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Crop diversification and nutrition outcomes in smallholder households: Panel data evidence from Southwestern and Northern Uganda

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ABSTRACT

This study examined the effect of adopting crop diversification on nutrition outcomes of smallholder households in southwestern and northern Uganda. We constructed three models of correlates of household dietary diversity, minimum dietary diversity for women, and stunting of children aged 6–59 months. A 3-year panel multi-topic dataset collected in 2012, 2014 and 2016 by USAID's Feed the Future Innovation Lab for Nutrition in southwestern and northern Uganda was utilized. Crop diversification was found to be positively and strongly associated with household dietary diversity, and with the probability of achieving the minimum dietary diversity for women. There was no clear association found between crop diversification and child stunting. The findings imply that an integrated approach that simultaneously addresses increasing both crop and livestock diversification, access to improved farm production technologies, access to nutrition information, and increasing opportunities to do off-farm work should be adopted in order to improve the nutrition of farm households in Uganda.

Key words: Crop diversification, dietary diversity, stunting, panel data, Uganda

RÉSUMÉ

Cette étude a examiné l'effet de l'adoption de la diversification des cultures sur les résultats nutritionnels des ménages de petits exploitants dans le sud-ouest et le nord de l'Ouganda. Nous avons construit trois modèles de corrélats de la diversité alimentaire des ménages, de la diversité alimentaire minimale pour les femmes et du retard de croissance des enfants âgés de 6 à 59 mois. Un ensemble de données multi-sujets sur 3 ans recueillies en 2012, 2014 et 2016 par Feed the Future Innovation Lab for Nutrition de l'USAID dans le sud-ouest et le nord de l'Ouganda a été utilisé. La diversification des cultures s'est avérée positivement et fortement associée à la diversité alimentaire des ménages et à la probabilité d'atteindre la diversité alimentaire minimale pour les femmes. Aucune association claire n'a été trouvée entre la diversification des cultures et le retard de croissance des enfants. Les résultats impliquent qu'une approche intégrée qui aborde simultanément l'augmentation de la diversification des cultures et de l'élevage, l'accès aux technologies améliorées de production agricole, l'accès à l'information nutritionnelle et l'augmentation des opportunités de travail non agricole devrait être adoptée afin d'améliorer la nutrition des ménages agricoles en Ouganda.

Mots clés: Diversification des cultures, diversité alimentaire, rabougrissement, données de panel, Ouganda

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INTRODUCTION

Malnutrition arising from an inadequate intake of calories and micronutrients remains a major public health problem in sub-Saharan Africa where 250 million people are undernourished (FAO *et al*., 2020). Most households affected by malnutrition are in rural areas and mainly depend on agriculture for their livelihood (FAO, 2018). Since the 1990 United Nations Children's Fund (UNICEF) conceptual framework (UNICEF, 1991) and the 1992 International Conference on Nutrition (FAO, 1992) that called for a multi-sectoral approach to tackling undernutrition, national governments in developing countries have been addressing population nutrition issues by intervening in various sectors. Due to its impact pathways, the agriculture sector demonstrates a higher potential than other sectors to influence nutritional outcomes in developing countries (Ruel and Alderman, 2013; Ruel *et al*., 2018). Regional bodies such as the African Union have called on governments, through the Comprehensive Africa Agriculture Development Programme, to prioritize nutrition interventions in their agriculture investment plans.

The Food and Agricultural Organization (FAO, 2014) identifies three nutrition-sensitive agricultural production implementation avenues. The first avenue relates to increasing agricultural production so that food can be accessed by all households at affordable prices. Second, food can be made more diverse through deliberate crop production diversity undertaken by farm families. Third, food can be made more nutritious by means of micronutrient fortification at the processing stage or biofortification at the breeding stage and by improving soil quality. Given these avenues, there are a range of policy options emanating from the agricultural sector that could influence the nutritional outcomes of a population that is largely dependent on agriculture. In Uganda, the explicit nutrition objectives incorporated in the 2013 National Agriculture Policy (MAAIF, 2013) show that the agriculture sector is at the forefront in the fight against malnutrition. The focus of this study is to assess the impact of crop diversification, as a strategy of Uganda's National Agriculture Policy, on nutrition.

Nutritional outcomes in Uganda remain at undesirable levels. The progress registered at reducing stunting by 4 percentage points, between 2011 and 2016 as indicated by the 2016 Uganda Demographic Health Survey report (UBOS and ICF, 2018), is slow. Stunting is higher in the rural areas (30%) than in the urban areas (24%), and has consistently been higher in the southwestern and northern regions of the country since 2006 (UBOS and Macro International Inc., 2007). Poor diversification of diets has also been observed for Uganda as shown in previous evidence. Ecker *et al*. (2010) found that farmers' diets in Uganda and other East African countries were dominated by grains and tuber-based staples with little or no consumption of vegetables and fruit, which is a pointer to low dietary diversity. Also, an analysis of the food consumption module of the 2009/2010 Uganda National Panel Survey data (UBOS, 2013) showed that starchy staples and grains contributed, on average, to about 70% of calories consumed nationally (Namulondo, 2016). Such a high proportion of starchy staples and grains in the diet is an indicator of low dietary diversity (Smith and Subandoro, 2007). In view of the existing evidence of a positive association between dietary diversity and micronutrient adequacy and nutritional status of both children and adults (Torheim and Oshaug, 1998; Ruel, 2002; Arimond and Ruel, 2004; Arimond *et al*., 2010), the low diversity of Ugandan diets implies a low nutritional status of vulnerable individuals in the community, a situation which calls for more intervention.

Can crop diversification improve the nutrition of farm households? Two levels of nutrition outcome indicators are considered in the literature, namely intermediate nutrition outcomes and final nutrition outcomes. Intermediate nutrition outcomes include dietary diversity, calorie intake and micronutrient intake while final outcomes include anthropometric measures (such as child stunting) and disability adjusted life years, where adequate dietary intake can reverse years of life to be lost or lived with disability (Pandey *et al*., 2016). Three strands of studies can be identified in the literature that examines the association between farm production diversity and nutrition outcomes. In the first strand, studies investigate whether farm diversification predicts dietary diversity. The findings, which vary in some cases depending on the measurement of crop diversity, show a positive association in some studies (Jones *et al*., 2014; Pellegrini and Tasciotti 2014; Snapp and Fisher 2015; Jones 2017; Lovo and Veronosi 2019; Muthini, Nzuma and Nyikal, 2020) while other studies (Kavitha *et al*., 2016; Sibhatu and Qaim, 2018) find no clear effect of production diversity on dietary outcomes. Studies in the second strand present mixed evidence in an assessment of the importance of production diversity and consumption of own production vis-à-vis market-oriented farming and market dependence in improving dietary outcomes. For instance, Chegere and Stage, 2020 who find a positive effect of production diversity on dietary diversity show no effect of market access on dietary diversity. In contrast, Koppmair *et al*., 2016 and Sibhatu *et al*., 2015 show that access to markets is more effective than production diversity in increasing household dietary diversity.

Considering that diversified food production would produce diet quality to a farm household, studies in the third strand of literature test the hypothesis of a positive association between farm production diversity and child anthropometric measurements, and present mixed findings. Shively and Sununtnasuk (2015) find no association between crop diversity and stunting in Nepal, although specific food-crop groups are found to be important in reducing the risk of stunting. On the other hand, Kumar, Harris and Rawat (2015) and Lovo and Veronosi (2019) find a positive and significant association between production diversity and height-for-age Z-scores in Zambia and Tanzania, respectively.

Due to the above mixed evidence and given that diets are context specific, whereby foods culturally accepted in one country may not necessarily be accepted in another, this study provides evidence from two regions of Uganda on the effect of farm production diversification on dietary outcomes, adjusted for market access and market participation of households. Previous analyses that use 7-day recall data on household food acquisition to construct dietary diversity disregard the fact that this data does not takes into account the intra-household food allocation essential to understanding dietary patterns of vulnerable members (i.e., women of reproductive age and children under five) of a household. While we acknowledge that each dietary assessment methodology has limitations, collection of 24-hour food recall data on at least two non-consecutive days provides reliable information regarding average dietary patterns of household members (FAO, 2018). Also, in contrast to previous cross-sectional studies, this study's use of panel data allows controlling for unobserved factors that influence dietary diversity or a child's nutritional status and change over time. This study, therefore, adds to the literature by utilising a three-wave panel dataset with dietary diversity indicators estimated using 24-hour food intake information to test the following hypotheses: i) a higher level of crop diversification is associated with a higher level of household dietary diversity; and ii) a higher level of crop diversification is associated with a higher probability of achieving the minimum dietary diversity for women. Additionally, the study tests the hypothesis that the risk of stunting for children aged 6-59 months is lower for households with a higher level of crop diversification.

Conceptual Framework: the effect of a crop diversification strategy on household nutritional status

The 1990 UNICEF conceptual framework (UNICEF, 1991), which explains the causes of malnutrition, forms the theoretical basis of our analysis. As it highlights the linkages between agriculture and nutrition, this framework implies that the complex and multiple causes of malnutrition require broader strategies to be integrated with nutrition interventions to curb the malnutrition problem in developing countries. Kadiyala *et al.* (2014) and Headey *et al.* (2011) modified the UNICEF conceptual framework for malnutrition and provided specific pathways that explain the linkages between agriculture and nutrition. These were mainly, consumption of own production; income earned from agricultural-related activities that are used to acquire nutritious foods and healthcare; and women's socioeconomic status and autonomy in household decision-making. We expect that households who diversify their crop production to include staple grains and tubers, legumes, vegetables and cash crops will have a diverse diet, first, by consuming own production and second, by using income earned from sales of surplus food and cash crops to acquire other nutrient dense foods from the market. Income earned could also be used to access health services. The subsequent improvement in dietary diversity and health care access of individuals would lead to a better household nutritional status.

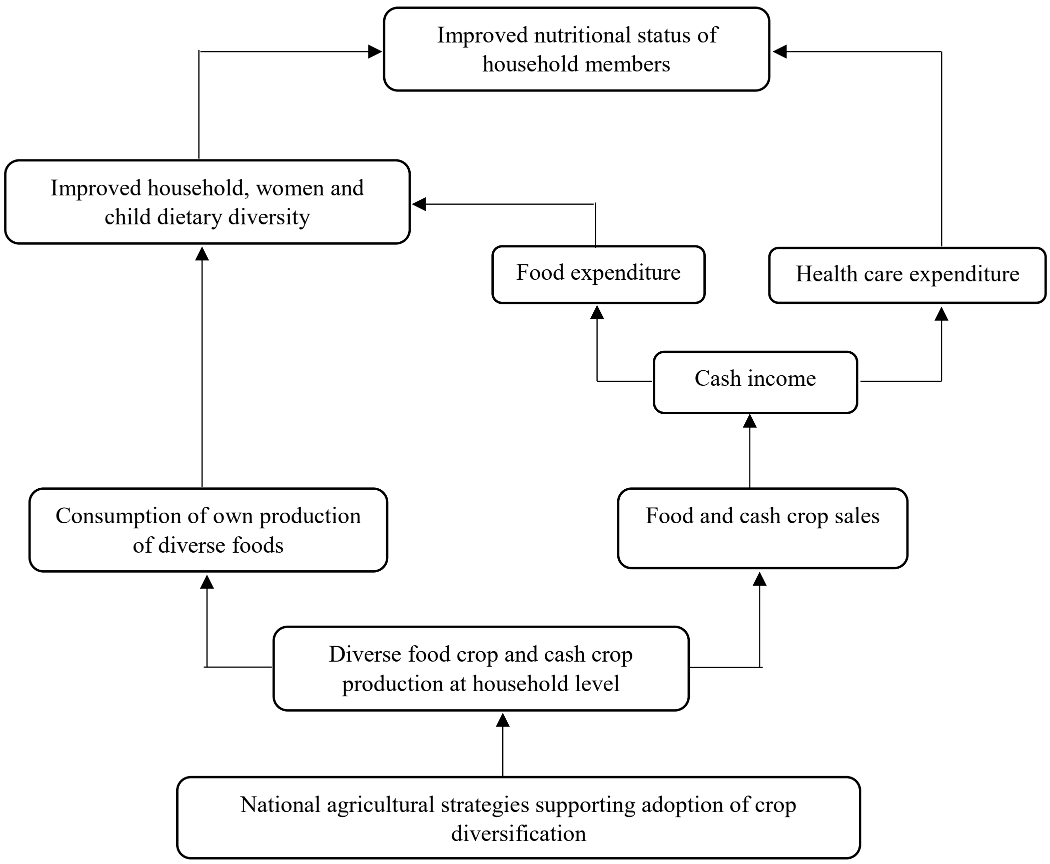


Figure 1. Pathways of the effect of a crop diversification strategy on a household's dietary outcomes
Source: Adapted from Headey *et al*. (2011) and Kadiyala *et al*. (2014)

MATERIALS AND METHODS

Data description. The data for this study were collected as part of the Community Connector Project by Feed the Future Innovation Lab for Nutrition in Uganda. Panel surveys were conducted in 2012, 2014 and 2016 in six districts in southwestern and northern Uganda (Fhi360, USAID/Uganda Community Connector Project, 2016). A multi-stage sampling framework was employed to identify 3,597 households in the baseline survey. The sampling framework involved randomly selecting 17–25 parishes from each of the six districts and then randomly selecting 5–8 villages from each selected parish. Households were then randomly selected from a list generated for each selected village. Of the households in the baseline survey, 3,302 and 3,196 were surveyed in 2014 and 2016, respectively. The main respondent of the survey was a woman of reproductive age (18–49 years), who prepared household meals and cared for infants and young children, identified as the caregiver. This survey was a multi-topic with different modules on household socio-demographic characteristics, dietary intake of young children and adults in a 24-hour recall, sanitation, breastfeeding, health status of the caregiver and children under five years of age, food security, crop and livestock production, income and expenditure, gender and decision-making, and anthropometric measurements of mothers and children under five. The low attrition rate of 7% to 8% was assumed to be random and was addressed by controlling for household demographics in the estimation models.

Construction of key dependent and independent variables. This study examined the effect of crop diversification on nutrition outcomes of farm households following a methodology similar to that in Jones *et al*. (2014), Sibhatu *et al*. (2015) and Koppmair *et al*. (2016) where a dietary diversity score is regressed on indices of farm production diversity and control variables including socio-demographic characteristics, market access and participation indicators, and farm characteristics. Three outcome variables were considered: Household Dietary Diversity score (HDD), Minimum Dietary Diversity for Women (MDD-W) and the anthropometric indicator of stunting in children under five scores. Hoddinott and Yohannes (2002) and Ruel (2002) define household dietary diversity as the number of different foods or food groups consumed by a household at a point in time. According to Ruel (2003), food items are grouped together when they have similar nutrients and have the same role in the diet. In this study, the HDD score was calculated based on 12 categories of foods consumed by the household in a 24-hour recall period, i.e., cereals; white tubers, roots and plantain; vegetables; fruit; meat; eggs; fish and other seafood; pulses; nuts and seeds; milk and milk products; oils and fats; and sugar, condiments and beverages.

MDD-W measures the number of food groups consumed by women of reproductive age out of the following 10 food groups (FAO and FHI 360, 2016): Grains, roots, tubers and plantain (starchy staples); pulses (beans, peas, lentils); nuts and seeds; dark green leafy vegetables; other Vitamin A-rich fruit and vegetables; other fruit; other vegetables; meat, poultry and fish; eggs; and dairy (milk and milk products). Thus, while the HDD score measures access to a diverse diet, the MDD-W with a cut-off of 5 food groups reflects the micronutrient adequacy of the diet of women of reproductive age in a household. Data on food intake were gathered from households based on a 24-hour recall period and the respondent was a caregiver/mother, aged 18–49 years, who prepared and served the meals.

Stunting is a widely used indicator of child nutritional status. From our conceptual framework, child nutritional status is depicted as a final outcome influenced by crop diversification via the mechanism of a child's consumption of diverse foods from own production and household food expenditure on diverse foods. Thus, the analysis used data on children who were assumed to have started complementary feeding, i.e., children aged 6-59 months. The stunting variable was constructed based on the height-for-age Z-scores in the dataset. These were calculated using growth standards compiled by the World Health Organization. Consequently, a 6–59-month-old child was considered stunted if her/his height-for-age Z-score was two or more standard deviations below the median height of the reference population (WHO, 2006). The analysis used data on an index child of 6–59 months old from 2,060 households.

Crop diversification was the main independent variable in our analyses. The crop diversity score, an indicator of crop diversification, was constructed by summing the number of diverse crop families produced. Accordingly, the following six food-crop families were constructed: grains; roots, tubers and plantain; legumes; fruit; vegetables; and oil seeds.

Estimation Models. A fixed-effects Poisson model with standard errors clustered at the household level, and thus robust to heteroscedasticity, was estimated for the count dependent variable of the HDD score with the following specification:

$$Y_{it} = \alpha_0 + \alpha_1 CD_{it} + \alpha_2 X_{it} + T_t + \omega_i + u_{it} \quad \text{\_\_\_\_\_\_ (1)}$$

Where Y_{it} is the HDD score for household i at time t. CD_{it} is the crop diversity score of household i at time t, and is a vector of control variables that includes socioeconomic characteristics, market access and participation indicators, and farm characteristics of household i at time t. ω_i is the time-invariant unobserved heterogeneity of household I, and u_{it} is an error term. The parameters to be estimated are represented by α.

Equations 2 and 3 are random-effect probit models estimated for the MDD-W and child stunting binary outcomes.

$$P(Y_{ait} = 1) = F(\alpha CD_{it} + \beta X_{ait} + \mu_{ai} + \varepsilon_{ait}) \quad \text{\_\_\_\_\_\_\_\_ (2)}$$

$$P(Y_{bit} = 1) = F(\alpha CD_{it} + \gamma X_{bit} + \mu_{bi} + \varepsilon_{bit}) \quad \text{\_\_\_\_\_\_\_\_(3)}$$

Where Y_{ait}=1 if the woman in household i at time t had met the MDD-W and 0 otherwise; Y_{bit}=1 if a child i at time t was found stunted and 0 otherwise; F represents the cumulative distribution of a standard normal distribution function; CD_{it} represents the crop diversity score; X_{ait} is a vector of control variables that could influence the MDD-W, while X_{bit} represents a vector of child, maternal and additional socioeconomic characteristics of household i at time t that could influence stunting of children aged 6–59 months. μ_{ai} and μ_{bi} are random effects assumed to be uncorrelated with the explanatory variables in the respective models, and ε_{ait} and ε_{bit} are error terms with a standard normal distribution and a mean of 0 and variance 1. Parameters to be estimated are represented by α, β and γ.

RESULTS AND DISCUSSION

Descriptive Results. Table 1 presents the summary statistics of variables used in the study and other household characteristics. The analysis included a total of 3,365 households aggregated from the northern and southwestern regions of Uganda. The summary statistics are discussed as follows. In the 24 hours that preceded the survey, households consumed an average of about 4 food groups out of 12 across the three waves. There was a small variation in the average HDD score arising from agricultural income-group differentials (high, medium and low), with households in the high-income group having a higher score (4.7) than those in the low income group (4.0). We found an average women's dietary diversity score of 3.14 out of 10 food groups corresponding to only 11% of households who met the MDD-W in the overall sample. The average number of different crop species produced was 5–6 crops, which translates to an average crop diversity score of 3.39 out of 6 food-crop families cultivated on an average land size of less than 3 acres.

Table 1, further, shows the average household size increased from 6 members in 2012 to about 7 members in 2016, and only 3% of the households were female headed. Caregivers/ mothers had an average of only 4 years of schooling completed, while over 98% of the mothers in the sample participated in household decision-making on income-use. A moderately high proportion of over 60% of households had access to a clean water source (piped water, public tap, borehole, protected well/spring and bottled water). Dissemination of nutrition and dietary knowledge is essential to influence nutritional outcomes as households and individuals tend to demand food items based on not only affordability, but also their knowledge of the nutritional values of the foods. The proportion of households that accessed nutrition information through media exposure, visits to health care facilities or visits of extension agents to households was higher in 2012 (71%) and reduced by about 20 percentage points in the subsequent waves.

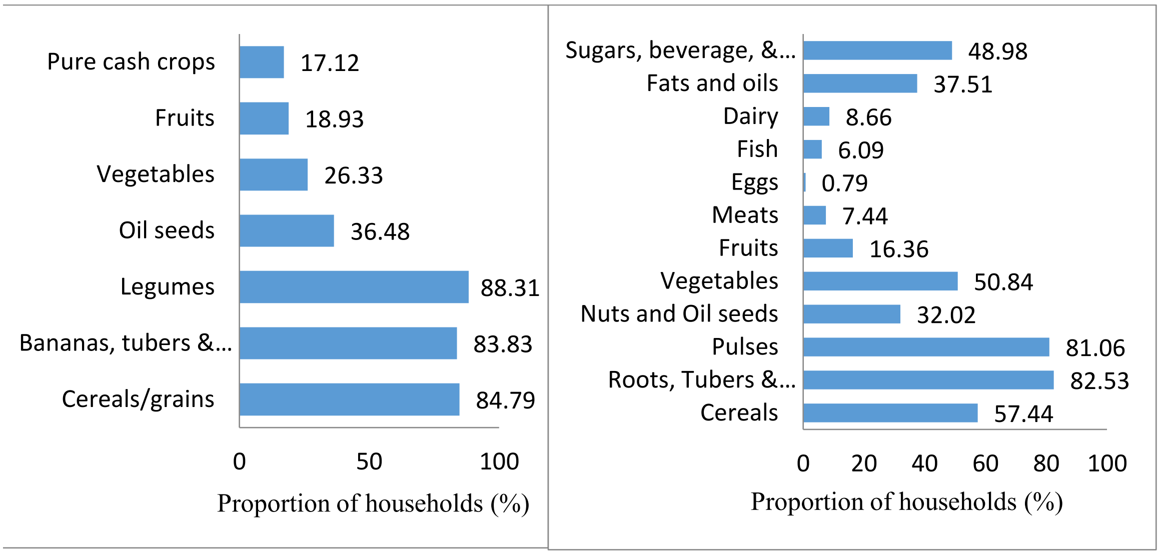
Table 1, furthermore, shows that majority of households in the sample were food insecure as fewer than 20% reported to have had enough food to eat. Moreover, food insecurity appeared to have increased over the survey years. Technologies that enhance productivity for smallholder farmers can result in food and nutrition security at the household level. The use of improved seed varieties and chemical fertilizer are shown in Koppmair *et al.* (2016) to be important determinants of dietary diversity for farm-households. In our sample, less than 30% of households used improved seed varieties while only about 4% reported to have used chemical fertilizers (Table 1). An average annual household agricultural income of about UGShs 550,000 was recorded for the households in this study's sample and over 70% of them had at least one member involved in an off-farm income-earning activity. Households in the sample reared an average of approximately two livestock categories out of the seven considered. About 65% of the total number of households in the analyses were from the Northern region (Table 1).

Figure 2 presents both household production of crops and consumption by food group. Fig. 2a shows that over 80% of households produced legumes, cereals/grains and bananas/ tubers/roots crop families, while only a smaller proportion produced vegetables (26.33%) and fruit (18.93%). Figure 2b shows that over 80% of households consumed roots/tubers/plantain food group. Pulses formed the second-most highly consumed food group, followed by cereals. However, fruit, meat, fish and dairy food groups were consumed by quite small proportions of households. This reveals diets that are not well-diversified and supports the finding of a low average HDD score shown in Table 1. The information in Fig. 2 suggests that households tend to consume what they produce. Thus, dependence on markets for daily food needs might be limited. Moreover, households sold only 25% of their crop output, on average (Table 1), indicating low market participation and high subsistence production. In addition, an average market distance of about 4 kilometres is rather high for households to buy daily food from the market, which suggests high dependence on own production.

Table 1. Selected characteristics of households and caregivers

Variable	Pooled Mean	Wave 1 Mean	Wave 2 Mean	Wave 3 Mean
Household dietary diversity score	4.35 (1.46)	4.46 (1.60)	4.14 (1.37)	4.40 (1.34)
Low income tercile	4.01 (1.34)	4.05 (1.47)	4.50 (1.58)	4.79 (1.66)
Middle income tercile	4.34 (1.43)	3.90 (1.25)	4.11 (1.31)	4.50 (1.53)
High income tercile	4.66 (1.53)	4.12 (1.27)	4.34 (1.30)	4.64 (1.37)
Women's dietary diversity score	3.14 (1.09)	3.31 (1.20)	3.00 (1.02)	3.06 (0.98)
Minimum dietary diversity for women achieved (1=Yes, 0=No)	0.11 (0.31)	0.15 (0.36)	0.08 (0.27)	0.07 (0.26)
Sex of household head (1= Female, 0=Male)	0.03 (0.17)	0.03 (0.16)	0.04 (0.19)	0.03 (0.17)
Household size	6.65 (2.47)	6.00 (2.57)	6.89 (2.28)	7.23 (2.34)
Years of schooling of caregiver/mother	4.02 (3.05)	4.04 (3.08)	3.98 (3.08)	4.02 (3.00)
Main woman participates in income-use decisions (1=Yes, 0=No)	0.99 (0.09)	0.99 (0.10)	0.99 (0.10)	0.99 (0.08)
Distance to nearest agricultural input/output market (Km)[2]	3.86 (3.11)	3.75 (3.00)	3.45 (2.71)	4.41 (3.50)
Share of output sold	0.24 (0.22)	0.26 (0.23)	0.24 (0.23)	0.23 (0.20)
Household had off-farm income (1=Yes, 0=No)	0.80 (0.40)	0.74 (0.44)	0.84 (0.37)	0.83 (0.37)
Agricultural income ('000 UGX)[1]	556.2 (664.5)	562.4 (661.9)	455.3 (605.0)	646.7 (708.2)
Food secure (1=Yes, 0=No)	0.16 (0.36)	0.18 (0.39)	0.16 (0.37)	0.12 (0.32)
Accessed nutrition information (1=Yes, 0=No)	0.59 (0.49)	0.71 (0.45)	0.52 (0.50)	0.51 (0.50)
Accessed a clean water source (1=Yes, 0=No)	0.66 (0.47)	0.64 (0.48)	0.66 (0.47)	0.69 (0.46)
Crop species count	5.76 (2.73)	5.74 (2.62)	5.00 (2.48)	6.52 (2.89)
Crop diversity score (crop families)	3.39 (1.09)	3.34 (1.05)	3.21 (1.10)	3.64 (1.09)
Size of land cultivated (acres)	2.73 (1.88)	2.90 (1.94)	2.65 (1.94)	2.60 (1.70)
Household cultivated vegetables (1=Yes, 0=No)	0.27 (0.44)	0.21 (0.41)	0.26 (0.44)	0.35 (0.48)
Livestock diversity score[3]	1.91 (1.26)	1.81 (1.26)	1.89 (1.22)	2.05 (1.27)
Used improved seed variety (1=Yes, 0=No)	0.26 (0.44)	0.30 (0.46)	0.22 (0.41)	0.25 (0.43)
Used chemical fertilizer (1=Yes, 0=No)	0.04 (0.19)	0.03 (0.17)	0.04 (0.20)	0.05 (0.21)
Household is in southwestern region (1=Yes, 0=No)	0.31 (0.46)	0.33 (0.47)	0.30 (0.46)	0.31 (0.46)

Source: Calculated based on Feed the Future Innovation Lab for Nutrition panel data 2012, 2014 and 2016 (Fhi360, USAID/Uganda Community Connector (CC) Project, 2016).
Note: Values are means with standard deviation in parentheses. N=7,739
[1] Exchange rate of 1 US$=3700UGX.
[2] Data for distance to the nearest market were collected only in the 2016 wave; a proxy of distance to the household's nearest source of healthcare was used for survey waves 1 and 2, and when household information was missing median values calculated at either the village level or parish level were used.
[3] Livestock diversity score was constructed as a sum of the number of livestock categories kept by a household. Accordingly, the following 7 categories of livestock were considered in constructing the score: cattle, sheep, goats, poultry, pigs, rabbits, and fish.



a. Crop families produced **b. Food groups consumed in 24-hour recall period**

Fig. 2. Crop production and household dietary diversity of the pooled sample (N=7,739)
Source: Calculated based on Feed the Future Innovation Lab for Nutrition panel data 2012, 2014 and 2016 (Fhi360, USAID/Uganda Community Connector (CC) Project, 2016).

Table 2. Selected characteristics of 6–59 months-old children and their mothers

	Pooled	Wave 1	Wave 2	Wave 3
Variable	Mean	Mean	Mean	Mean
Male child (1=Yes, 0=No) 0.51 (0.50)	0.50 (0.50)	0.54 (0.50)	0.49 (0.50)	
Weight at birth >=2.5 kg (1=Yes, 0=No)	0.95 (0.21)	0.96 (0.20)	0.95 (0.21)	0.94 (0.23)
Child was breastfeeding (1=Yes, 0=No)	0.87 (0.34)	0.86 (0.34)	0.88 (0.32)	0.88 (0.33)
Child's diet meets minimum acceptable[1] (1=Yes, 0=No)	0.14 (0.35)	0.17 (0.37)	0.10 (0.31)	0.12 (0.33)
Child received at least one vaccination (1=Yes, 0=No)	0.14 (0.35)	0.17 (0.37)	0.10 (0.31)	0.12 (0.33)
Stunted (1=Yes, 0=No) 0.25 (0.43)	0.25 (0.43)	0.23 (0.42)	0.26 (0.44)	
At least 4 antenatal care visits reported by mother (1=Yes, 0=No)	0.61 (0.49)	0.56 (0.50)	0.67 (0.47)	0.66 (0.47)

Note: Standard deviations are in parentheses. N=2,738.
[1]Based on a child dietary diversity score, calculated using 7 food groups, namely: grains, roots, tubers and plantain; legumes and nuts; dairy products; meat and fish; eggs; vitamin A-rich fruit and vegetables; and other fruit and vegetables. A minimum acceptable diet of at least 4 food groups consumed was considered (WHO, 2008).

Table 2 shows some characteristics of children aged 6–59 months from 2,022 households whose data were used for our analysis. About 50% of the children were male, about 95% had a birth weight of at least 2.5 kilograms, over 85% were still breastfeeding at the time of the surveys, and 90% had received at least a measles or diphtheria vaccination. Majority of the children in the analysis had an undiversified diet. Less than 15% of the children in the pooled sample had a diet that achieved the minimum acceptable level of at least four food groups. The proportion of children who were found stunted appeared to have increased marginally between 2012 and 2016. Overall, 25% of the children in the sample were stunted. About 60% of the mothers in the overall sample reported they had received antenatal care at least four times.

Econometric results

Bivariate association between crop diversity and nutrition outcomes. The results of the bivariate models in Table 3 show strong statistically significant associations between crop diversification and the dependent variables of HDD score, MDD-W and stunting. Specifically, if crop diversification was the only strategy pursued, an increase of 6.5% in household dietary diversity would arise from increasing crop diversity by one food-crop family while the probability of achieving the MDD-W would increase by 3.7% points. Conversely, the risk of stunting would reduce by 8.7% points as a result of increasing crop diversity by one food-crop family.

Association between crop diversification and household dietary diversity. Poisson estimator results in Table 4 show that the association between crop diversity and HDD score is sustained with the inclusion of control variables in the model. Specifically, increasing crop diversity by one food-crop family increased the HDD score by 6%.The effect is also larger in magnitude than any other statistically significant effect in the model. The number of livestock categories kept by a household was also positively associated with the HDD score as expected. An increase in the livestock diversification score by one livestock category increased household dietary diversity by 1.1%.

Other positive and statistically significant effects were found for the household's use of improved seeds, having an off-farm income source or job, being food secure, the mother/caregiver's access to nutrition information, and the mother/caregiver's years of schooling. No association was found between the HDD score and market access and participation indicators. Specifically, distance to the nearest market had a positive but statistically insignificant effect, whereas the share of marketed output had a negative statistically insignificant effect on the HDD score. However, the relationship found between market distance and HDD score was not surprising given the large average distance of about 4km between households' location and the nearest market, which makes it difficult for households to depend on the market for their food. A similar finding is shown in the work of Chegere and Stage (2020) who reported no association between market distance and household dietary diversity for Tanzania. Conversely, we interpreted the positive statistically significant effect of having an off-farm income to mean that markets still had a role in increasing the number of food groups consumed by households in predominantly subsistence farming. The adoption of agricultural technology such as the use of improved seeds and the consequent increase in farm productivity implies an increased surplus output, which can be marketed. This would improve a household's access to markets to buy diverse foods. Mothers with more years of schooling, who might have completed primary education were expected to have a higher HDD score probably because formal education improves access to nutrition knowledge needed to prepare diverse diets. The positive effect of food security on diet diversity indicates that households only begin to consider the quality of their diets if there is enough food to eat for every member.

Association between crop diversification and minimum dietary diversity for women

The results in Table 4 show that increasing crop diversity by one food-crop family would increase the probability of achieving the MDD-W by 2.8% points. In addition, increasing the number of livestock categories kept would increase the probability of achieving MDD-W by 1.1% points. Other factors found to be important to achieving the MDD-W included a woman's access to nutrition information and living in a food secure household. Further, unlike HDD which was not influenced by market distance, a negative statistically significant association between the probability of achieving the

Table 3. Bivariate association between crop diversification and nutrition outcomes

Variable	HDD score[1]	MDD-W[2]	Stunting[3]
Crop diversity score	0.063*** (0.005)	0.037*** (0.003)	-0.0865*** (0.0275)
Model Prob > chi2	0.0000	0.0000	0.0016
Number of observations	7,161	7,739	2,738

Note: Standard errors in parentheses are clustered by household.
[1]Poisson fixed-effects model includes household and year fixed effects.
[2,3]Results are marginal effects from a random-effects probit model
***p<0.01.

MDD-W and market distance was observed. This finding suggested that geographical market access was important to acquire food items like vegetables, which were consumed by a relatively greater proportion of households than were produced. The finding also confirms that markets are important to acquire food items like animal products, some vegetables and fruits that households do not produce. The importance of markets in achieving the MDD-W was, further, verified by the positive and statistically significant effects of having an off-farm income and of agricultural income on the probability of achieving the MDD-W. The positive effect of agricultural income suggested that income from the sale of output was used to access markets to buy food items that households do not produce. As expected, a woman's years of schooling was positively and significantly associated with the probability of achieving the MDD-W.

Association between crop diversification and stunting. Table 4 shows that crop diversification had no effect on stunting when control variables were introduced to the model. Instead, livestock diversification was found to be strongly associated with a lower risk of stunting. Specifically, a household's increase in the number of livestock kept by one categories would reduce the probability of stunting by 3.1% points. Households that keep cattle or poultry have access to animal source protein in the form of meat, milk and eggs, which enhance a child's diet and increase nutrient adequacy. Consumption of these food items is shown in the literature to be associated with a lower risk of child stunting (Khamis *et al*., 2019). Also, livestock ownership provides a source of income that households can use to acquire nutrient-dense foods for young children. Further, this study found a strong influence of both child and mother/caregiver's dietary diversity on stunting. The findings indicated that a diet that achieves the minimum child diet diversity reduces the probability of stunting by 4.9% points whereas a mother who achieved the MDD-W reduced the probability of stunting by 6.8% points. This is similar to previous findings in Khamis *et al*. (2019) and Hasan *et al*. (2019), which indicated that achieving the minimum dietary diversity for a child or mother was associated with reduced child stunting. Other factors found to be important in improving child nutritional status included a mother's years of schooling, mother's antenatal care visits, household size, and a household's access to an improved water source. These variables were found to be positively associated with a lower risk of stunting. Similar findings in previous research were reported by Fekadu *et al*., 2015; Torlesse *et al*., 2016; Ali *et al*., 2019; Khamis *et al*., 2019. Additional child-level characteristics that were associated with a lower risk of stunting were breastfeeding and birth weight. Specifically, breastfed children and had a 6.3% lower risk of being stunted than children who were not breastfed while children whose birth weight was at least 2.5kg had 12.9% lower risk of being stunted.

Table 4. Multivariate association between crop diversification and nutrition outcomes

Variable	HDD score1	MDD-W[2]	Stunting[3]
Crop diversity score	0.058*** (0.007)	0.028*** (0.004)	-0.005 (0.008)
Livestock diversity score	0.011*** (0.005)	0.011*** (0.003)	-0.031*** (0.007)
Distance to agricultural input/ output market (km)	0.002 (0.005)	-0.004*** (0.001)	0.001 (0.003)
(Crop diversity score) x distance to agricultural input/output market	-0.0004 (0.001)		
Share of output sold	-0.012 (0.025)	0.007 (0.018)	
Household had off-farm income source (Yes=1)	0.040** (0.013)	0.021** (0.009)	
Household used improved seed (Yes=1)	0.053*** (0.011)	0.015* (0.008)	
Household size	0.003 (0.003)	-0.002 (0.001)	-0.006* (0.003)
Years of schooling completed by caregiver/mother	0.008** (0.003)	0.007*** (0.001)	-0.0063** (0.003)
Main woman/ caregiver participates in income-use decisions (Yes=1)	0.055 (0.039)	-0.022 (0.040)	0.095 (0.073)
Caregiver received nutrition information (Yes=1)	0.025** (0.010)	0.031*** (0.007)	
Household was food secure (Yes=1)	0.028** (0.013)	0.036*** (0.010)	
Agricultural income (UGX)	1.40e-08 (9.12e-09)	1.69e-08*** (5.57e-09)	
Household used an improved water source (Yes=1)			-0.044** (0.018)
Child's sex (Male=1)			-0.168*** (0.016)
Child received at least one basic vaccination (Yes=1)			0.024 (0.028)
Child's weight at birth >=2.5 kg (Yes=1)			-0.129*** (0.043)
Child had ever breastfed (Yes=1)			-0.063** (0.026)
24-hour minimum child dietary diversity achieved (Yes=1)			-0.049** (0.022)
Mother achieved Minimum Dietary Diversity for women (Yes=1)			-0.068*** (0.024)
Mother reported at least 4 antenatal care visits (Yes=1)			-0.053*** (0.017)
Model Prob > chi^2	0.0000	0.0000	0.0000
Number of observations	7,161	7,739	2,738

Note: Standard errors in parentheses are clustered by household.
[1]Poisson fixed-effects model includes household and year fixed effects.
[2,3]Results are marginal effects from a random-effects probit model
*p<0.1, **p<0.05, ***p<0.01.

CONCLUSION AND POLICY IMPLICATIONS

This study examined the impact of the crop diversification strategy on dietary diversity of farm households and the nutritional status of children under-five in southwestern and northern Uganda. We found positive statistically significant associations between food-crop diversification and household dietary diversity, and between food-crop diversification and achieving minimum dietary diversity for women. As crop diversification is an existing strategy of the Uganda's National Agricultural Policy, our findings serve as reassurance for the policy and for agricultural programmes with a farm production diversification agenda aimed at improving nutrition outcomes in Uganda. Moreover, the results imply that households can increase dietary diversity by diversifying production to include non-staple food crops like vegetables and friuts and non-traditional crops like moringa oleifera with enormous nutrition benefits (Gopalakrishnan, Doriya and Kumar, 2016). However, for nutrition programming, priority setting in the face of limited resources points to an integrated approach that simultaneously addresses increasing both crop and livestock diversification, access to improved farm production technologies, access to nutrition information, and increasing opportunities to do off-farm work in order to improve the nutrition of farm households in Uganda.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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