Panel Data Analysis of a Crop Diversification Strategy in South-Western and Northern Uganda

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and
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Abstract

This study contributes to the evidence on the impact of agricultural policies and programmes on nutritional outcomes at the household level. We specifically examined the effect of adoption of crop diversification on household and child nutrition outcomes among small-scale farm households in South-western and Northern Uganda. We constructed two models of correlates of intermediate nutritional outcomes (Household Dietary Diversity and Minimum Dietary Diversity for Women) and one model of correlates of a final nutrition outcome (child stunting). A 3-year panel multi-topic dataset collected by Feed the Future Nutrition Innovation Laboratory as part of the Community Connector Project in Southern-western and Northern Uganda was used. In all estimations, we found that crop diversification is positively and significantly associated with Household Dietary Diversity and Minimum Dietary Diversity for Women. The findings also suggest that to increase dietary diversity, the crop diversification strategy needs to be accompanied by interventions that increase farm household's access to improved seed varieties, and increase farm households' nutrition knowledge. In other findings crop diversification has a negative and significant effect on child stunting when child and caregiver's characteristics are controlled for in the estimation model.

Key words: *crop diversification, dietary diversity, stunting, panel data, South-western and Northern Uganda*

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1. Introduction

Malnutrition arising from inadequate intake of energy and nutrients is still a major public health problem in Sub-Saharan Africa (SSA) (Von Grebner et al., 2016) and accounts for the largest cause of disease burden in these countries (Black et al. 2008). Most of the households affected by malnutrition in SSA are in the rural areas and depend mainly on agriculture for their livelihood. Often, direct interventions to address specific nutrient deficiencies- such as micro-nutrient supplementation in sub-groups of the population - receive a lot of attention, yet the multiplicity of malnutrition causes calls for broader strategies to feed into food and nutrition policies of developing countries. Experts have emphasised the need to support nutrition-specific interventions with nutrition-sensitive economic and social policies in order to improve their effectiveness (Ecker and Nène, 2012; Bhutta et al., 2008). Due to its impact pathways, the agriculture sector has already been identified to have a higher potential than other sectors to influence household nutritional outcomes in developing countries (Ruel and Alderman, 2013). 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. Secondly, food can be made more diverse through deliberate crop production diversity undertaken by farm families. Thirdly, food can be made more nutritious by means of micronutrient fortification at the processing stage or biofortication at the breeding stage and by improvement of soil quality. Given these avenues, there are a range of policy options emanating from the agricultural sector that could be used to influence the nutrition outcomes of a population. These avenues also imply that for a developing country such as Uganda where about 70% of the population are employed in agriculture (World Bank, 2018), the agriculture sector has potential to drive national nutrition outcomes. In this study, we examined the relationship between crop diversification, as an agricultural policy intervention, and nutrition outcomes for farm households in Uganda.

Although nutritional outcomes in Uganda are still at undesirable levels, some progress has been registered in the fight against malnutrition. The 2016 Uganda Demographic Health Survey report showed that child stunting reduced by 4% between 2011 and 2016. Stunting, however, remained higher in rural areas (30%) than urban areas (24%). The poor nutrition outcomes are also unevenly distributed within the regions of the country. As the 2006, 2011 and 2016 Uganda Demographic Health

Survey reports show, the prevalence of stunting has, over the years, been highest in the South-west region and moderately high in the Northern region. Intermediate nutritional outcomes such as household dietary diversity, which are known to have a positive effect on the nutritional status of children and adults (Ecker et al., 2010; Arimond and Ruel, 2004; Ruel, 2002; Hoddinott and Yohannes, 2002; Rose et al., 2002; Gibson 1994) are also still at undesirable levels in Uganda. A study by 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 fruits, which are important sources of vitamins and minerals for poor farm households. Additionally, an analysis of the food consumption module of the 2009/2010Uganda National Panel Survey data found that starchy staples and grains contributed, on average, to 71% of calories consumed nationally (Namulondo, 2016). Based on the guidelines in Smith and Subandoro (2007), such a high proportion of starchy staples and grains in the diet is an indicator of low dietary diversity.

There is evidence that for small-scale farm households, production diversity achieved through farmers integrating vegetables, legumes, fruits and small livestock into their farming systems can deliver improved nutrition outcomes (Akerele et al. 2017; Koppmair et al. 2016; Dillio et al., 2015; Kumar et al., 2015; Sibhatu et al. 2015; Lovo and Veronsi, 2014; Jones et al., 2014; and Remans et al., 2011). However, this evidence is limited and because of cultural differences that exist among populations and influence food practices, conclusions based on a study on one country may not be relevant for another country with a different cultural situation. For instance, dietary practices in Tanzania are influenced by the Swahili culture with rice forming a major food crop grown and consumed while in Uganda, food consumption patterns are dependent on traditional crop production patterns, which tend to vary by region. An analysis of nationally representative data showed that the major calorie sources were plantain (matooke) and sweet potatoes and sweet potatoes and cassava in western and northern Uganda, respectively (Namulondo, 2016). It's therefore necessary to verify whether adherence to a society's cultural and/or traditional food practices is associated with better nutrition outcomes.

In addition, considerable evidence (Akerele et al. 2017; Sibhatu et al. 2015; and Jones et al. 2014) is based on household food consumption data which are not collected for dietary purposes. A notable limitation is that the collection of this data does not take into account the quantities of food wasted, stored or given to domestic animals. Consequently, overestimation of food and nutrient intake may arise if less than acquired food was consumed in the recall period longer than 24 hours (Smith and Subandoro 2007), and this may affect the relationship between nutrition outcomes and crop diversification. Thus, in this study we addressed such data limitations by using 24-hour food recall data. Additionally, other factors besides crop diversity that influence nutrition outcomes may vary by country depending on relevant country conditions. For instance, while the use of chemical fertilizer is shown to be an important determinant of dietary diversity in Malawi (Koppmair et al., 2016), its role might be limited in the context of Uganda which doesn't have a fertilizer subsidy policy. In this

study we aimed to examine the effect of a small-scale crop diversification agricultural intervention on nutrition outcomes, using farm household-level panel data from south-western and northern Uganda. Our priors were twofold: i) a higher level of crop diversity is associated with a higher level of household dietary diversity and dietary diversity for women, ii) the probability of child stunting is lower in households with a higher level of crop diversity. The rest of the paper is organized as follows. An overview of the literature and conceptual framework are presented in section 2, while the data and the estimation approach are discussed in section 3. The results and discussion are presented in section 4 and a conclusion is provided in section 5.

2. Policy context and related literature

Empirical evidence that demonstrates the relationship between individuals' food intake and their health, and the imperfections in the food systems which imply that households cannot rely only on the market to acquire diverse, nutritious and affordable food provide the rationale for evaluating the impact of agricultural strategies on nutrition. Since the 1990 UNICEF conceptual framework and the 1992 International Conference on Nutrition 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, with the agriculture sector at the forefront. Uganda has incorporated explicit nutrition objectives in her agriculture policy and the national development plan. The goal of Uganda's 2013 National Agriculture Policy (NAP) is "to achieve food and nutrition security and improve household incomes" (MAAIF, 2013). The first specific objective of this policy requires that all households and individuals are food and nutrition secure in Uganda. One strategy to achieve this objective relates to farm production diversification: Here the government of Uganda promotes "the production of nutritious foods to meet household needs and for sale…" (MAAIF, 2013). Accordingly, in operationalizing this strategy, 12 food commodities were prioritized for investment in the areas of research, extension, provision of quality inputs, pest, vector and disease control, post-harvest handling, and improving market access and value addition. These food commodities include bananas, beans, maize, rice, cassava, Irish potatoes, tea, coffee, fruits and vegetables, dairy, fish, and livestock. In a complementary strategy, the policy supports consumption of diversified nutritious foods through promotion of production of bio-fortified foods including indigenous foods at household and community levels. Also, the second objective of the policy identifies farm diversification as one of the strategies that would lead to increase in farming households' incomes. Additionally, the policy provides for development of extension systems through which farmers receive new knowledge and information on good agricultural practices. Diversified farm production systems are a component of the recommended agricultural practices included in training manuals of extension systems whereby farmers are taught to intercrop and plant micro-nutrient rich varieties. Clearly production diversification is appreciated as a policy instrument that is expected to directly and indirectly influence household nutrition. Uganda's Agriculture Policy is operationalized by the Agricultural Sector Strategic Plan and is being implemented by state and non-state actors such as donor

agencies who work in partnership with Uganda's government. An example of this partnership was the USAID-Uganda's Community Connector Project which supported the implementation of the 2010-2015 Agricultural Sector Development Strategy and Investment Plan in Uganda.

USAID's community connector project in Uganda

This was a Feed the Future initiative with the objective of improving the nutrition, health and livelihood of poor rural households, dependent on subsistence farming, through integrated agricultural and nutrition interventions. The project that began in 2012 and lasted five years was implemented in 15 districts in Northern and Southwestern Uganda. USAID worked with local governments in these districts to implement evidence-based interventions that would improve agricultural production and livelihood activities, household nutrition, hygiene practices and gender equitable practices. Beneficiary households were expected to adopt 10 intervention components (USAID Uganda Community Connector Technical Notes Series No. 6) that comprised of: creating homestead gardens of nutritious foods such as pumpkin, amaranth and other traditional vegetables; at least a pawpaw tree, an avocado tree or other fruits tree near the homestead; an agricultural income generating activity; rearing of goats, chicken or apiary; acquisition of production assets such as hoes, ox-ploughs, watering cans, and spray pumps; availability of water, sanitation and hygiene facilities; clean and neat homestead compound; family members supporting each other in production and feeding decisions; stocks of enough food to last up to three months in the garden or store; and women or family were saving. The mid-term review report of the project indicated that these intervention components had been widely adopted by the beneficiary households (USAID Uganda Community Connector Technical Notes Series No. 6).

Empirical studies

Previous studies on the relationship between agricultural production and nutrition have found impacts of agricultural production diversity on different levels of nutrition outcome indicators. Pandey et al. (2016) identified two levels of nutrition outcome indicators namely, intermediate nutrition outcomes which include dietary diversity, calorie intake and micronutrient intake while final nutrition outcomes include anthropometric measures and Disability Adjusted Life Years. Studies that estimated dietary diversity outcomes of crop diversity include Jones et al. (2014), who utilized Malawian household-level cross-sectional data and concluded that farm production diversity had the potential to increase household dietary diversity. Herforth (2010) demonstrated a positive association between the number of crops grown and the farm households' dietary variety measured by the number of different foods, in the diet in the East African countries of Kenya and Tanzania. Sibhatu et al. (2015) used

household cross-sectional data from Indonesia, Kenya, Ethiopia and Malawi and found a positive association between on-farm production diversity and household dietary diversity. However, when market access was controlled for in the regression model of this study, the results suggested that households' market access was more effective in increasing diet diversity than increasing production diversity. In a similar study, Koppmair et al. (2016) demonstrated that the effect of farm diversity on household, mothers' and child dietary diversity was smaller than that of market access and agricultural technology adoption in Malawi. Akerele and Shitu (2017) also reported a positive and statistically significant effect of farm production diversity on household dietary diversity in Nigeria. However, in Kavitha et al. (2016), it was concluded that crop diversity alone did not improve household dietary diversity in the semi-arid regions of India.

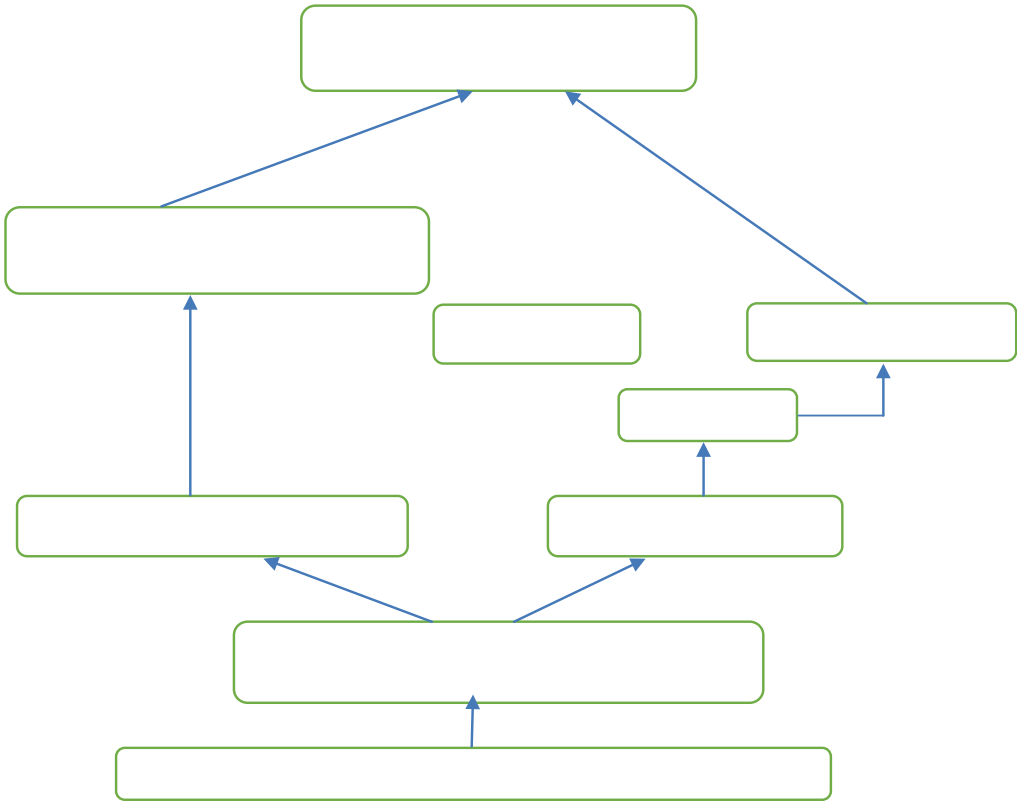
In the empirical evidence that tested the hypothesis of a positive association between farm production diversity and final nutrition outcomes is Kumar et al., (2015) who found a positive association between on-farm diversity and the anthropometric measure of height-for-age Z-scores in Zambia. Similarly, Lovo and Veronsi (2014) found a positive and statistically significant effect of crop diversification on height-for-age Z-scores for Tanzania. Another study on Nepal (Shivey and Sununtnasuk, 2015) reported positive correlations between the consumption of own production and better outcome indicators of stunting and height-for-age Z scores. The general evidence seems to suggest that farm production diversity is positively associated with the nutritional status of farm households in developing countries. However, this evidence is rather limited and there is need to understand what other factors besides farm production diversity that influence nutritional outcomes as these might vary by population.

Conceptual framework

The UNICEF conceptual framework which explains the causes of malnutrition (UNICEF 1990), highlights the linkages between agriculture and nutrition. However, this framework also shows that the complex and multiple causes of malnutrition require broader strategies to be integrated with agriculture interventions in order to curb the malnutrition problem in developing countries. Kadiyala et al. (2014) and Headey et al. (2012) 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, incomes earned from agricultural related activities that are used to acquire nutritious foods and healthcare, and women's socio-economic status and their position in household decision-making in utilization of resources. Figure 1 shows the major pathways of impact of a crop diversification strategy on nutrition outcomes at the household level. We show that adoption of crop diversification at farm-household level may directly increase dietary diversity if foods with different nutritional values are produced for home

consumption. Incomes realized from sale of cash crops and surplus food can be used to acquire food not produced at home, hence increasing diversity of the household's, women's and child's diet. Allocation of income to non-food items increases health-care expenditure and also improves household sanitation. Therefore, attainment of the minimum dietary diversity together with access to healthcare improves final nutritional outcomes of women and children who are the vulnerable members of a household.

Figure 1: Pathways of the impact of a crop diversification strategy on household nutrition outcomes



Source: Adapted from Kadiyala et al. (2014) and Headey et al. (2012)

3. Data and estimation approach

The study used data collected as part of the Community Connector Project by Feed the Future Innovation Laboratory for Nutrition (ILN) in Uganda. The Nutrition Innovation Laboratory Africa conducted panel surveys in 2012, 2014 and 2016 in six districts in southwestern and Northern Uganda. This was a multi-topic study covering household characteristics such as diet intake, water and hygiene, breastfeeding, health status of the caregiver and children under 5 years of age, food security, crop and livestock production, income and expenditure, women's participation in household decision making and anthropometric measurements. A 2-stage sampling framework was employed to identify 3,597 households with caregivers of children 0-23 months in the baseline survey. 3,302 and 3,196 of these households were re-interviewed in 2014 and 2016.

Our analyses concentrated on the impact of crop diversity on nutrition outcomes at the household level among small-scale farmes. The methodology followed was similar to that in Koppmair et al. (2016), Jones et al. (2014) and Sibhatu et al. (2015), where a dietary diversity score and indices for farm production diversity were constructed. Jones et al. (2014) used cross-sectional data and identified a vector of socio-demographic and income-level indicator variables and a vector of agricultural-related variables that affect household dietary diversity. On the other hand, Sibhatu et al. (2015) estimated a Poisson model in which household dietary diversity was regressed on a vector of market access variables in addition to a production diversity index. The study demonstrated the importance of households' access to markets to have their surplus production marketed and to buy non-staple foods in influencing the households' dietary diversity. Koppmair et al. (2016) used cross-sectional data and controlled for adoption of agricultural technology in their model in addition to market participation indicators.

Three dependent variables were considered in this analysis: the household dietary diversity score, the minimum dietary diversity for women and, the anthropometric indicator of stunting in children under five. 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 carry similar nutrients and have the same role in the diet. Following Sibhatu et al. (2015) and Koppmair et al. (2016), the Household Dietary Diversity Score (HDDS) was adapted and calculated based on 12

categories of foods consumed by the household, i.e., cereals; white tubers, roots and plantain; vegetables; fruits; meat; eggs; fish and other sea foods; pulses; nuts and seeds; milk and milk products; oils and fats; sugar, condiments and beverages. The minimum dietary diversity for women (MDD-W) score measures the number of food groups consumed by women of reproductive age out of the following 10 food groups: Grains, roots, tubers and plantain (starchy staples); Pulses (beans, peas, lentils); Nuts and seeds; Dark green leafy vegetables; Other Vitamin A rich fruits and vegetables; Other fruits; Other vegetables; Meat, Poultry and fish; Eggs; and Dairy (Milk and milk products) (FAO, 2016). Thus, while the HDD score measures access to a diverse diet, the MDD-W with a cutoff of 5 food groups reflects micronutrient adequacy of the diet of women of reproductive age in a household. Data on food intake was 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.

To construct the child stunting variable, growth standards compiled by the WHO (WHO, 2006) were employed to calculate height-for-age Z-scores of children under five. A child was then 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). Two indicators of crop diversity (the main independent variable in this analysis) were constructed: the crop count which is simply the number of different crop species produced on a farm and the crop diversity score, constructed by summing the number of diverse crop families produced. However, beyond the descriptive analysis we focused on the crop diversity which reflects dietary diversity. The following six crop families were constructed- grains; roots, tubers and plantain; legumes; fruits; vegetables; and cash crops (non-food crops).

A Poisson Fixed Effects regression was estimated for the count dependent variable of HDD with the following covariates: household characteristics (household size, a dummy of whether or not the caregiver completed primary education, household decision making dummy of the woman, household income indicator, household's access to nutrition information, food security status of the household, a dummy for off-farm income, market access and participation indicators (i.e., distance to the nearest input/output market and share of output sold in the market), and agricultural technology adoption indicator i.e. whether improved seeds were used for crop production. We included a variable that measures women's participation in household decisions following previous studies that have controlled for the effect of women's empowerment on child and adult nutritional outcomes (Amugsi et al. 2015; Headey and Hoddinott 2015). Specifically, an indicator of whether the main woman of the house participated in the decision of allocation of income from land use was adopted. Similarly, access to nutrition information was included as a dependent variable in the models because research (Waswa et al. 2015; Inayati et. 2012; Kabahenda et al., 2011) has shown that even food secure households might be affected by malnutrition if they lack nutrition related knowledge on caring and dietary practices. In the survey, caregivers were required to mention whether they had received any nutrition information through media sources, visits to health care facilities or household visits of extension agents.

The dependent variable MDD-W is binary with “1” representing households that meet the minimum dietary diversity for women of at least 5 food groups and “0” representing otherwise. Accordingly, a binary logistic model was estimated with the following independent variables: an indicator of crop diversification, sex of household head, household size, a dummy of whether or not the caregiver completed at least primary education, household decision making dummy of the woman, household’s access to nutrition information, food security status of the household, a dummy for off-farm income, a dummy for whether the household grows vegetables, a household income indicator and market access and market participation indicators. Finally, we analysed the impact of crop diversification on child stunting in smallholder farm households. To examine the impact of the crop diversification intervention on final nutrition outcomes, the child nutrition status indicator of stunting was employed as the outcome variable. In this case, four binary logistic regression models were estimated with the aim of understanding how the effect of crop diversification varies with inclusion of child characteristics, caregiver’s characteristics and household characteristics in the models.

4. Results and discussion

Descriptive results

Table 1 presents selected household characteristics. The result shows that the average household size increased from 6 members in 2012 to about 7 members in 2016. About 21% of the caregivers (mothers) had completed primary education across the panel waves. The proportion of women who participated in household decision making on how income from land use was to be utilized is 69% in the pooled sample.

Table 1: Selected characteristics of households in the samples

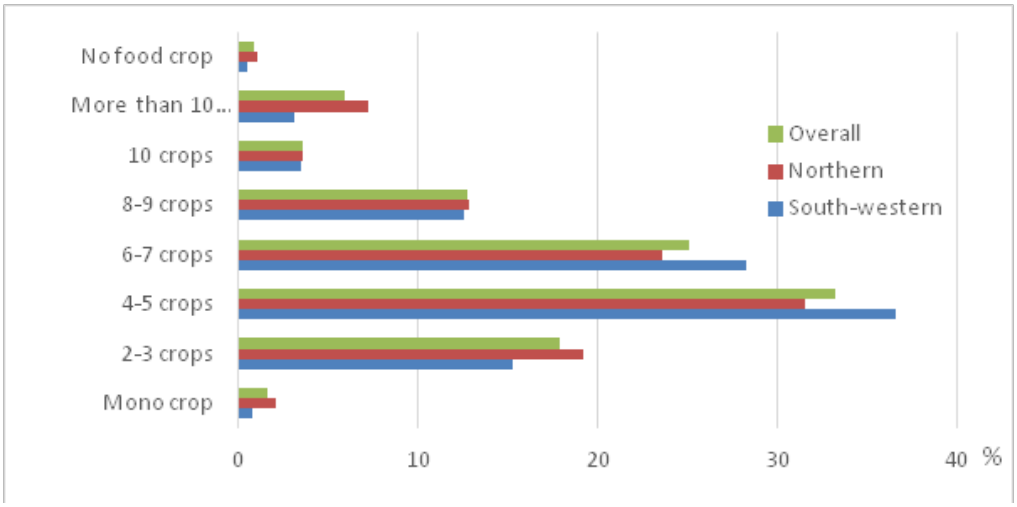
	Pooled	2012	2014	2016
Household size	6.58 (2.49)	6.0 (2.58)	6.74 (2.31)	7.09 (2.43)
Caregiver completed primary education (%)	21.49	21.93	20.94	21.47
Women's decision making on farm income (%)	69.43	73.42	68.84	65.55
Distance to nearest input/output market (km)	3.88 (3.11)	3.80 (3.02)	3.49 (2.74)	4.40 (3.47)
Sold agricultural output in the market (%)	88.46	89.24	85.28	90.86
Share of output sold	0.25 (0.23)	0.26 (0.23)	0.25 (0.24)	0.25 (0.21)
Household has off-farm income (%)	79.29	74.40	82.07	81.91
Agricultural income ('000 shs)	725 (1,195)	692 (1,072)	594 (1,069)	897 (1,410)
Food secure households (%)	15.26	17.85	15.23	12.36
Accessed nutrition information (%)	57.94	70.70	51.09	50.66
Household grows vegetables (%)	26.33	21.03	25.60	33.04
Accessed clean water source (%)	66.25	64.25	66.00	68.77
Improved sanitation (%)	85.18	83.10	83.13	89.64
Crop species count	5.78 (2.77)	5.74 (2.65)	5.11 (2.54)	6.52 (2.95)
Crop diversity score (crop family)	3.51(1.11)	3.44 (1.07)	3.34 (1.11)	3.77 (1.11)
Cultivated land (ac)	2.76 (1.98)	2.93 (2.06)	2.67 (1.97)	2.68 (1.87)
Used improved seed (%)	25.50	29.30	21.44	25.43
Used chemical fertilizer (%)	4.10	3.05	4.11	5.26
Number of observations	10,095	3,597	3,302	3,196

Source: Calculated based on Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.
Note: Values are means (with SDs in parentheses) or percentages.

Since data for the distance to the nearest market were collected for only the 2016 wave, a proxy of distance to the household's nearest source of healthcare was used, and when household information was missing median values calculated at either the village level or parish level were used. An average distance of 4 to 5 kilometers to the nearest input/output market is relatively high for a household to depend on the market for their daily food supplies. In addition, household market participation is low as only about 25% of output is sold on average. Access to improved sanitation (access to a toilet) was high, at about 80%, in all the survey years while the proportion of households that had access to a clean water source was moderately high at about 66% in the pooled sample. The dissemination of nutrition and dietary knowledge is critical to influence nutritional outcomes since households and individuals are known to demand food items based on not only affordability but also on 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% in the subsequent 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. However, in this study's sample, less than 30% of households used improved seed varieties while only 5% (the highest proportion across the 3 waves) reported to have used chemical fertilizer in the 2016 wave.

The average number of different crop species grown was 5-6 crops. This translated to an average of 3.51 (SD=1.11) out of 6 crop families grown. Given an average land area cultivated of about 3 acres, such an average number of crops grown is reasonable since previous research shows that the number of crops grown is positively related to land holding in smallholder farming. Figure 2 augments the finding on crop count in Table 1. It shows that approximately 2% of the households in the aggregated sample grew only one crop while less than 1% (approximately 0.84%) grew no food crop. This implies that less than 1% of the households depended totally on the market for their food needs. Approximately 6% of households in the aggregate sample grew more than 10 crops. Higher proportions of the households grew 4-5 crops and 6-7 crops in the south-west and north regions i.e., 36.6% and 31.5%, and 28.2% and 23.5%, respectively.

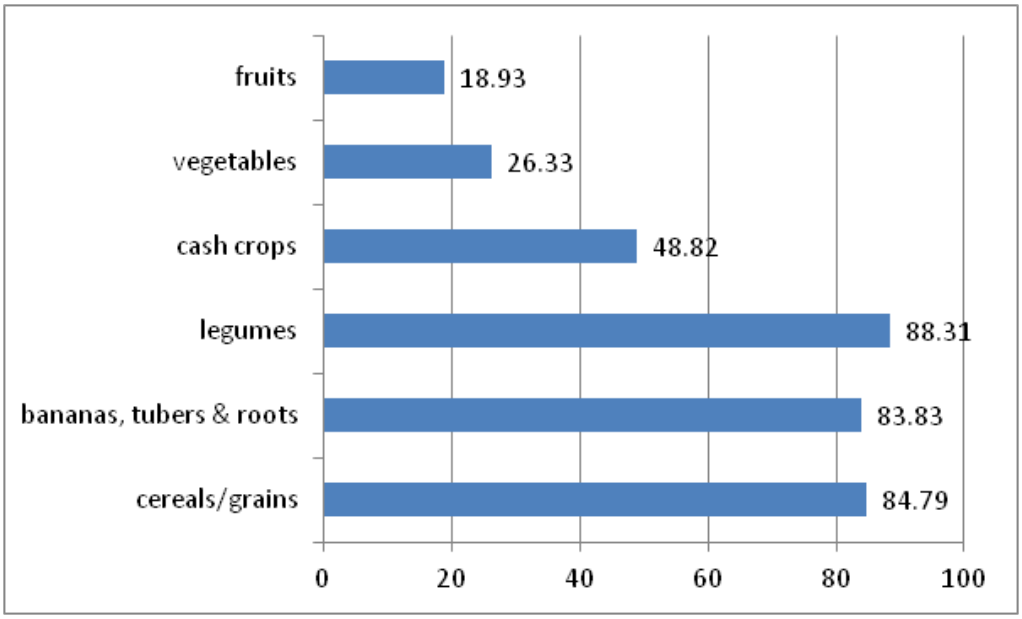
Figure 2: Crop count of farm households in the pooled sample



Source: Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.

In Figure 3, we show the crop families most grown in the aggregate sample. We found that over 80% of the households grew legumes, cereals/grains, and bananas, tubers and roots. However, a smaller proportion of households grew vegetables (26.33%) and this is reflected in a lower crop diversity score.

Figure 3: Percentage of households growing various crop families



Source: Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.

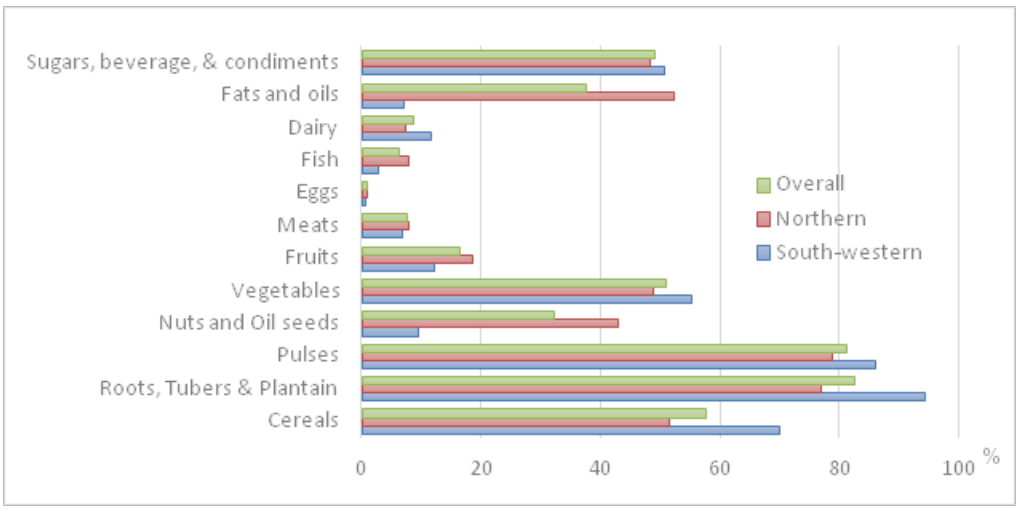
Table 2: Household dietary diversity and women's dietary diversity

	HDDS1	WDDS2	MDD-W3 (%)	Sample size	
Pooled	Northern	4.41(1.55)	3.21(1.14)	11.84	6,818
	S. western	4.06(1.42)	2.90(1.07)	8.15	3,277
2012	Northern	4.67(1.64)	3.48(1.23)	18.64	2,403
	S. western	3.98(1.47)	2.93(1.08)	8.71	1,194
2014	Northern	4.13(1.48)	3.04(1.09)	8.50	2,234
	S. western	3.97(1.40)	2.82(1.07)	7.58	1,068
2016	Northern	4.43(1.46)	3.08(1.04)	7.75	2,181
	S. western	4.23(1.35)	2.95(1.06)	8.08	1,015

Source: Calculated based on Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.
Note: Values are means (with SDs in parentheses) or percentages. 1=Household Dietary Diversity Score; 2=women's dietary diversity score; 3=Minimum Dietary Diversity for Women.

In Table 2, we present the findings on dietary diversity. The average Household Dietary Diversity score of the pooled sample showed that households consumed about 4 food groups out of 12 food groups in the 24 hours that preceded the survey. The score was higher in Northern region (4.41) than South-western (4.06) in the pooled sample. Variations in the HDD score arising from income differentials are also observed with households in income tercile 3 having a higher score (4.69) than those in tercile 1 (3.94). We found an average Women's Dietary Diversity score of 3.21 (SD=1.14) and 2.90 (SD=1.07) out of 10 food groups in the North and Southwest regions, respectively. This corresponds to 11.84% and 8.15% of households that meet minimum dietary diversity for women in the North and South-west regions, respectively (Table 3). This low proportion of households meeting the minimum dietary diversity for women is not surprising given the low proportion of households that produced vegetables.

Figure 4: Household 24-hour recall of food groups consumed in the pooled sample



Source: Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.

Further examination of household dietary diversity is provided in Figure 4. Figure 4 shows that over 80% of the households consumed the roots, tubers and plantain food group. The second most consumed food group was pulses followed by cereals. About 50% only consumed vegetables while less than 20% of the households consumed fruits, meats, fish and dairy. Eggs was the least consumed food group. This pattern is indicative of a diet with low diversity on average. Such a diet also has implications for achieving the minimum dietary diversity for women. In passing, we note that the findings in Figure 3 and Figure 4 have implications for the importance of geographical access to markets in improving household dietary diversity. Crop families most grown (Figure 3) formed the food groups most consumed (Figure 4). This is an indicator of the limited role that food markets play in providing rural households' daily food needs.

Table 3: Selected characteristics of children under five years old

		Pooled	2012	2014	2016
Age of index child in months (%)	0-5	21.33	23.62	25.69	14.60
	6-23	67.34	74.28	72.35	53.98
	23-59	11.33	2.10	1.96	31.42
Male child (%)		50.02	50.18	52.77	47.47
Weight at birth (>=2.5 kg) (%)		95.10	95.77	95.00	94.06
Breast feeding now (%)		88.76	88.03	89.47	89.24
Child's diet is below minimum CDD (%)		29.85	36.45	27.98	24.34
Meets minimum frequency of feeding (%)		92.85	90.44	93.91	94.46
Received basic vaccinations (%)		52.92	49.15	56.04	55.81
Height-for-age Z-score (mean)		-0.75	-0.61	-0.65	-1.02
Sample size		4,637	2,059	1,399	1,179

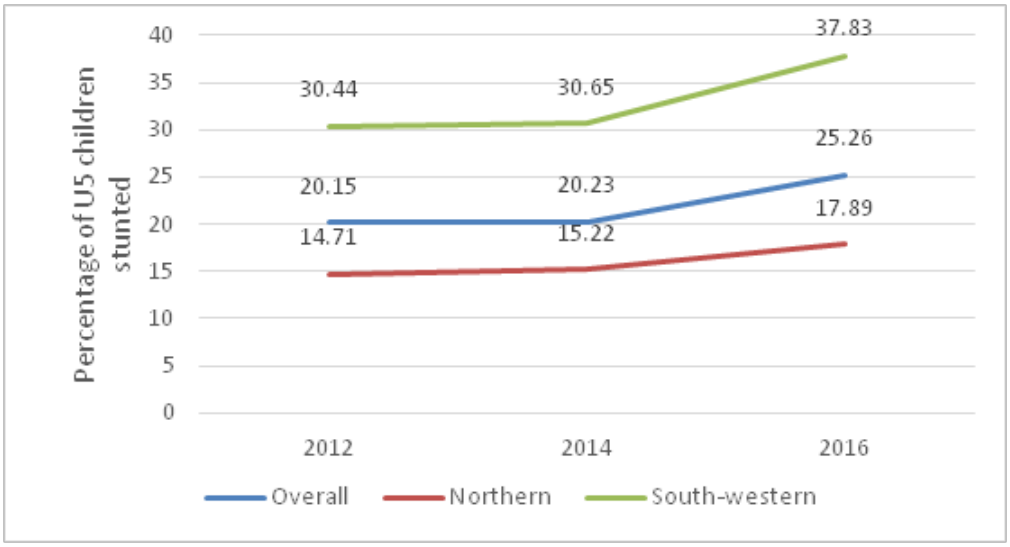
Source: Calculated based on Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.

Table 3 shows some characteristics of the children under five years in the samples. About 50% of the children in the pooled sample were male and 50% of the children had received both measles and DPT vaccinations. The proportion of children with a birth weight of at least 2.5 kilograms is 95% while over 85% of the children were breast feeding at the time of the surveys. The proportion of children in the samples that had at least two meals a day was over 90% and approximately 30% of the children in the pooled sample had a diet that fell below the minimum child dietary diversity (CDD) of at least 4 food groups. The child dietary diversity score was calculated based on 7 food groups, namely grains, Roots, Tubers & Plantain; Legumes & nuts; dairy products; flesh foods; eggs; vitamin A rich fruits & vegetables; and other fruits & vegetables. The average child dietary diversity score was about 5.4 food groups out of 7 in the pooled sample.

In Figure 5, stunting is observed to have been on an increasing trend in both regions. Between 2012 and 2016, stunting increased by about 3 and 5 percentage points in northern and southwestern Uganda, respectively. Overall, the percentage of children

who were stunted in 2016 was about 25%, which is 4 percentage points below the national average of 29% recorded in the Uganda DHS of 2016.

Figure 5: Trends in stunting by region



Source: Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.

Association between crop diversity and nutrition outcomes

We carried out simple correlation analyses to get a feel of how nutritional outcomes are associated with the crop diversity score (Table 4). As expected, the correlation coefficients is positive between crop diversity score and household dietary diversity and minimum dietary diversity for women but we find a rather weak association between crop diversity score and stunting. However, to understand the effect sizes, we undertook further econometric analyses whose results are presented in the following sub-sections.

Table 4: Correlations between crop diversity score and nutrition outcomes in the pooled sample

	HDD	MDD-W	Stunting
Crop diversity score	0.2485 (p<0.01)	0.1546 (p<0.01)	-0.0244 (p<0.1)

Source: Estimated based on Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.
Note: crop diversity score is measured by crop family.

Table 5 presents the bivariate and multivariate regression results of the effect of crop diversity on HDD. Four models were fitted to observe whether the effect of crop diversification on dietary diversification is sustained with the introduction

of other covariates in the bivariate model. Control covariates were selected based on previous studies that controlled for household characteristics, market access and participation, and adoption of agricultural technology in the multivariate regression of dietary diversity on crop diversity (Jones et al. 2014; Sibhatu et al. 2015 and Koppmair et al. 2016). The results show that crop diversification has a small positive and statistically significant effect on HDD in all the four models. The bivariate regression result indicates that increasing crop diversity by one crop family increases the number of food groups consumed by 6.5% while growing one additional crop increases the number of food groups consumed by 3.1%. The inclusion of control covariates marginally reduces the size of this effect (as shown in Models 2, 3 and 4), which remains larger than that of other variables in all the three models, with the exception of use of improved seed.

Table 5: Fixed Effects Poisson regression results of the determinants of household dietary diversity

Variable	Model 1		Model 2		Model 3		Model 4	
		Robust		Robust		Robust		Robust
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Crop diversity score (crop families count)	0.065***	0.004	0.058***	0.005	0.059***	0.005	0.056***	0.005
Crop diversity score (crop species count)	0.031***	0.002						
Household size (log)			-0.021	0.014	-0.027*	0.015	-0.031**	0.015
Caregiver completed primary education			0.036*	0.022	0.032	0.024	0.035*	0.023
Woman makes decision on farm income use			0.014	0.011	0.013	0.012	0.009	0.011
Received nutrition information			0.043***	0.010	0.042***	0.010	0.038***	0.010
Household is food secure			0.022*	0.012	0.025*	0.014	0.024*	0.014
Agricultural income (log)			0.014***	0.004	0.014***	0.005	0.013***	0.005
Household has off-farm income source			0.038***	0.013	0.036***	0.014	0.035**	0.014
Share of output sold					-0.019	0.028	-0.025	0.28
Distance to input/ output market (log)					0.010**	0.005	0.009*	0.005
Used improved seed							0.057***	0.011
Number of observations	9,860		6,365		5,999		5,999	

Source: Estimated based on Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.
Note: *, **, ***: coefficient is statistically significant at the 10%, 5% and 1% level, respectively.

When household characteristics are controlled for in Model 2, we find that the completion of primary education by the caregiver and the food security status of the household are positively and significantly associated with HDD. In addition, a household's access to nutrition information increases household intake of number of food groups by 4.3% while a household's increase in agricultural income and having an off-farm income source increases HDD by 1.4% and 3.8%, respectively. When the indicators of market access and participation are controlled for in Model 3, we find a small statistically significant effect of market distance on dietary diversification. Specifically, an increase in the distance to an agricultural input or output market increases HDD by 1.0 percentage points. This implies that markets still have a role in providing food notwithstanding their distant location and the larger fraction of food consumption that comes from own production. But the findings also show that the availability of an off-farm income source increases intake in the number of food groups by 3.6% while agricultural income increases the number of food group intake by 1.4%. Thus, with households remotely located to daily food markets, earning an income from selling produce or working away from the farm increases both geographical and financial access to food markets and households could improve dietary diversity by buying food items that are not produced at home. An increase in household size is found to have a negative and statistically significant effect on dietary diversification. The effect size and level of significance of household size increases in Model 4 which controls for adoption of agricultural technology. Specifically, an increase in household size reduces dietary diversification by 3.1 percentage points. Adoption of agricultural technology is proxied by whether a household used improved seeds. The use of improved seeds increases farm productivity and provides a surplus for sale, prompting a move away from subsistence farming. The results show that a households' use of improved seeds leads to an increase in intake of the number of food groups by 5.7%.

Table 6 presents the result of a binary logistic regression. The result shows positive associations between crop diversity and the MDD-W. In the bivariate regression in Model 1, the odds ratio associated with the crop diversity score coefficient is 1.585, which implies that increasing the number of crop families grown by one is associated with a 58.5% increase in the odds of a household achieving the minimum dietary diversity for women. When we control for household characteristics in Model 2, the significance of the association between crop diversity measured by crop diversity score and MDD-W does not change. The other covariates found to be statistically significant include completion of primary education by the caregiver, household size, level of agricultural income, having an off-farm income source, accessing nutrition information, food security status and distance to an agricultural input/output market. Specifically, completion of primary education by the caregiver/woman increases the odds of achieving MDD-w by 51.7%. Higher agricultural income is associated with higher odds of achieving MDD-W. The odds ratio of 1.117 indicates that a 1 shilling increase in agricultural income is associated with 11.7% higher odds of achieving

MDD-W, while women in a food secure household have a 50% (OR=1.501) higher odds of achieving MDD-W. Larger households are associated with lower odds of achieving MDD-W. The odds of achieving MDD-W reduce by 18.1% (OR=0.819) with an increase in the household size by one member. Accessing nutrition information increases the household's odds of achieving MDD-W by 46.4% (OR=1.464). Having an off-farm income source increases the odds of achieving the MDD-W by 23.2% (OR=1.232) while adoption of improved agricultural technology in the form of improved seeds increases the odds of achieving MDD-W by 24.7% (OR=1.247)

Table 6: Logistic regression results of the effect of crop diversity on Minimum Dietary Diversity for Women

Variable	Bivariate regression			Multivariate regression		
	OR	95% C.I.	P	OR	95% C.I.	P
Crop diversity score (crop families)	1.585	1.491-1.686	0.000	1.474	1.363-1.594	0.000
Female headed household				1.326	0.277-0.422	0.237
Household size (log)				0.819	0.681-0.984	0.033
Woman completed primary education				1.517	1.268-1.816	0.000
Agricultural income (log)			1.117	1.037-1.203	0.004	
Household has off-farm income source				1.232	0.995-1.525	0.055
Received nutrition information				1.464	1.231-1.740	0.000
Household is food secure				1.501	1.239-1.820	0.000
Distance to input/output market (log)				0.909	0.843-0.980	0.013
Share of output sold				1.068	0.697-1.636	0.763
Used improved seed				1.247	1.051-1.479	0.011
Log likelihood		-3281.33			-2253.49	
Wald chi2		216.93			238.71	
Prob > chi2		0.000			0.000	
Number of observations		10,032			6,821	

Source: Estimated based on Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.

Table 7 presents the results of a binary logistic analysis of the effect of crop diversification on child stunting in South-western and Northern Uganda. Four models were fitted to assess how the effect of crop diversity on stunting changes with the inclusion of child characteristics, caregiver's characteristics and other household and community characteristics in the regressions. In the bivariate regression, we find no statistically significant association between crop diversification and stunting. Controlling for child characteristics in Model 2 improves the statistical significance of the association between the crop diversity score and stunting. Specifically, a 1%

increase in the crop diversity score is associated with 8.5% decrease in the odds of stunting (OR=0.915, p<0.05). In Model 3, an increase in the crop diversity score is associated with 8.1% decrease in the odds of stunting (OR=0.919, p<0.1). Inclusion of caregiver's characteristics in Model 3 reduces the statistical significance of the effect of crop diversification on stunting. We find a non-significant negative association between crop diversity score and stunting in Model 4 after controlling for household and community characteristics.

Table 7: Logistic regression results of the effect of crop diversity on stunting

Variable	Model 1		Model 2	
	Coef.	Odds Ratio	Coef.	Odds Ratio
	(Std. error)	(95% C.I.)	(Std. error)	(95% C.I.)
Crop diversity score (crop families)	-0.051	0.950	-0.088**	0.915
	(0.037)	(0.884, 1.022)	(0.044)	(0.840, 0.997)
Child's sex (male)			-1.122***	0.326
			(0.106)	(0.264, 0.401)
Child's age in months (0-5 (ref))			-	-
6-23			1.255***	3.509
			(0.204)	(2.353, 5.233)
24-59			2.822***	16.810
			(0.368)	(8.179, 34.549)
Child received at least 2 basic vaccinations			0.392***	1.481
			(0.110)	(1.192, 1.839)
Weight at birth (>=2.5 kg)			-0.751***	0.472
			(0.203)	(0.317, 0.702)
Child is breast feeding			-0.227	0.796
			(0.144)	(0.600, 1.057)
Child's diet below minimum diet diversity			0.318**	1.375
			(0.146)	(1.033, 1.829)
Region	X		X	
Year indicators	X		X	
Log likelihood	-2368.355		-1825.834	
Wald chi2	1.90		235.85	
Prob > chi2	0.1686		0.000	
Number of observations	4,548		4,031	

Unexpectedly, we find that children who had received two vaccinations of DPT and measles were more stunted than those that did not receive any vaccination or received only one of the two vaccinations. Specifically, Model 2 shows that receiving at least two vaccinations of DPT and measles raises the odds of stunting by 48% (OR=1.481, p<0.01). The significance of this association is sustained in Model 3 which controls for the caregiver's characteristics and Model 4 which controls for household characteristics. One interpretation might be the timing of the vaccinations. A previous study determined that children in Africa who received basic vaccinations later in infancy tended to be more stunted than those that were unvaccinated (Berendesen et al., 2016). As expected, child's birth weight is negatively associated with stunting. Model 2 shows that a birth weight of at least 2.5kgs reduces the odds of stunting by 52.8% (OR=0.472, p<0.01). The significance of the effect of birth weight on stunting is sustained in Models 3 and 4. Further, Model 2 shows that a male child has a 67.4% probability of being stunted compared to a female child (OR=0.326, p<0.01) while a child's diet being below the minimum dietary diversity increases the odds of stunting by 37.5% (OR=1.375, p<0.05). The statistical significance of these effects is sustained through Models 3 and 4.

In Model 3, we find the caregiver's years of schooling and antenatal care visits are significantly associated with child stunting. Specifically, an additional year of the caregiver's schooling is associated with a 4.6% lower odds of stunting (OR=0.954, p<0.01), while having had at least 4 antenatal care visits in the previous pregnancy reduces the odds of stunting by 26.5% (OR=0.735, p<0.01). The statistical significance of these effects is sustained through Model 4. Model 4 controls for household size, access to a clean water source and livestock diversity score in addition to crop diversification, child characteristics and caregiver's characteristics. Noteworthy, while we find no association between crop diversity score and stunting, the model shows that an increase in the Livestock diversity score[1] by one livestock family lowers the odds of stunting by 20% (OR=0.801, p<0.01). Households that keep livestock (cattle, goats, poultry, sheep, pigs, and fish) have access to animal source protein in form of milk, eggs and meat which enhance child growth and nutrition outcomes. In addition, livestock-keeping provides a source of income which households can use to acquire nutritious food for children.

Children from households with access to an improved water source (piped water, tube well or borehole and protected well or spring) have 28.2% lower odds of being stunted compared to those without an improved water source (OR=0.718, p<0.01). The odds of stunting increase by 3.7% (OR=0.963, p<0.05) with an increase in household size by 1 member.

Table 7 Continued

Variable	Model 3		Model 4	
	Coef.	Odds Ratio	Coef.	Odds Ratio
	(Std. error)	(95% C.I.)	(Std. error)	(95% C.I.)
Crop diversity score	-0.084*	0.919	-0.004	0.996
	(0.045)	(0.841, 1.004)	(0.045)	(0.910, 1.089)
Child's sex (male)	-1.090***	0.336	-1.053***	0.349
	(0.109)	(0.271, 0.417)	(0.107)	(0.283, 0.430)
Child's age in months (0-5(ref))	-	-	-	-
6-23	1.230***	3.422	1.178***	3.250
	(0.210)	(2.265, 5.171)	(0.206)	(2.169, 4.868)
24-59	2.800***	16.454	2.641***	14.025
	(0.375)	(7.888, 34.322)	(0.365)	(6.862, 28.668)
Child received at least 2 basic vaccinations	0.402 ***	1.495	0.410***	1.507
	(0.113)	(1.197, 1.867)	(0.111)	(1.213, 1.874)
Weight at birth (>=2.5 kg)	-0.633***	0.531	-0.736***	0.479
	(0.212)	(0.351, 0.804)	(0.207)	(0.319, 0.718)
Child is breast feeding	-0.222	0.801	-0.228	0.796
	(0.152)	(0.594, 1.079)	(0.149)	(0.595, 1.066)
Child's diet below minimum diet diversity	0.325**	1.384	0.356**	1.428
	(0.150)	(1.033, 1.856)	(0.147)	(1.071, 1.904)
Sex of household head (Female)	0.005	1.005	0.087	1.091
	(0.269)	(0.593, 1.702)	(0.264)	(0.650, 1.829)
Years of schooling completed by caregiver	-0.047***	0.954	-0.047***	0.954
	(0.017)	(0.923, 0.986)	(0.017)	(0.923, 0.986)
At least 4 antenatal care visits	-0.307***	0.735	-0.285***	0.751
	(0.101)	(0.603, 0.896)	(0.098)	(0.620, 0.911)
Household size			-0.037*	0.963
			(0.021)	(0.924, 1.003)
Access to improved water source			-0.330***	0.718
			(0.100)	(0.590, 0.875)
Livestock Diversity Score			-0.222***	0.801
			(0.042)	(0.738, 0.869)
Region	X		X	
Year indicators	X		X	
Log likelihood	-1670.354		-1641.543	
Wald chi2	219.61		251.41	
Prob > chi2	0.000		0.000	
Number of observations	3,691		3,688	

Source: Estimated based on Innovation Laboratory for Nutrition panel data 2012, 2014 and 2016.
Note: *, **, ***: coefficient is statistically significant at the 10%, 5% and 1% level, respectively.

5. Conclusion

This study contributes to the evidence on the impact of agricultural policies and programmes on nutritional outcomes at the household level. We found statistically significant associations between the crop diversification strategy and nutritional outcomes. Since the Uganda government has adopted crop diversification as a strategy to improve household incomes and nutrition outcomes, the results of the study imply that a minimum household dietary diversity will be achieved with a very high level of crop diversity (measured by crop groups) on household farms. This is because the effect sizes are small, and the average crop diversity score is low (3.51 out of 6 crop groups). Thus, there is room to increase household dietary diversity by increasing crop diversification. Specifically, farm-households should supplement the food staples of grains, plantains and tubers, and legumes by other crop groups such as vegetables and fruit trees. Notwithstanding, the strategy needs to be accompanied by use of improved farm production technology such as improved seeds in order to realize higher output. Higher output would increase a household's market participation by increasing the share of output sold. This would in turn increase a household's geographical and financial access to agricultural output markets. The increase in cash income could be used to obtain food items which may not be produced at home such as animal products which would improve household dietary diversity. Similarly, a household's access to the food market increases with having an off-farm income source because households would look to buy food items with the cash earned. However, our findings imply that subsistence farming plays a more important role than markets in delivering dietary diversity to the households since the effect of crop diversity on HDD is higher than that of most covariates in Table 5. Moreover, only a small proportion of households (less than 1%) that does not produce any food crops (Figure 2) and therefore, entirely depend on the markets for their daily food needs.

We find a positive and significant association between crop diversity and another intermediate nutrition outcome- the minimum dietary diversity for women. This implies that crop diversity increases micronutrient adequacy of household diets. However, in other findings crop diversification has a negative and significant effect on child stunting when child and caregiver's characteristics are controlled for in the estimation model. We also find that livestock-keeping plays a more important role in reducing child stunting when compared with crop diversification. Other important factors that influence child nutritional status include the child's birth weight, child dietary diversity, caregiver's characteristics such as number of years of schooling, antenatal care visits of the caregiver and community characteristics such as access to an improved water source.

Notes

1. Livestock Diversity Score was constructed as a sum of the number of livestock families kept by a household. Accordingly, the following categories of livestock were included in the score: cattle, sheep, goat, pig, poultry, donkey, rabbits, fish farm, bee keeping and other.

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