GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN IN PUBLICA COMMODA SEIT 1737

GRK 2654
Sustainable Food Systems

RTG 2654 Sustainable Food Systems

University of Goettingen

SustainableFood Discussion Papers

No. 13

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November 2024

RTG 2654 Sustainable Food Systems · Heinrich Düker Weg 12 · 37073 Göttingen · Germany
www.uni-goettingen.de/sustainablefood

ISSN (2750-1671)

Suggested Citation

Mohammed, F.Y., M.G. Khonje, M. Qaim (2024). Women's roles in decision-making and nutrition-sensitive agriculture. SustainableFood Discussion Paper 12, University of Goettingen.

Imprint

SustainableFood Discussion Paper Series (ISSN 2750-1671)

Publisher and distributor:
RTG 2654 Sustainable Food Systems (SustainableFood) – Georg-August University of Göttingen
Heinrich Düker Weg 12, 37073 Göttingen, Germany

An electronic version of the paper may be downloaded from the RTG website:

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Women's roles in decision-making and nutrition-sensitive agriculture

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Abstract

The small farm sector is home to many of the world's food insecure and undernourished people. Strategies to make smallholder farming more nutrition-sensitive often focus on agricultural diversification. In addition, women's empowerment is widely considered useful to improve diets and nutrition. Many studies have analyzed the effects of farm production diversification and of women's empowerment on dietary outcomes, but mostly in separate strands of literature. Here, we connect these strands of literature to contribute to a better understanding of the multifaceted links between farm production diversity, women's roles in decision-making, and household diets. Using primary data from Malawi, we show that women's decision-making is positively associated with farm production diversity and with household dietary diversity. Furthermore, women's decision-making increases the positive association between farm production diversity and dietary diversity. We also differentiate between different domains of decision-making, including agricultural production, market sales, cash income control, and food purchases. The results suggest that strengthening women's agency can make smallholder farming more nutrition-sensitive through multiple channels.

Keywords: Farm production diversity, Dietary diversity, Female decision-making, Africa, Malawi

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Acknowledgments

This study was funded by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) through the Sustainable Food Systems Research Training Group (RTG 2654).

1 Introduction

Food insecurity and undernutrition remain important challenges, particularly in Africa, where many poor people depend on agriculture for their livelihoods. Agricultural production in Africa is dominated by smallholder farmers, mostly cultivating less than two hectares of land (Lowder *et al.*, 2016; Giller *et al.*, 2021). Smallholder farmers typically produce staple grains for home consumption (FAO, 2015a) and face multiple market imperfections (World Bank, 2006), thus often having limited access to nutritious and diversified foods. Strategies to make smallholder farming more nutrition-sensitive – with the intention to improve dietary diversity and nutrition outcomes – often involve interventions to increase farm production diversity and strengthen women's agency, among others (FAO, 2015b; Ruel & Alderman, 2013; Ruel *et al.*, 2018). In this study, we examine the multifaceted links between smallholder production diversity, women's roles in decision-making, and household diets.

Previous studies examine the relationship between smallholder production diversity and household diets and nutrition in different settings (Jones *et al.*, 2014; Malapit *et al.*, 2015; Koppmair *et al.*, 2017; Ecker, 2018; Sibhatu & Qaim, 2018; Gupta *et al.*, 2020; Muthini *et al.*, 2020; Bonis-Profumo *et al.*, 2021; Mehraban & Ickowitz, 2021; Sariyev *et al.*, 2021; Liu *et al.*, 2023). In many situations, associations between production diversity and dietary diversity are positive but small in magnitude. There is also a sizeable literature on the links between women's empowerment and diet and nutrition outcomes (Sraboni *et al.*, 2014; Malapit *et al.*, 2015; Bonis-Profumo *et al.*, 2021; Debela *et al.*, 2021; Sariyev *et al.*, 2021; Huang *et al.*, 2023). Most of these studies show positive associations, although the results and mechanisms depend on the context (Johnston *et al.*, 2015; Njuki *et al.*, 2022).

Most studies on either the effects of production diversity or the effects of women's empowerment on diets and nutrition belong to separate strands of literature. Only a few studies combine the two strands up to a certain degree. De Pinto *et al.* (2020), Sariyev *et al.* (2021), and Connors *et al.* (2023) analyze links between women's decision-making and farm diversity, yet primarily focusing on crop production without considering livestock activities. Malapit *et al.* (2015) and Huang *et al.* (2023) examine to what extent the positive nutrition effects of women's empowerment can substitute for the negative effects of low farm production diversity in Nepal and China, respectively. In the African context, Argaw *et al.* (2021) and Jones *et al.* (2014) compare associations between production diversity and dietary diversity in male- and

female-headed households. More research is needed to better understand the relevant links and mechanisms in typical African smallholder settings.

Here, we use primary data collected recently through a survey of agricultural households in Malawi to address four research questions. First, what is the association between women's decision-making and farm production diversity, including crop and livestock activities? Second, what is the association between farm production diversity and household dietary diversity? Third, what is the association between women's decision-making and household dietary diversity? And fourth, how does women's decision-making influence the association between farm production diversity and household dietary diversity? For all questions related to women's decision-making we look at the proportion of decisions primarily made by women across various relevant domains. In addition, we also differentiate between domains, such as agricultural production decisions, sales decisions, income use decisions, and food purchase decisions. Results can help to improve the design of strategies to make smallholder farming more nutrition-sensitive.

2 Materials and methods

2.1 Survey data

We use primary data collected from agricultural households in rural Malawi in 2022. A multistage sampling technique was employed, First, we purposively selected five extension planning areas (EPA) in three districts – Dowa, Ntchisi, and Kasungu – that are all located in the Central Region of Malawi but differ in terms of agroecological conditions. Second, in each EPA we randomly selected three sections. Third, in each section, we randomly selected three villages. Fourth, in each village, we randomly selected 12 households for personal interviews. Our total sample includes 537 households. Survey respondents were informed about the objectives of the study and were asked for their written consent to participate. The study protocols were reviewed and approved by the Ethics Committee of the University of Göttingen.

We had developed a structured questionnaire for the personal interviews to collect comprehensive data on household demographics, agricultural production, non-farm economic activities, asset ownership, food and non-food consumption, and other socioeconomic details. In most households, the household head and the spouse participated in the interviews, each addressing the topics they were most knowledgeable about. For instance, questions on

household food consumption were often answered by a female adult. Food consumption was captured over the last seven days prior to the interview. In addition to the quantities of the different food items consumed, we asked for the sources (e.g., own production, market purchases, gifts) and values of each food item. Agricultural production activities, such as the types of crop and livestock species produced, were captured over the last 12 months, differentiating by cropping season. Other economic activities (e.g., wage employment) were also captured over a 12-month period.

For agricultural production and sales, as well as for income use and food purchases, we also asked who in the household is primarily responsible for making concrete decisions. Answers to these questions are used to construct the women's decision-making variables for the analysis (see details below). Recent research shows that responses to questions on who in the household makes certain decisions can vary depending on who is being asked, a male or a female household member (Ambler *et al.*, 2021). During our interviews, male and female adults were both present, so we only capture one joint response for each decision-making question.

In addition to the household interviews, we carried out short market surveys in the sample villages and surroundings to gather information on the diversity and prices of food items available. Furthermore, a short community questionnaire was administered with village leaders to capture information on access to roads, markets, schools, clinics, and other amenities.

2.2 Measurement of key variables

Women's decision-making

In every household, many decisions are being made on a regular basis and not all decisions are necessarily being made by the same person. Who in the household makes decisions can vary between domains and also between decisions within each domain. As explained in the previous section, we included a larger number of questions on who in the household primarily makes certain decisions in different parts of the questionnaire. For each question, respondents were asked to name the household member primarily making the decision. Based on these answers, we first classify whether each decision is made by a male or a female member, and then we calculate "women's decision-making" as the proportion of all decisions being made by female household members. That is, a value of 0.3 would mean that 30% of all decisions are made by female household members.

Building on the literature on female empowerment in agricultural households (Peterman *et al.*, 2011, Heckert *et al.*, 2019; Quisumbing *et al.*, 2022), we capture decision-making in four different domains, namely agricultural production decisions, agricultural product sales decisions, agricultural cash income use decisions, and food purchase decisions. For each domain, we used several questions on decision-making, as shown in Table A1 in the online appendix. Agricultural production decisions refer to the types of crops grown on the different plots and the different livestock species kept. Sales and cash income use decisions refer to the different crop and livestock products, whereas food purchase decisions are differentiated by food item. We calculate one "overall" women's decision-making variable, referring to the proportion of decisions made by female members across all questions and domains. Furthermore, we calculate women's decision-making variables for each of the four domains.

Dietary diversity

We measure dietary diversity in terms of the household dietary diversity score (HDDS), which is a commonly used indicator of household access to food quantity and variety and thus a proxy of food security and dietary quality (FAO, 2010). HDDS counts the number of different food groups consumed by the household over a specified recall period. The 12 food groups considered are cereals; roots and tubers; vegetables; fruits; meat; eggs; fish; legumes and nuts; milk and milk products; oils and fats; sugar and honey; beverages, condiments, and spices. Thus HDDS can take values between 0 and 12, with higher values indicating more diverse diets. We use the seven-day food consumption data to calculate HDDS, which is a common recall period used in the literature (Sraboni *et al.*, 2014; Sibhatu *et al.*, 2015; Muthini *et al.*, 2020; Sariyev *et al.*, 2021).

Farm production diversity

Farm production diversity refers to the different types of crop and livestock outputs produced on the farm. For consistency, we use the same 12 food groups as for the construction of the HDDS, which is a common approach in the literature (Dillon *et al.*, 2015; Hirvonen & Hoddinott, 2017; Koppmair *et al.*, 2017; Argaw *et al.*, 2021; Mehraban & Ickowitz, 2021; Sariyev *et al.*, 2021). The farm production diversity score (FPDS) is the number of different food groups produced, which can range between 0 and 12.

2.3 Regression models

We use regression models to address the four research questions mentioned above. The first research question "what is the association between women's decision-making and farm production diversity" is analyzed with the following model:

$$FPDS_i = \beta_0 + \beta_1 W_i + \beta_2{}' \boldsymbol{C_i} + \varepsilon_i \quad (1)$$

where *FPDS* is the farm production diversity score of household *i*, *W* is women's decision-making (proportion of decisions made by female household members), $\boldsymbol{C}$ is a vector of control variables, and ε is a random error term. Control variables include farm characteristics (farm size, number of cropping seasons, input use, etc.), household characteristics (household size, wealth, sex, age, education of household head, non-farm income, etc.), access to markets and services, and regional dummies. We are particularly interested in the coefficient β_1. A positive β_1 would indicate that women's decision-making is positively associated with farm production diversity. We run the model in equation (1) with several specifications for *W*, focusing on overall women's decision-making (across all domains) as well as on decision-making in each of the four domains explained above.

The second research question "what is the association between farm production diversity and household dietary diversity" is analyzed with the following model:

$$HDDS_i = \alpha_0 + \alpha_1 FPDS_i + \alpha_2{}' \boldsymbol{C_i} + u_i \quad (2)$$

where *HDDS* is the household dietary diversity score of household *i*, and the other variables are as explained above. Here, we are particularly interested in the coefficient α_1. A positive coefficient would mean that farm production diversity is positively associated with household dietary diversity.

The third research question "what is the association between women's decision-making and household dietary diversity" is examined with the following model:

$$HDDS_i = \gamma_0 + \gamma_1 W_i + \gamma_2{}' \boldsymbol{C_i} + \mu_i \, . \quad (3)$$

The fourth research question "how does women's decision-making influence the association between farm production diversity and household dietary diversity" is analyzed with the following model:

$$HDDS_i = \delta_0 + \delta_1 FPDS_i + \delta_2 W_i + \delta_3 (FPDS_i \times W_i) + \delta_4{}' \boldsymbol{C_i} + \vartheta_i \, . \quad (4)$$

In equation (4), we are particularly interested in the coefficient δ_3 of the interaction term. A positive δ_3 would mean that the association between farm production diversity and household dietary diversity is larger in households where women have more decision-making power; a negative coefficient would mean the opposite. Again, we look at overall women's decision-making and additionally also differentiate by decision-making domain.

In all four equations, we have count variables on the left-hand side, so that a Poisson estimator is more appropriate than ordinary least squares. We use the generalized Poisson estimator, which relaxes the equidispersion assumption of the standard Poisson model, meaning that it can account more flexibly for underdispersion or overdispersion of the dependent variable (Hilbe, 2014). Note that *FPDS* and *W* may both be endogenous. We were unable to find valid instruments for these variables. While we control for a large range of observed heterogeneity, we cannot rule out endogeneity bias and therefore interpret the estimated coefficients as associations and not as rigorously identified causal effects.

3 Results

3.1 Descriptive statistics

Table 1 presents an overview of the descriptive statistics of the variables used in the analysis and regression models. Out of the total of 537 households in the sample, 529 reported that they were involved in agricultural production during the last 12 months. The average farm cultivates 2.3 acres of land, underlining that the landholdings are very small. Due to water constraints, most households grow crops only during one season per year; only 25% of the sample households cultivate two seasons per year.

The mean HDDS is 5.3, meaning that households consumed 5.3 different food groups. This is a very low value for a seven-day recall period and points at widespread dietary deficiencies. Approximately 80% of all households have an HDDS below 7 food groups, while only 16% have an HDDS exceeding 8 food groups. Excluding the less nutritious food groups (oils and fats; sugar and honey; beverages, condiments, and spices), over 90% of the households consumed less than 7 food groups (Table A2 in the online appendix).

Figure 1 shows the types of food groups consumed. Nearly all households consumed cereals and vegetables, whereas 60% consumed legumes, such as beans, cowpeas, and peanuts. Almost half of the households consumed fish during the seven-day recall period. Figure 1 also shows

the main sources of food. For cereals, own production dominates, while for all other food groups markets are the most important source. For vegetables, gifts, including transfers among community members, are also an important source. Very few households consume meat, eggs, and milk on a regular basis, and those that do mostly obtain these animal-sourced foods from the market.

Table 1: Descriptive statistics of variables used in the analysis

Variable	Obs	Mean	Std. dev.	Min	Max
Dietary and production diversity measures					
Household dietary diversity score (HDDS)	537	5.32	2.05	1	11
Farm production diversity score (FPDS)	529	2.74	1.23	1	7
Women decision-making					
Overall, all domains (share of decisions)	536	0.38	0.40	0	1
By domain					
Production decisions (share)	529	0.34	0.43	0	1
Sales decisions (share) [a]	390	0.29	0.42	0	1
Cash income use decisions (share) [a]	390	0.27	0.44	0	1
Food purchase decisions (share)	530	0.44	0.38	0	1
Other variables					
Head age (years)	537	44.81	15.94	18	89
Highest education level (years)	537	7.49	2.88	0	17
Female-headed household (dummy)	537	0.29	0.45	0	1
Household size (adult equivalents)	537	3.87	1.68	0.74	10.97
Number of shocks	537	4.11	2.02	0	9
Non-farm income (1000 MWK)	537	161.81	248.03	0	2064
Durable assets value (1000 MWK)	537	44.81	124.59	0	810
Productive assets value (1000 MWK)	537	17.40	47.90	0	374
Total input cost (1000 MWK)	537	55.89	181.57	0	3580
Total land cultivated (acres)	528	2.34	1.92	0	17
Extension service access (dummy)	537	0.31	0.46	0	1
Produced two seasons (dummy)	537	0.25	0.43	0	1
Number of months accessible by car	537	9.35	2.68	3	12
Distance to daily market (in km)	537	4.16	4.26	0	15
Number of food items in market	537	19.94	5.09	7	28

[a] For product sales and cash income use decisions, only households that sold any agricultural output are considered, which is why the number of observations is smaller.

These numbers suggest that own production is probably not the main source of dietary diversity for the small farm households in Malawi. Indeed, the mean HDDS from own production is only 1.4, while the mean HDDS from market purchases is around 4. Even when excluding the less nutritious food groups that are mostly purchased, mean HDDS from market purchases is 2.7 – still significantly larger than HDDS from own production.

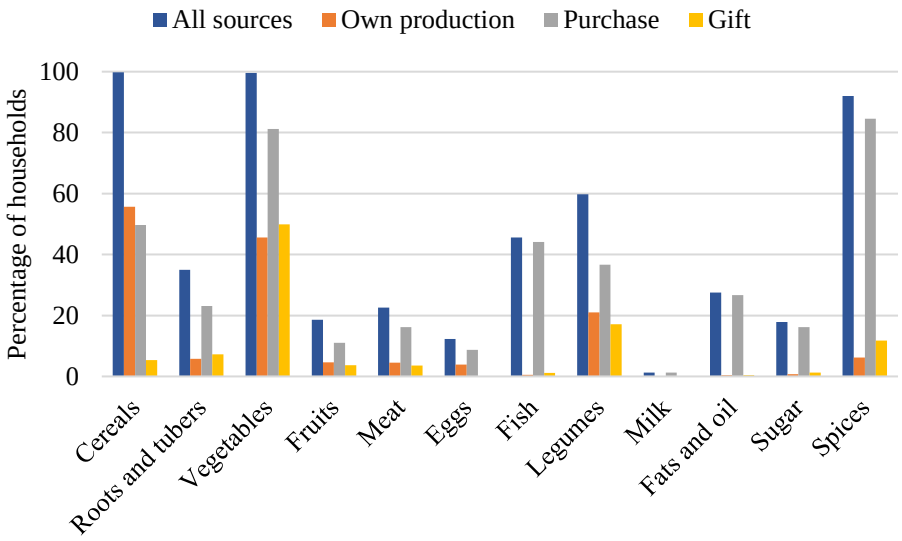


Figure 1: Proportion of households consuming different food groups and food sources

In terms of farm production diversity, Table 1 reveals that the average FPDS is 2.7 (3.6 different crop and livestock species, partly belonging to the same food groups). Figure 2 shows that over 90% of the households produce less than five food groups, which is unsurprising given the small farm sizes and seasonal water constraints. Almost all households produce cereals, while two-thirds produce legumes (Figure A1 in the online appendix). Around half of the households own livestock, mostly poultry, small ruminants, and cattle. Households producing crops in two seasons per year tend to have a somewhat higher FPDS (3.3) than the majority of households only producing in one crop season (2.6).

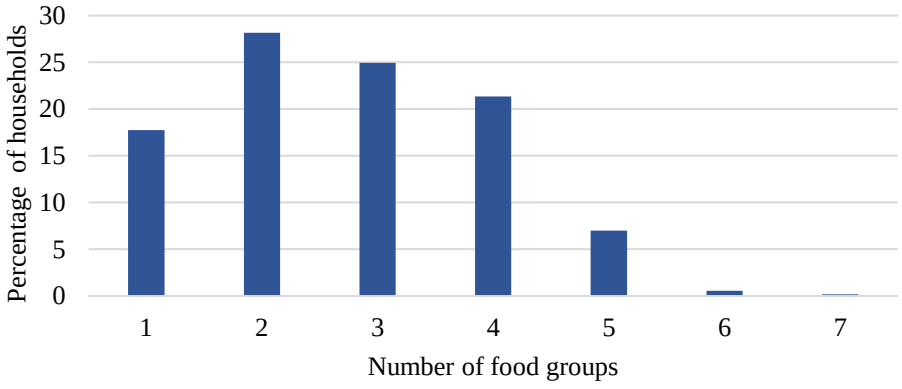


Figure 2: Proportion of households producing different numbers of food groups

Table 1 also shows women's decision-making in the different domains. Across the domains, women only make 38% of all decisions, underlining that males are the main decision-makers in the local context. Women's decision-making power differs somewhat between the different domains. It is highest for food purchases, but even here women only account for 44% of the decisions made. The lowest proportions of women's decision-making are observed for agricultural product sales (29%) and the related use of cash incomes (27%).

3.2 Regression results

Women's decision-making and farm production diversity

Table 2 summarizes the estimation results from the regression model explained above in equation (1) on the relationship between women's decision-making and FPDS. Column (1) of Table 2 shows the model with overall women's decision-making across all domains. We see a positive and significant coefficient of 0.713, which can be interpreted as a marginal effect. That is, farm households in which women make all decisions produce around 0.7 food groups more than farm households in which all decisions are made by men. This is a relatively large effect, given that the average farm household only produces 2.7 food groups and the estimates control for many potentially confounding factors. In other words, female decision-making is associated with a 26% higher farm production diversity than male decision-making.

Table 2: Associations between women's decision-making and farm production diversity

	(1) FPDS	(2) FPDS	(3) FPDS	(4) FPDS	(5) FPDS
Women's decision-making (share of decisions)					
Overall (all domains)	0.713***				
	(0.227)				
Production decisions		1.218***			
		(0.169)			
Sales decisions			0.169		
			(0.148)		
Cash income use decisions				-0.052	
				(0.158)	
Food purchase decisions					0.423***
					(0.157)
Control variables included	Yes	Yes	Yes	Yes	Yes
Observations	528	528	390	390	522

Notes: Results from regression models with farm production diversity score (FPDS) as dependent variable. Marginal effects (calculated at mean values) from generalized Poisson models are shown with clustered standard errors in parentheses. Full model results with all control variables are shown in Table A3 in the online appendix. *, **, *** Statistically significant at the 10%, 5%, and 1% level, respectively.

The other columns in Table 2 show results from models with women's decision-making in the separate domains. Unsurprisingly, we see a large positive and significant coefficient for the agricultural production domain (column 2). Farm households in which women make all agricultural production decisions produce 1.2 food groups more than farm households in which all production decisions are made by men. The coefficients for the domains of product sales and cash income use decisions are statistically insignificant (columns 3 and 4). Interestingly, the coefficient in column (5) is again positive and statistically significant, meaning that women's decision-making in the domain of food purchases is positively associated with FPDS. It is plausible that food purchase decisions and farm production diversity are linked; as was shown above, for most households food markets and own production are complementary sources of dietary diversity.

Farm production diversity and household dietary diversity

Table 3 summarizes results of the regression models parameters with HDDS as dependent variable. At first, we concentrate on column (1) of Table 3, showing the association between FPDS and HDDS (research question 2, estimated with the model explained in equation 2). The coefficient is positive and statistically significant, but relatively small in magnitude. Each additional food group produced on the farm is associated with a 5.7% higher food group consumption in the farm household. Given that the mean HDDS in sample households is 5.3, an increase in FPDS by one food group is associated with an increase in HDDS by only around 0.31 food group.

Women's decision-making and household dietary diversity

Column (2) of Table 3 shows associations between women's decision-making and HDDS (research question 3, estimated with the model explained in equation 3). In part A of the Table, we see that women's overall decision-making (across all domains) is positively and significantly associated with HDDS. After controlling for confounding factors, households in which all decisions are made by women consume more food groups than households in which all decisions are made by men. It suggests that female decision-making contributes to enhanced dietary quality in smallholder farm households.

Differentiating by decision domains, as shown in parts B-E of Table 3, reveals that women's decision-making is positively associated with HDDS for all domains, even though not all of the associations are statistically significant. Significant associations are observed for women's decision-making on agricultural product sales (part C) and on food purchases (part E).

Table 3: Associations between farm production diversity, women's decision-making, and household dietary diversity

	(1) HDDS	(2) HDDS	(3) HDDS	(4) HDDS	(5) HDDS
Part A					
Farm production diversity score (FPDS)	0.056***		0.049***	0.024	0.024
	(0.014)		(0.014)	(0.016)	(0.019)
Women' decision-making, overall (WO)		0.197**	0.162**		0.004
		(0.077)	(0.073)		(0.106)
FPDS×WO interaction				0.061***	0.060*
				(0.021)	(0.031)
Control variables included	Yes	Yes	Yes	Yes	Yes
Observations	528	528	528	528	528
Part B					
Farm production diversity score (FPDS)	0.056***		0.054***	0.048***	0.045***
	(0.014)		(0.013)	(0.014)	(0.016)
Women's decision-making, production (WP)		0.085	0.019		-0.045
		(0.063)	(0.058)		(0.085)
FPDS×WP interaction				0.014	0.026
				(0.017)	(0.025)
Control variables included	Yes	Yes	Yes	Yes	Yes
Observations	528	528	528	528	528
Part C					
Farm production diversity score (FPDS)	0.056***		0.049***	0.041**	0.040**
	(0.014)		(0.018)	(0.018)	(0.020)
Women's decision-making, sales (WS)		0.102**	0.092*		-0.016
		(0.049)	(0.048)		(0.107)
FPDS×WS interaction				0.031**	0.036
				(0.014)	(0.032)
Control variables included	Yes	Yes	Yes	Yes	Yes
Observations	528	390	390	390	390
Part D					
Farm production diversity score (FPDS)	0.056***		0.050***	0.042**	0.035*
	(0.014)		(0.018)	(0.018)	(0.020)
Women's decision-making, income (WI)		0.081	0.077		-0.101
		(0.053)	(0.052)		(0.098)
FPDS×WI interaction				0.032*	0.060*
				(0.017)	(0.031)
Control variables included	Yes	Yes	Yes	Yes	Yes
Observations	528	390	390	390	390
Part E					
Farm production diversity score (FPDS)	0.056***		0.054***	0.038**	0.028
	(0.014)		(0.014)	(0.015)	(0.019)
Women's decision-making, food (WF)		0.101**	0.079*		-0.075
		(0.045)	(0.043)		(0.092)
FPDS×WF interaction				0.032**	0.052*
				(0.013)	(0.028)
Control variables included	Yes	Yes	Yes	Yes	Yes
Observations	528	522	522	522	522

Notes: Results from regression models with household dietary diversity score (HDDS) as dependent variable. Models in parts A-E were estimated separately using women's decision-making in different domains as explanatory variables. Generalized Poisson models parameters are shown with clustered standard errors in parentheses. Full model results with all control variables are shown in Tables A4-A8 in the online appendix. *, **, *** Statistically significant at the 10%, 5%, and 1% level, respectively.

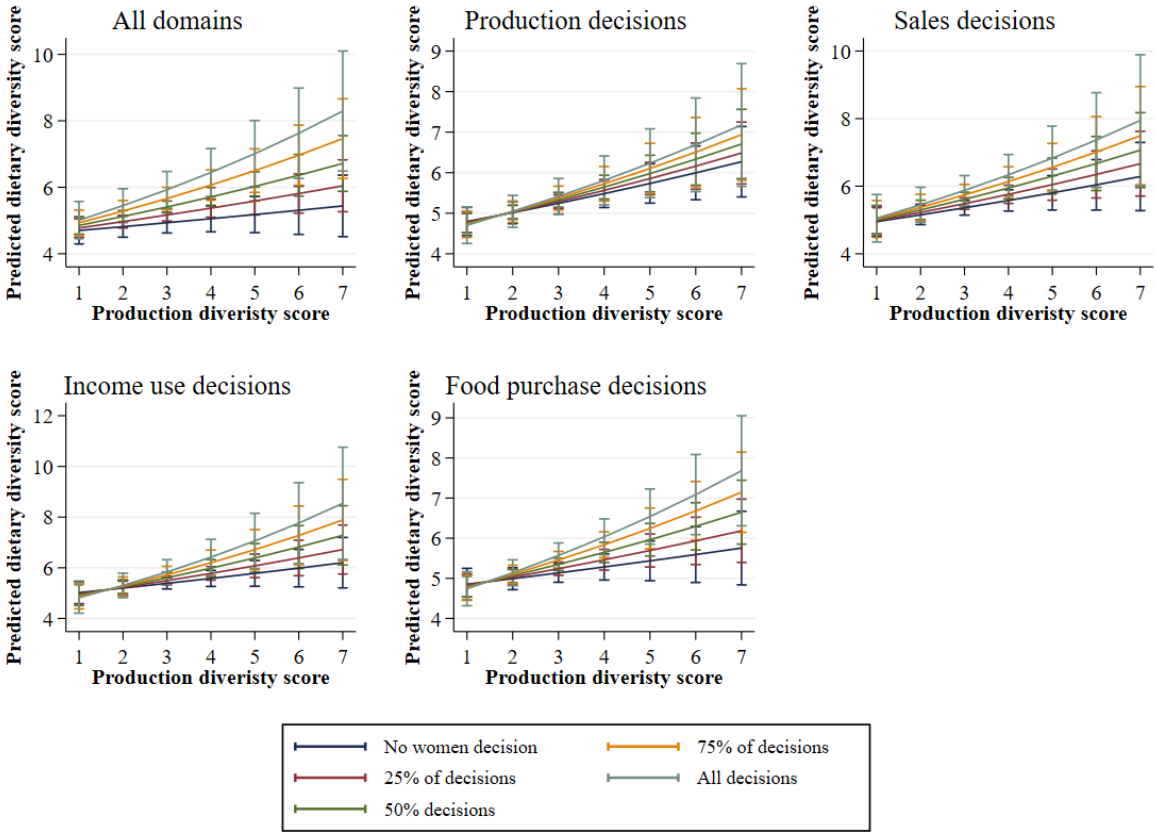
Women's decision-making and the association between FPDS and HDDS

Column (3) of Table 3 shows models where both FPDS and women's decision-making are jointly included as explanatory variables for HDDS. The associations between women's decision-making and HDDS remain positive, but they are somewhat smaller in magnitude than without additionally including FPDS (compare columns 1 and 3). This means that some of the positive association of women's decision-making is channeled through FPDS, which makes sense, as we showed above that female decisions are positively associated with farm production diversity.

In column (4) of Table 3, we include the interaction term between FPDS and women's decision-making to address research question 4. The interaction term produces a positive and significant coefficient in part A (across all decision domains) and also in parts C, D, and E. These interaction term coefficients imply that the positive association between FPDS and HDDS increases further with a stronger role of women in decision-making. The estimates in column (4), part A, suggest that FPDS is only insignificantly associated with HDDS in households where male members make all decisions, but the association is larger and statistically significant in households where all decisions are made by women. In column (5), we jointly include FPDS, women's decision-making, and the interaction term. The interaction term coefficients remain positive throughout, only that in some of the models they turn statistically insignificant, which is due to collinearity.

Overall, women's decision-making seems to increase the association between farm production diversity and household dietary diversity, especially when women decide on agricultural products sales, how the cash income is being used, and which food items are being purchased. These relationships are also shown graphically in Figure 4. The Figure uses the estimates from column (5) of Table 3 to make predictions of HDDS for different levels of FPDS and women's decision-making. Such graphical presentation better shows interaction effects in non-linear models. As can be seen, higher levels of female involvement in decision-making lead to steeper positive slopes in the relationship between FPDS and HDDS. Or, put differently, for every given level of FPDS the predicted HDDS is higher if women are more involved in household decision-making. The confidence intervals are larger at higher levels of FPDS, because the number of observations with high levels of FPDS in the sample is small.

Figure 4: Predicted dietary diversity by level of farm production diversity and sex of the decision-maker



Notes: Predicted household dietary diversity scores (HDDS) with 95% confidence intervals. Predictions based on generalized Poisson regressions presented in Tables A4-A8 in the online appendix (models with interaction terms, as shown in column 5 of Table 3).

4 Discussion and conclusion

This study aims to contribute to a better understanding of the associations between farm production diversity, women's roles in decision-making, and household dietary diversity, using recent survey data from the small farm sector in Malawi. We have addressed four research questions using various regression models. First, we have shown that women's decision-making is positively associated with farm production diversity, meaning that farm households in which women make more decisions produce more food groups than farm households in which men make most or all of the decisions. Second, we have shown that farm production diversity is positively associated with household dietary diversity. Third, we have revealed that women's decision-making is positively associated with household dietary diversity. And fourth, we have found that the association between farm production diversity and household dietary diversity increases with women's decision-making.

More generally, our data show that own production and market purchases are complementary sources of food for most smallholder households. Transfers of food among local community members are also observed. The relevance of different sources varies by food group. For cereals, own production is the most important source for most households. For many other food groups, own production plays some role, but market purchases are dominating.

Some of our research questions had been analyzed previously, with different data, while others had not. Our finding that production diversity is positively associated with dietary diversity and that the magnitude of the association is small is fully consistent with previous work (Jones et al., 2014; Malapit *et al.*, 2015; Sibhatu et al., 2015; Koppmair *et al.*, 2017; Sibhatu & Qaim, 2018; Muthini *et al.*, 2020; Bonis-Profumo *et al.*, 2021; Mehraban & Ickowitz, 2021; Sariyev *et al.*, 2021).

Our result that women's decision-making is positively associated with dietary diversity is also in line with many previous studies, even though the concrete results depend on the context (Sraboni et al., 2014; Njuki et al., 2022; Quisumbing et al., 2022). The way women's decision-making power is measured may also play a role. It should be noted that there is no uniform methodology. Several recent studies use the Women's Empowerment in Agriculture Index (WEAI), which includes gendered decision-making within households but also other aspects of women's empowerment, such as time allocation and leadership in the community (Quisumbing & Doss, 2021). In our study, we chose to focus on women's decision-making within households in domains that are particularly relevant for dietary diversity outcomes, namely agricultural production, agricultural product sales, cash income use, and food purchases. As one would expect, women's decision-making in the domain of agricultural production is particularly relevant for the association with farm production diversity. For the direct association with household dietary diversity, women's decision-making on agricultural product sales and food purchases is especially relevant.

Our finding that women's decision-making increases the size of the association between farm production diversity and household dietary diversity had not been shown previously. Two existing studies suggest that the relationship between production diversity and dietary diversity is larger in female-headed than in male-headed households (Jones *et al.*, 2014; Argaw *et al.*, 2021). However, only focusing on the sex of the household head does not allow statements on the implications of male versus female decision-making within households. In their studies in Nepal and China, Malapit *et al.* (2015) and Huang *et al.* (2023) analyze the role of female

empowerment within households using WEAI. They show that WEAI is positively associated with diet and nutrition outcomes, which is unsurprising. Somewhat more surprising is that in their models the interaction terms between production diversity and WEAI have significantly negative coefficients. A negative interaction term means that women's empowerment reduces the effect of farm production diversity on dietary diversity, which is the opposite of what we find in our models. On the one hand, the different results may be due to the fact that WEAI captures additional dimensions of women's empowerment beyond decision-making, such as women's time allocation, which can have important effects on diet and nutrition outcomes (Johnston *et al.*, 2015; Debela *et al.*, 2021). On the other hand, it is also possible and likely that the results are not the same everywhere but depend on the concrete empirical context.

Our broader result that markets and food purchases matter more than own production for dietary diversity in smallholder households is consistent with many previous studies from different countries in Africa (Carletto *et al.*, 2017; Sibhatu & Qaim, 2017; Bellon *et al.*, 2020; Muthini *et al.*, 2020; Argaw *et al.*, 2021; Matita *et al.*, 2021; Mulenga *et al.*, 2021). Against this background, it also makes much sense to see that women's decision-making in the domains of agricultural product sales and food purchases is most strongly associated with dietary diversity.

In conclusion, our results suggest that strengthening women's decision-making power can help to make smallholder farming more nutrition-sensitive through multiple channels. This involves women's decision-making in terms of agricultural production, marketing, income use, and food purchases. Women often have a different agricultural production behavior and a different income spending behavior than men, leading to more favorable outcomes for family diets and nutrition. Increasing farm production diversity can also help in some situations. Beyond strengthening women's decision-making power and increasing production diversity, improving market access and the functioning of markets for nutritious foods in rural areas are other important avenues for enhancing dietary diversity and nutrition in smallholder households.

Supplementary Information

An online appendix with additional Tables and Figures is available for this article.

CRediT authorship Contribution statement

Feiruz Yimer Mohammed: Conceptualization, Data curation, Formal analysis, Visualization, Writing-original draft. **Makaiko G. Khonje:** Validation, Writing- review & editing. **Matin Qaim**: Conceptualization, Writing- review & editing, Supervision, Funding acquisition

Competing interests

The authors declare no competing interests.

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