (Appendix: Table B6). However, of the same set of production and market activity indicators, only food expenditures made by household over the previous 7 days were significantly associated with daily energy intake per adult equivalent. In contrast to the dietary diversity score, larger household size and the presence of the household in the fifth income quintile were both associated with significantly lower daily energy intake per adult equivalent.

Estimation of the same regression models along with an interaction term controlling for the multiplicative relation between agricultural biodiversity and proportion of harvest sold by household showed not significant relationship between the interaction term and dietary diversity (see Table B2 in the Appendix).

Association between Production Diversity and Food Purchase Behavior

Food purchase behavior may have a significant impact on dietary diversity. Therefore, we also examined the association between agricultural biodiversity and dietary diversity only with respect to the food purchased in the market. Results from the regression models show a significant negative coefficient estimate on the agricultural biodiversity (see Table B5 in the Appendix), be it CSR or CNFR, implying that more diversified farms tended to purchase less diversified foods. As Sibhata et al. (2015) suggest, this result may not be surprising: the more diverse the farm production, the less diverse the food purchases needed by households.

The regressions models also include a square term for agricultural biodiversity. As expected, in each model, the coefficient estimate on this term is significant, meaning that as rural households become increasingly more diversified, the effect on dietary diversity diminishes.

Regression results further show that dietary diversity only with respect to food purchased in the market was not significantly associated with either total area cultivated by the household, proportion of harvest sold by the household, or total quantity sold by the household. However, food expenditures made by household over the previous 7 days were found to be significantly and positively associated with the dietary diversity, both in CSR and CNFR regressions.

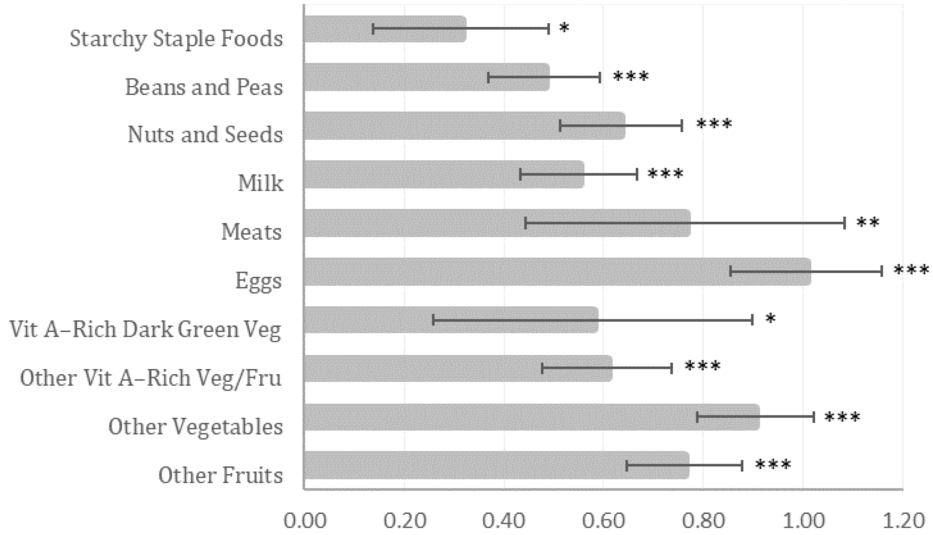
Robustness Check

As a robustness check, we re-estimated the model above with two alternative measures of agricultural biodiversity: Simpson index and food crop production richness (FCPR). The regressions results for these two alternative measures of agricultural biodiversity are largely in line with those obtained above for the CSR and CNFR (Tables B3, B4 and B6 in the Appendix), although the coefficient estimates on the agricultural biodiversity measured by the Simpson index are significantly larger than those obtained for the other measures. This suggests that the results may be at least partially driven by the way production diversity is measured.

Additional Analysis Linking Agricultural Biodiversity and Dietary Diversity

To better understand the link between agricultural biodiversity and household dietary diversity, we also examined the relation between the latter and the production of crops or products from specific food groups. Figure 1 shows that households producing beans and peas, nuts and seeds, milk, eggs, other vitamin A-rich vegetables and fruits, other vegetables, and other fruits exhibited significantly higher dietary diversity scores ($p<0.001$) than households that did not produce crops or products from these groups.

Figure 1.
Differences in mean household DDS between households producing and households not producing crops or products from a given food group



Note: Difference ± SE in mean household diet diversity scores between households producing and households not producing crops or products from the given food group. Means are least squares means adjusted for household income, household size, sex of head of household, age of head of household, mother's education, land area cultivated, amount of harvest produced, proportion of harvest sold, and food expenditures over the previous 7 days, and regional fixed effects. *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Discussion

The present study examined the relationship between agricultural biodiversity and dietary quality and dietary diversity in Paraguayan rural households using data from the nationally representative Income and Expenditure Survey of 2011-12.

The study found that, regardless of the measure of agricultural biodiversity employed, agricultural biodiversity was positively associated both with dietary diversity and dietary quality. Further analysis revealed that, for just about any food group produced by the household, the same households showed significantly higher dietary diversity scores than households that did not produce crops or products from these groups.

Additional results showed that household income quintile had no significant impact on dietary diversity, although the presence of a household in the highest income quintile was significantly negatively associated with lower energy intake. This suggests that despite not necessarily having more diverse diets, the highest income quintile households may prefer quality over the quantity.

Finally, our results showed that more diversified households tended more diversified farms tended to purchase less diversified foods. That said, rural households purchased on average more than 40% of the food that they consumed.

It is evident that more research is needed to understand the mechanisms linking agricultural biodiversity and dietary diversity. Equally important is the question of what measures of agricultural diversity should be used to assess these links? Our results showed that although important production and market activity indicators such as total area cultivated by household, the proportion of produce sold by household, and the food expenditures made by household over the previous 7 days (and, to an extent also the total quantity sold), were all significantly associated with dietary quality when crop species richness CSR was used a measure of agricultural biodiversity, the results were less consistent when other measures of agricultural biodiversity were used.

The key limitations of this study are the use of apparent consumption data instead of the actual consumption data, a 7-day recall period, the use of food composition tables that may not always provide an exact nutrient composition of every food item.

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