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Hybrid Seed Use and Diversity of Diets among Women in Smallholder Maize-Growing Households in Zambia

Melinda Smale[1], Mourad Moursi[2], Ekin Birol[2], and Hugo De Groote[3]

ABSTRACT

Despite the policy importance of household nutrition and food security in rural Zambia, we are not aware of any analyses since a 1994 study by Shubh Kumar that have related the adoption of hybrid seed to dietary diversity among smallholder maize growers in Zambia. We estimate regression models to test the relationship between hybrid seed use and four indicators of dietary diversity: food group diversity (24-hour), vitamin A diversity (7-day), food frequency (7-day), and frequency of consuming foods fortified with vitamin A (7-day). We find that, according to the first three indicators, women in maize-growing households that plant hybrid seed have more diverse diets. Findings are weak when we consider the frequency of consuming foods fortified with vitamin A, highlighting the importance of testing multiple indicators. Results suggest that in Zambia, families of smallholder maize farmers who do not grow hybrid seed are likely to be a disadvantaged group, with respect to maize productivity and other diet-related welfare indicators.

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CONTENTS

I. INTRODUCTION

Zambian smallholders have benefited from public investments in maize research since the 1970s (Howard and Mungoma 1997), as well as two phases of state-managed subsidy programs to support their use of hybrid seed and fertilizers (Mason et al. forthcoming) and one of the more vibrant, liberalized seed industry in Eastern and Southern Africa (Kassie et al. 2013; Smale et al. 2013). Despite the lengthy experience of Zambian smallholders with hybrid seed, surprisingly little research appears to have been conducted on the impacts of hybrid maize until recently (Langyintuo and Mungoma 2008; Hamazakaza, Smale, and Kasalu 2013; Mason and Smale 2013). Since an in-depth study implemented by the International Food Policy Research Institute (IFPRI) during the late 1980s in the Eastern Province of Zambia (Kumar 1994), we are not aware of analyses that have related the adoption of hybrid maize to dietary diversity among smallholder farmers in this country.

Kumar (1994) found that the impact of adopting hybrid maize on food intake was greater on farms under four hectares (ha) than on larger farms. While staple food consumption was higher in areas where hybrid maize adoption rates were higher, Kumar concluded that dietary diversity may have declined due to greater reliance on a farmer's own maize production and fewer purchased food types. Historically, the Eastern Province has had lower rates of hybrid seed adoption, and farmers have insisted on continuing to grow local maize varieties because of strong consumption preferences for flint-type grain. Thus, the negative relationship between hybrid maize adoption and food intake where hybrid maize was a cash crop, particularly among smallholders, was a striking result.

Malnutrition and food security continue to occupy the center stage of agricultural policy in Zambia. For example, despite progress in supplementing the consumption of vitamin A through health programs and fortified sugar, vitamin A deficiency (among other micronutrient deficiencies) continues to jeopardize maternal and child health. Vitamin A deficiency is a cause of night-blindness, impaired growth, weakened immune systems, and increased risk of death due to infection among children. Among pregnant women, vitamin A deficiency may also contribute to increased risk of morbidity, increased risk of neonatal mortality, and night-blindness (West 2002). In Zambia, over half of children under five years of age are considered to be vitamin A deficient, as indicated by low plasma retinol concentrations (NFNC/University of Zambia/MOST/CDC 2004); rates could be higher in the presence of infection (Hotz et al. 2011). Based on data drawn from Zambia's 2005/06 Living Conditions Monitoring Survey, Fiedler et al. (2012) concluded that while sugar fortification has reduced inadequate vitamin A intake (IVAI) from 87 percent to 79 percent, sugar alone will not substantially improve the nutrient intake status of the Zambian people.

Economic principles suggest that growing hybrid seed could contribute in contradictory ways to the diets of smallholder, maize-growing households in Zambia. Orientation toward subsistence production can persist in remote areas with uncertain markets, where farm sizes are small or farmers are particularly cash-constrained, and/or where production conditions are particularly risky. Growing higher-yielding maize may enable smallholders who rely heavily on their own production for subsistence to re-allocate land from maize to other food or cash crops. In turn, growing more diverse crops may contribute to dietary diversity through on-farm production and consumption. At the same time, when more remunerative alternatives are lacking or there are strong consumption preferences for local maize, hybrid maize often plays the role of a cash crop, as has been documented for decades in Eastern Province (e.g., Kumar 1994; Howard and Mungoma 1997; Hamazakaza, Smale, and Kasalu 2013). In that case, smallholder farmers who sell their harvest have the opportunity to diversify the foods consumed by their households. Overall, diet diversification that is meaningful for nutritional status is predicated not only on steady cash flows but also on access to reliable markets for a range of food products. That is a tall order in rural Zambia.

The purpose of this analysis is to test the hypothesis that growing hybrid maize affects dietary diversity and the diversity of vitamin A-rich food sources among smallholder maize growers in Zambia. We have no apriori reason for predicting the direction of effects. We define dietary diversity indicators according to recent research advances (Arimond et al. 2010). We relate hybrid seed use directly to dietary outcomes based on a cross-sectional survey of 1,128 maize-growing farm households in the major maize-producing regions of Zambia, applying various econometric methods to test our hypotheses.

The objective of this paper is to support the design of strategies to introduce provitamin A-enriched maize among Zambian smallholder famers. HarvestPlus and its partners aim to reduce the prevalence of vitamin A deficiency in at-risk populations through the introduction of improved varieties of provitamin A maize (Bouis et al. 2011). Although maize is the most commonly consumed food in Zambia, only 23 percent of households purchase pre-milled roller and breakfast maize—the only maize meal products that are considered to be fortifiable (Fiedler et al. 2012). Since most households rely on their own harvested grain or do not purchase fortifiable maize meal products, improved maize varieties will be a major vehicle for addressing vitamin A deficiency.

In the next section, we summarize the data sources. We then explain how we measure dietary diversity, according to recent advances in published research. A conceptual framework is outlined in section 4, followed by the empirical strategy. Results are presented and interpreted in section 6, and we draw policy conclusions in the closing section.

2. DATA SOURCES

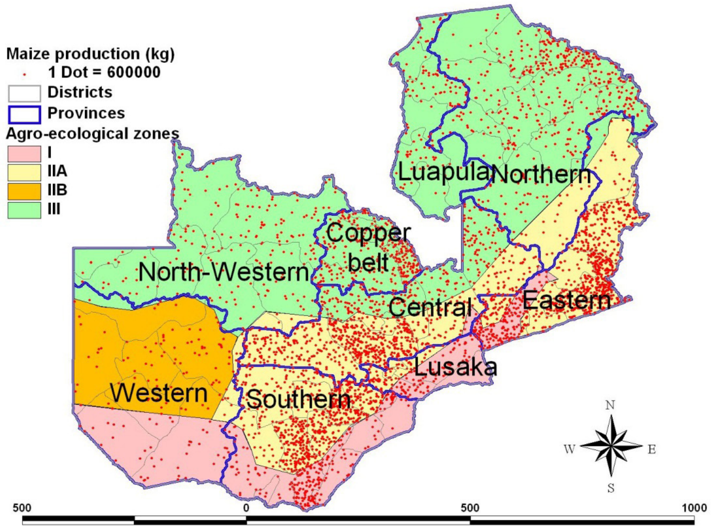
The data were collected through face-to-face interviews in a survey that was implemented by HarvestPlus, the International Maize and Wheat Improvement Center (CIMMYT), and the University of Zambia. The population domain includes five provinces (Central, Copperbelt, Eastern, Lusaka, Northern, and Southern), located in three agroecological zones (AEZ I, AEZ IIA, and AEZ III) of Zambia (Figure 1).

The three AEZs served as strata. The total number of households in the sample was allocated proportionate to population and maize production (20 percent for AEZ I, 40 percent each for the other two zones). First-stage sampling units were standard enumeration areas (SEA). Numbering 113, these were selected with probability proportionate to size, by AEZ, from lists maintained by the Central Statistical Office. The second-stage units were all households living in each SEA. Ten households were selected in each SEA by simple random sample drawn from a list. By design, data are self-weighted. Data were collected by three survey teams, each including a supervisor and five enumerators, from June to August 2011. The full sample consists of 1,128 households, of which only 19 cultivated more than 20 ha. These were eliminated in our analysis. In Zambia farmers cultivating less than 20 ha are defined as "smallholders."

We also make use of secondary data sources for crop commodity prices. District-level retail price data for key crops like maize, cotton, and sweet potato were obtained from the Central Statistical Office's Consumer Price Index database for the two years preceding the survey (2009–2010).

Pixel-level data on rainfall and soil quality were utilized in the analysis. Long-term average rainfall data for the period 1950–2000 were obtained from WorldClim, an online global climate database (Hijmans et al. 2005). Five-year average rainfall data was assembled from CPS Unified Global Daily Precipitation Analysis defined by optimal interpolation of gauge observations (Schneider et al. 2011). Short-term average rainfall data for the preceding year, 2010, was retrieved from the GPCC Full Data Product (V6), which is based on quality-controlled data from 67,200 stations worldwide. Information on soil nutrient availability was obtained from the Food and Agriculture Organization (FAO) (FAO/IIASA/ISRIC/ISSCAS/JRC 2009).

Figure 1: Distribution of Maize Production in Zambia



Source: Hugo De Groote, 2011.

3. MEASURING DIETARY DIVERSITY

The prevalence and irreversible consequences of micronutrient malnutrition among both urban and rural populations in South Asia and Sub-Saharan Africa are well-known by researchers and governments. A decade ago, challenges associated with measuring nutrition with anthropometry and testing procedures in developing countries led to the development of indices of household dietary diversity using cost-effective survey instruments based on recall. Research implemented by IFPRI (e.g., Hoddinott and Yohannes 2002) confirmed that a more diversified diet is associated with improvement in nutritional parameters, including: birth weight; child anthropometric status; improved hemoglobin concentrations; caloric and protein adequacy; percentage of protein from animal sources (high quality protein); and per capita consumption (a proxy for household income). Studies that validated dietary diversity against nutrient adequacy in developing countries confirmed a positive relationship and a consistently positive association between dietary diversity and child growth (Ruel 2002; Arimond and Ruel 2003; Working Group on Infant and Young Child Feeding Indicators 2006; Moursi et al. 2008).

In an in-depth review of the literature on this topic, Ruel (2002; 2003) concluded that although dietary diversity was universally recognized as a key component of healthy diets, there was a lack of consensus on how to operationalize this concept. Reference periods ranged from 1 to 15 days, and questions remained regarding the classification of foods by group, portion size and frequency of intake, scoring systems, cutoff points, and reference periods for recall.

In a widely-used approach documented by Swindale and Bilinsky (2006), the household dietary diversity score was operationalized as a count over 12 food groups consumed in either a 7-day or 24-hour reference period. To consider micronutrients, food groups were expanded and/or regrouped by micronutrient and counted.

Meanwhile, researchers had learned that inequitable intra-household distribution may prevent women's access to micronutrient-rich foods even when they are available. Typically, women's scores were found to be representative of their children's (Nguyen et al. 2013). Thus, in cases where the organization of the household and decision-making processes suggested that distributional considerations were likely to be remarkable, analysts proposed scores constructed on the basis of individual interviews. For example, individualized diversity scores were recommended in the case of polygamous or extended family groups, or when focusing specifically on the nutrition of women and children. Accordingly, Smale, Diakite, and Keita (2012) applied these in the Douentza region in rural Mali, where agricultural production (and consumption) units are headed by a patriarch and composed of multiple households of the patriarch and his married sons.

Arimond et al. (2010) took the dietary diversity research a step further with an analysis of different food group diversity indicators used to predict micronutrient adequacy of women's diet among poor populations. They constructed 8 candidate diversity indicators and assessed their performance against the mean probability of adequacy for 11 micronutrients in 5 countries. Findings confirmed the predictive strength for the diversity indicators, although the best performing indicator depended on the country context. Based on their findings, they recommended an indicator constructed on nine food groups: 1) all starchy staples; 2) all legumes and nuts; 3) all dairy and dairy products; 4) organ meat; 5) eggs; 6) flesh foods and other small animal protein; 7) vitamin A-rich, dark-green leafy vegetables; 8) other vitamin A-rich vegetables and fruits, and 9) other fruits and vegetables. Fats and oils are an optional group that was excluded from their analysis. In the context of micronutrient analysis, fats and oils are considered as calories only.

The food group diversity indicator Arimond et al. (2010) recommend is based on 24-hour recall. This reference period has been shown to perform better when there was a minimum quantity of consumption required for a food group to "count" in the diversity score. In their analysis, Arimond et al. used data collected from individuals and set the minimum consumption cut off requirement at 15 grams. In other words, an individual had to consume at least 15 grams of meat in order for her to receive a count of +1 in the flesh food category.

The trajectory of research on dietary diversity leads us to choose four diversity indicators in this analysis. Each indicator illuminates a different aspect of consumption. We constructed the first indicator, which we refer to as "food group diversity," over 10 groups. Enumerators elicited an inventory of foods consumed from the primary female decisionmaker in the household with reference to the preceding 24-hour period. Groups were defined as: 1) starchy staples (maize, other cereals, sweet potato, other roots and tubers); 2) legumes and nuts (beans, groundnuts, other pulses); 3) dairy (milk, cheese); 4) organ meats (kidney, liver); 5) eggs; 6) flesh foods (fish, red meat, poultry); 7) vitamin A-rich fruits (mango, papaya, guava); 8) vitamin A-rich vegetables (green leafy vegetables, orange sweet potato); 9) other fruits and vegetables; 10) vitamin A-fortified foods (sugar, Blue Band margarine). Thus, to reflect conditions specific to

Zambia, we added a tenth group (fortified foods) to the 9 groups recommended by Arimond et al. (2010). The 10 groups were constituted from the 19 categories included in the survey instrument (See Appendix Table 1).

Given the scale of the baseline survey and its multiple objectives, we were unable to collect data on quantities consumed in each category. We define vitamin A-rich foods as a "source" based on the Codex Alimentarius definition (60 Retinol Activity Equivalents (RAE) per 100g of vitamin A).[1] The food group diversity indicator ranges in value from 1 to 10.

Our second indicator is a count of the groups containing foods that are sources of vitamin A or beta-carotene, which we call "vitamin A diversity." Again, we based our construction on the original 19 groups in the survey instrument. Both 24-hour and 7-day indicators were constructed, but the 7-day indicator was preferred for econometric analysis because it has a more normal distribution (see Appendix Figure A.1). The vitamin A diversity indicator ranges from 0 to 9. In addition to fortified sugar and Blue Band margarine and the sources mentioned in the previous paragraph, leafy green vegetables, flesh meats, organ meats, eggs, milk and cheese are sources of vitamin A in Zambia.

The third indicator we use is a "food frequency" index, constructed according to Arimond and Ruel (2002). One of the main limitations of the first two indicators is that neither takes into account consumption differences within a given food group. For example, one individual may have consumed meat three times during the reference period while another only ate it once, but both score +1 for meat consumption. Arimond and Ruel (2002) proposed that data collected for a seven-day recall period also account for the frequency of consumption. For each food group, a household or individual receives a score of 0 for frequencies fewer than four times per week, a score of unity for frequencies from four to six (inclusive) times per week, and a score of 2 for frequencies of seven or more. The diversity count is then summed across food groups. With 10 groups, the hypothetical range of this indicator is considerably greater (1 to 20); in the data, the maximum is 17.

Our fourth indicator is the frequency of consuming vitamin A-fortified foods in the past seven days, which include sugar and Blue Band margarine. Since these are costly consumption items, we hypothesize that the relationship of growing hybrid maize to this outcome variable could differ from that of the other indicators. We refer to this indicator as "vitamin A-fortified food frequency." The values of this indicator are 0, 1, and 2.

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[1] RAE differs from Retinol Equivalents (RE), which were common in older food composition tables.

4. CONCEPTUAL FRAMEWORK

The theory of the agricultural household (Singh, Squire, and Strauss 1986; de Janvry, Fafchamps, and Sadoulet 1991) provides the conceptual underpinning of our empirical strategy. According to this framework, the household combines farm resources and family labor to maximize utility over leisure and consumption goods produced on the farm or purchased on the market. Decisions regarding crop and variety choice are constrained by: production technology, conditioned on the farm physical environment and land area; family labor time allocated to labor and leisure; and a full income constraint. The full income constraint stipulates that a season's expenditures of time and cash cannot exceed the sum of net farm earnings and income that is "exogenous" to crop and variety choices. In a single-period model, "exogenous" income includes stocks, remittances, pensions, and other transfers from the previous season.

The theory of the agricultural household is suitable for analyzing the decisions of farmers who are not fully commercialized and/or who operate with missing or imperfect markets. When markets are perfect and farmers are neutral to risk, consumption and production decisions are separable, and the model of the agricultural household simplifies to profit-maximization. Crop and variety choices are then based on relative prices and farm physical conditions.

Although there is considerable heterogeneity in the objectives pursued by Zambian maize growers, most of the smallholder farmers interviewed in our survey do not operate in a context of perfectly functioning markets. Nor can we assume that they are neutral to risk. In this setting, consumption and production decisions are non-separable. Household characteristics that affect preferences and access to markets influence crop and variety choices. In addition, the prices actually faced by farmers are not market prices but shadow prices that reflect their household characteristics as well as market characteristics.

We follow Van Dusen's (2006) adaptation of the household model to the analysis of crop diversity, applying it here to dietary diversity. Household utility is defined over the consumption of goods produced on the farm (X) and purchased goods (Z), given a vector of exogenous socioeconomic and household characteristics (Φ_{hh}). Households maximize utility subject to a full income constraint, a time constraint for household labor valued at the local market wage, w, a non-tradability constraint, a constraint on production technology, and a diversity constraint defining the optimal bundle of food attributes or combination of foods consumed at the household level. Households choose the level of production of j crops, j = 1, 2, …J, denoted by Q_j. The cost function C ($Q; \Phi_{farm}$) incorporates the technological constraints for the household, where Φ_{farm} is a vector of exogenous farm characteristics. Following the standard agricultural household model presented in Singh, Squire and Strauss (1986) and Van Dusen (2006), the model can be expressed as follows:

$$\text{Max } U(X, Z; \Phi_{hh}) \tag{1}$$

$$Z = p(Q-X) - C(Q; \Phi_{farm}) + Y + wT \tag{2}$$

$$H(Qj, X; \Phi_{market}) = 0 \tag{3}$$

$$D = D(Qj, X, Z; \Phi_{market}) \tag{4}$$

The household chooses a vector of consumption levels (X,Z), and output levels, Q, such that the general solution to the maximization of household utility under binding constraints is a set of constrained optimal production levels Qc, consumption levels Xc, and purchase levels Z:

$$Q = Qc_j(p, \Phi_{hh}, \Phi_{farm}, \Phi_{market}) \tag{5}$$

$$X = Xc_j(p, Yc, \Phi_{hh}, \Phi_{farm}, \Phi_{market}) \tag{6}$$

$$Z = Z(p, Yc, \Phi_{hh}, \Phi_{farm}, \Phi_{market}) \tag{7}$$

where Yc represents the full income for the constrained optimal production levels Qc.

The household's constrained dietary diversity outcome can be expressed as follows:

$$Dc = D(Xc_j, Z (p, Yc, \Phi_{hh}, \Phi_{farm}, \Phi_{market})) \tag{8}$$

Prices (p) are endogenous to the household and are, in turn, functions of household and market characteristics, as well as observed prices. These prices are also known as "effective" or "decision" prices because they determine farmer choice but their values are unobserved.

5. EMPIRICAL STRATEGY

Our regression model is a reduced form equation that relates hybrid seed use and other explanatory factors to dietary diversity among maize-growing farm households in Zambia. Following equation (8), the reduced form equation is rewritten as:

$$\delta_i = \beta_0 + \beta_1 X_i + \gamma H_i + \varepsilon_i \qquad i = 1,..,N \qquad (9)$$

Where δ expresses dietary diversity, X is a vector of exogenous explanatory variables, ε is the random error term, and i indexes households. H is use of hybrid seed in maize production, introduced explicitly to test the hypothesis of interest. Following the theory of the agricultural household, we control for household, farm, and market characteristics among exogenous variables.

It is possible that our variable of interest, H (hybrid seed use), is endogenous due to measurement error, simultaneity, or selection bias. That is, the unobserved factors that predict the dietary diversity indicators might be correlated with the household's decision to grow hybrid seed. In that case, estimating equation (9) would result in biased estimates, overstating the impacts of hybrid seed use on dietary diversity.

Thus, we estimate the model via a two-stage least squares equation, with a binary variable measuring hybrid seed use in the first stage even though the assumed model is linear. Angrist and Krueger (2001) state that even in the case of a dichotomous variable in the first of the two equations, a two-stage least squares equation produces consistent estimators that are less sensitive to assumptions about functional form. They advocate this approach over use of nonlinear models such as probit or logit (2001). A two-stage least squares equation, which relies on the central limit theorem, is considered to be robust; even with a dummy endogenous variable, second stage estimates are consistent (Kelejian 1971).

Using standard model diagnostics for the instrumental variables, a two-stage least squares regression include tests of the relevance of the instrument set, model identification, and endogeneity of the adoption variable. Model diagnostics include i) the evaluation of the joint F-test for excluded instruments in the first stage regression; ii) the Chi-squared test with the Anderson canonical correlation coefficient; and iii), the Chi-squared test with the Sargan statistic. A rejection of the null hypotheses in the Anderson test indicates that the matrix is full column rank (the model is identified). Failure to reject the null hypothesis in the Sargan indicates that the "extra" instrumental variables are exogenous in the structural equation, thereby supporting the validity of the instruments.

To relate dietary diversity outcomes to the scale of use of hybrid seed and to validate our regression results based on the binary variable, we also test the endogeneity of hybrid seed quantities (kilograms-kg) planted in each outcome equation.

Because many farmers in Zambia have grown or been exposed to maize hybrids for years, we define hybrid users as growers of first-generation (F1) hybrids. Farmers who grew only local maize and/or recycled hybrids, seed of hybrids they could not identify, or improved open-pollinated varieties have not been classified as hybrid users. All seed distributed through the Farm Input Support Programme (FISP) is F1 hybrid seed. Note that we do not need accuracy in variety names to generate the dependent variable or the explanatory variable accounting for receipt of subsidized receipt. However, most growers of F1 seed (seed purchased in that season) were able to report at least the company name or full name of the hybrid they had planted. One reason for this is that beneficiaries request specific hybrids by name when applying for the FISP each season. Increasingly, maize breeders report that farmers who attend demonstrations record variety names.

Separate regressions were estimated for each dietary diversity outcome variable of interest. Outcome variables include four dietary diversity scores: 1) the 24-hour household dietary diversity score; 2) the 7-day vitamin A dietary diversity score; 3) the food frequency score; and 4) vitamin A-fortified food frequency. These variables, as well the explanatory variables (equations 8 and 9), are summarized in Table 1.

Finally, we compare the regressions estimated by instrumental variables and ordinary least squares methods for the first three indicators (food group diversity, vitamin A diversity, and food frequency) to count data regressions estimated with the assumption that the underlying data are generated by a Poisson process. We apply ordered logit regression to test hypotheses concerning the fourth indicator, which has three outcomes that are ordinal and ordered (from less frequent to more frequent, where more frequent is hypothesized to be "better").

Literacy is a household characteristic that is related to knowledge about hybrid seed. We also expect that it is related to food consumption and possibly to dietary diversity. We measure this proxy for human capital as the total number of literate persons per household, which averages 3.7 across the full sample. Mean household size is 6.9, by comparison. We also control for female headship, defined in terms of involvement in day-to-day decisionmaking. About 20 percent of households in the sample are *de facto* female-headed.

Potential labor constraints are expressed in terms of the number of young, mature, and older adults in the household, counted as separate factors. Other asset endowments include land resources, measured as the total area cultivated in both preceding (major and minor) seasons per capita, to ensure exogeneity. Total land area to which households had access had a large number of missing observations, and enumerators sensed that farmer estimates were relatively unreliable.

In this cross-sectional, single-year survey, we have measured expenditures and income, but these cannot be considered as exogenous to dietary diversity. As Yc, we employ total assets, which is a measure of longer-term income. We use the natural logarithm of asset values because of their skewness. The amount of credit received was non-zero in only 21 cases and was not included as a separate indicator of financial capital.

Prices and market services include the seed-to-grain price ratio, hypothesized to be a major determinant of the commercial demand for seed (Heisey et al. 1998; Smale and Olwande 2013). Seed prices were calculated as the kilogram-weighted average cost per kilogram of seed planted by the farmer, divided by the district-average maize price in the preceding season. Prices in the current season would not have been known at the time of planting. Fertilizer prices were not entered because data were sparser, measured by unit of volume rather than nutrients, and highly correlated with seed and maize prices. Bean, cotton, and sweet potato prices are included as potential output complements or substitutes, also expressed as district means in the preceding season. Prices were not collected in the survey, as explained under data sources. Cell phone and radio ownership measure access to market information services.

Broadly speaking, the natural capital of the household is strongly influenced by the agroclimatic and farming conditions of the area. Of the variables included in the data we consulted (see section 2), we calculated the long-term (50-year) average and the five-year average. We interpret the long-term average as controlling for essential features of the agroecology that are relatively immutable. The five-year average represents the decisionmaking history of greatest relevance to the farmer because it lies within memory. We also include the rainfall measured at the planting time. In terms of soil variables, all of the variables we examined (nutrient retention capacity, rooting conditions, oxygen availability to roots, excess salts, toxicity, workability, acidity) were highly correlated with nutrient availability. We included only nutrient availability in the regressions. The rating system for nutrient availability uses three diagnostic factors from the top 30 centimeters (cm) of the soil. These factors include organic carbon (percent), base saturation (percent), and soil reaction (pH). Numeric values assigned to factor ratings according to the degree of limitations are reported in the Appendix (Table A.2).

We employ two instrumental variables. In the regressions testing the endogeneity of the binary variable for hybrid seed use in dietary diversity outcomes, we use a binary variable expressing whether or not the farm household was a beneficiary of FISP. Preliminary regressions resulted in failure to reject the hypothesis that FISP participation is a recursive determinant of hybrid seed use. FISP orders are placed before the planting period. In turn, FISP participation can only affect dietary diversity after the harvest through its impact on maize productivity as a consequence of planting hybrid seed and applying fertilizer. The amount of FISP seed received is used as the first instrumental variable in scale of hybrid use equations.

The second instrumental variable is the frequency of registered associations per 1,000 kg of maize produced, also measured at the district scale of observation. This variable expresses the density of associations that qualify for FISP benefits. Our hypothesis is that the greater this density, the more likely any individual household is to receive subsidized seed (and fertilizer).

Table 1: Variable Definition and Summary Statistics

Variable	Construction	Mean	St. Dev.
Outcome			
Food group diversity	Count of food groups (out of 10) consumed in previous 24-hour period	5.28	1.66
Vitamin A diversity	Count of food groups (out of 19) consumed that are rich in vitamin A, previous 7 days	3.94	1.54
Food frequency	Count of food groups (out of 10) consumed in previous 7 days, weighted by frequency of consumption (less than 4=0, 4-6=1, 7+=2)	8.00	2.94
Vitamin A-fortified food frequency	Frequency of consumption of foods fortified with vitamin A in previous 7 days (Blue Band margarine, sugar; less than 4=0, 4-6=1, 7+=2)	1.09	0.921
Dependent			
Hybrid seed planted	Total kg planted, named F1 hybrid	18.5	38.1
Explanatory			
Female headship	Day-to-day household head female=1, 0 else	0.192	0.394
Literacy	Number of literate household members	3.65	2.35
Young adults	Number of adults aged 14 through 18	1.06	1.11
Mature adults	Number of adults aged 19 through 45	2.09	1.29
Older adults	Number of adults aged 46 or over	0.92	0.93
Land size	Total land cultivated in major and minor seasons (ha) divided by household size	0.43	0.42
Assets	Logarithm of total value of farm equipment and structures, livestock, and other household assets such as transport equipment and savings (ZMK)	16.65	1.51
Cell	Own cellphone=1; 0 else	0.695	0.461
Radio	Own radio=1; 0 else	0.770	0.421
Seed-to-grain price	Ratio of farm-gate, kg-weighted average seed price in 2010 to district mean maize grain price (per kg) in 2009	9.05	3.83
Bean price	District mean bean price 2009-10	3516	954.9
Cotton price	District mean cotton price 2009-10	1817	398.2
Sweet potato price	District mean sweet potato price 2009-10	520	180.8
LT rainfall	Long-term average rainfall (mm)	985	177.7
5-year rainfall	5-year average rainfall (mm)	729	55.0
Planting rainfall	Rainfall in October 2010	5.36	7.07
Nutrient availability	Index for soil texture, soil organic carbon, soil pH, total exchangeable bases	2.15	0.758
Receive subsidy	Received subsidized seed from Farm Input Support Programme (FISP) in 2010 (1=yes, 0 else)	0.654	0.476
FISP seed	Hybrid seed received from FISP (kg)	11.4	18.5
Association frequency	Number of registered associations per ton of maize produced in district	4.18	2.87

Source: Authors, based on data from HarvestPlus Maize Seed Adoption Survey, Zambia (2011); CSO Retail Price Database (2009-–2010); Schneider et al. (2011); Hijmans et al. (2005); and FAO (2009).
Note: ZMK=Zambian Kwacha

6. RESULTS

6.1 Descriptive Statistics

Table 2 shows the percentage of respondents who reported consuming foods classified among the 10 groups used to construct the individual dietary diversity score, considering all households and comparing those who grow maize hybrids with those who do not. As noted above, in accordance with recent research on measuring dietary diversity, enumerators elicited an inventory of foods consumed from the primary female decisionmaker in the household with reference to the preceding 24-hour period to represent women and their children's food consumption.

As would be expected, the most frequently consumed items were starchy staples, consisting predominantly of maize but including other cereals. Other vitamin A-rich fruits and vegetable were next in order of importance. These include pumpkin, tomatoes, mango, and papaya, items that are more likely to be consumed in one season than another and in relatively small quantities as ingredients in stews or as snacks. Other fruits and vegetables were also consumed often by respondents interviewed. Nuts and legumes were next in order of overall frequency, mostly reflecting the consumption of groundnuts. Vitamin A-fortified foods (primarily sugar) were consumed by over two-thirds (68 percent) of women interviewed in the previous 24 hours. Dark-green leafy vegetables were consumed by nearly one quarter of respondents (24 percent). Again, consumption of this last group is seasonal. Flesh foods, including red meat, poultry, and fish (fresh or dried), were consumed by over half (53.8 percent). Less frequently consumed food groups included dairy products (22 percent), eggs (22 percent), and organ meats (5 percent).

At significance values of five percent or less, women and children in households growing hybrid maize were more likely to have consumed foods classified in any of the food groups, with the exception of other fruits and vegetables and nuts and legumes. Bivariate relationships are strongest for foods containing large amounts of protein, such as dairy products, flesh foods, eggs, or organ meats, but these are also highly significant for the group containing food that is fortified in vitamin A (sugar, Blue Band margarine).

Table 2: Comparison of Food Groups Consumed in 24 Hours Preceding Survey, by Use of Maize Hybrids

	Grow Maize Hybrids			
	No	Yes	All Farmers	p-value*
Starchy staples	86.9	90.8	89.5	0.055
Nuts and legumes	71.2	73.3	72.6	0.481
Dairy	16.3	25.3	22.4	0.001
Organ meats	2.6	6.1	5.0	0.015
Eggs	17.2	24.1	21.9	0.010
Flesh foods and other small animal protein	45.6	57.7	53.8	0.000
Vit A-rich dark-green, leafy vegetables	20.3	25.8	24.0	0.053
Other vit A-rich fruits and vegetables	85.2	89.4	88.0	0.047
Other fruits and vegetables	82.6	83.2	83.0	0.795
Vit A-fortified foods	58.7	72.0	67.8	0.000

Source: Authors
*Pearson chi-squared test comparing distributions between hybrid and non-hybrid growers.

Table 3: Comparison of Mean Values of Dietary Diversity Indicators, by Use of Maize Hybrids

	Food Group Diversity 24-hour (1–10)	Vitamin A Diversity 7-day (0–9)	Food Frequency 7-day (1–20)	Vitamin A-Fortified Food Frequency 7-day (0–2)
All maize growers	5.28	3.94	8.00	1.09
Grow maize hybrids				
Yes	5.48	4.13	8.28	1.17
No	4.87	3.56	7.45	0.901
p-value, t-test difference in means	0.000	0.000	0.000	0.000

Source: Authors.
T-tests compare means between hybrid and non-hybrid growers.

Mean scores for all four diversity indicators are shown in Table 3, comparing users of F1 hybrid maize seed and non-users across the entire sample of maize-growing households. Out of a total of 10 possible categories of food, women in households growing maize hybrids consumed a mean of 5.5 in a 24-hour period, compared with a mean of 4.9 among non-users. Vitamin A diversity was also higher among hybrid maize growers, averaging 4.1 out of a total of 9 groups, compared to 3.6 among farmers who did not grow hybrids. Mean food frequency was 8.3 among hybrid maize growers and only 7.5 among non-growers. However, both of these scores are less than half the hypothetical maximum of 20 for this indicator, illustrating that consideration of the frequency of consumption has a dampening effect on relative dietary diversity. As expected given the findings reported in Table 3, the frequency of consumption of foods fortified with vitamin A is also greater among women and children in households growing hybrid maize.

Thus, descriptive statistics support the hypothesis that the net direction of various possible effects of hybrid seed use on dietary diversity appear to be positive. Next, we test this hypothesis econometrically using multivariate analysis and testing for selection bias with instrumental variables.

6.2 Econometric Results

Diagnostic tests performed with instrumental variables regression result in failure to reject the hypothesis that growing hybrid maize is exogenous in household dietary diversity, vitamin A diversity, or food frequency. Only in the model testing the impact of the amount of hybrid seed planted on the frequency of consuming foods fortified with vitamin A is the hypothesis of exogeneity rejected. The null hypothesis of homoskedasticity could not be rejected in any of the regressions. Other tests support the identification of hybrid seed use and validity of the instruments, and the null hypothesis of homoscedasticity could not be rejected in any of the regressions (Table 4).

As a consequence of these findings, we estimated all regressions with the binary variable for hybrid seed use using ordinary least squares (OLS). Recognizing potential clustering effects of households due to the sample design, robust standard errors were estimated with village clustering. Regression coefficients and robust standard errors are shown in Table 5. Poisson regressions were also tested for the first two indicators only, given that the third has a much wider range of values. Results are shown in the Appendix (Table A.3) and are similar in terms of the significance of coefficients but not in terms of their magnitude.

The impact of growing hybrid seed on food group diversity is significant at 1 percent, raising the score by 0.30 points on average. Higher asset values that are strongly correlated with land size, cell phone and radio ownership (which provide less costly access to information), and adult literacy rates are strongly associated with more diverse diets. More young adults in the household is weakly but negatively associated with consumption of more diverse food groups by women, and subsequently children, during the preceding 24 hours. Higher long-term rainfall and greater availability of nutrients in the soil is positively associated with this outcome, possibly reflecting cropping systems with more fertile soils and moisture that contribute to the capacity to produce a broader range of crops or supplement diets through cash purchase from crop sales. Positive associations with other crop prices are difficult to interpret given that the regression model is reduced form, and no theory-related hypotheses are evident. Higher district mean prices, lagged, could mean that farmers responded in the current season by planting these crops. Cotton is a cash crop, but sweet potato can be sold or consumed.

Table 4: Diagnostic Tests, Instrumental Variables Regressions

Test	Food Group Diversity	Vitamin A Diversity	Food Frequency
Grow hybrid			
F-test	66.9	66.9	66.9
(instruments)	(0.000)	(0.000)	(0.000)
Anderson statistic	120.99	120.99	120.99
(Chi-squared)	(0.000)	(0.000)	(0.000)
Sargan statistic	0.002	0.002	0.002
(Chi-squared)	(0.964)	(0.964)	(0.964)
Pagan-Hall	22.418	29.339	24.852
(Chi-squared)	(0.376)	(0.106)	(0.254)
Wu-Hausman	0.015	0.750	0.240
(F-test)	(0.903)	(0.765)	(0.625)
Kg hybrid seed			
F-test	5.21	5.21	5.21
(instruments)	(0.006)	(0.006)	(0.006)
Anderson statistic	10.54	10.54	10.54
(Chi-squared)	(0.005)	(0.005)	(0.005)
Sargan statistic	1.094	1.094	1.094
(Chi-squared)	(0.296)	(0.296)	(0.296)
Pagan-Hall	18.429	8.124	21.873
(Chi-squared)	(0.622)	(0.995)	(0.407)
Wu-Hausman	0.008	3.88	0.240
(F-test)	(0.927)	(0.049)	(0.624)

Source: Authors.
Value of test-statistic (p-value). Note that the instrument tests are identical across models because the first-stage regression is the same.

Findings with respect to diversity in sources of vitamin A are similar, although the impact of growing hybrid seed is even larger in magnitude (0.36). A greater number of older adults in the household is negatively associated with vitamin A diversity, although the effect is weak in terms of statistical significance. This result may reflect the life-cycle stage of the household or a greater number of adult dependents. Total land area, including both rainy and dry seasons, in addition to assets and ownership of a cell phone and radio, is a significant factor with a relatively large coefficient (0.42). Vitamin A diversity is greater in locations with lower five-year rainfall and less abundant planting rains in 2010. Inspection of the underlying data shows that in the southern agroecological zone, which is drier, households were more likely to consume orange sweet potato, organ and flesh meats, and dairy products but not vegetable-based sources of vitamin A. The coefficients on price are also positive in this regression, and orange sweet potato is a source of vitamin A. Although the count of food groups is similar between the food group diversity and vitamin A diversity, the reference period is only 24 hours for food group diversity and 7 days for vitamin A diversity.

The dependent variables in the first two impact regressions shown in Table 5 reflect the incidence of consumption across food groups within a specified reference period. Food frequency accounts for how often foods have been consumed, across groups. Growing hybrid seed has no visible effect on food frequency among smallholder maize growers in Zambia. Other results in this model are similar to those reported in the first two models. Total land area cultivated across both growing seasons is also significant, with larger magnitude (0.59). The effect of literacy is strongest in this regression. The number of adults in the household (in each category) is negatively associated with the frequency of consuming from diverse food groups, perhaps because it reduces availability per capita, other factors held constant. In contrast to the other models, higher rainfall in the preceding five seasons, as well as more rainfall over the long run, positively influences the frequency

Table 5: Impact of Growing Hybrid Maize Seed on Dietary Diversity

	Food Group Diversity	Vitamin A Diversity	Food Frequency
Grow hybrid	0.301***	0.364***	0.216
	(0.110)	(0.104)	(0.182)
Female headship	0.093	-0.020	0.308
	(0.122)	(0.118)	(0.205)
Literacy	0.125***	0.054*	0.308***
	(0.035)	(0.032)	(0.053)
Young adults	-0.117*	0.001	-0.257***
	(0.061)	(0.057)	(0.096)
Mature adults	-0.057	0.016	-0.179**
	(0.046)	(0.043)	(0.079)
Older adults	-0.066	-0.105*	-0.189**
	(0.055)	(0.056)	(0.095)
Land size	0.184	0.421***	0.594***
	(0.129)	(0.150)	(0.218)
Assets	0.143***	0.080**	0.268***
	(0.035)	(0.036)	(0.060)
Cell	0.340***	0.396***	1.042***
	(0.123)	(0.101)	(0.194)
Radio	0.331***	0.317***	0.147
	(0.125)	(0.114)	(0.208)
Seed-to-grain price	0.020	0.008	0.040
	(0.013)	(0.013)	(0.026)
Bean price	9.26e-05	-7.72e-05	0.000***
	(6.65e-05)	(5.85e-05)	(0.000)
Cotton price	0.000**	0.000***	0.001**
	(0.000)	(0.000)	(0.000)
Sweet potato price	0.001**	0.001*	0.001
	(0.000)	(0.000)	(0.001)
LT rainfall	0.002***	0.001***	0.004***
	(0.000)	(0.000)	(0.001)
5-year rainfall	0.002	-0.003**	0.005**
	(0.001)	(0.001)	(0.002)
Planting season	-0.011	-0.027***	-0.025
	(0.010)	(0.008)	(0.017)
Nutrient availability	0.145**	0.158**	0.086
	(0.068)	(0.065)	(0.121)
Constant	-3.265***	1.317	-9.144***
	(1.246)	(1.113)	(2.081)
Observations	1,045	1,045	1,045
R-squared	0.207	0.140	0.293

Source: Authors.

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

of consuming foods from more diverse groups. These findings highlight the importance of considering various, comparative definitions for dietary diversity measurement before drawing policy conclusions.

Almost identical results were obtained when examining the impact of the scale of hybrid seed use on dietary diversity (Table 6). The regression model for vitamin A diversity was estimated with two-stage least squares because we failed to reject the exogeneity of hybrid seed quantities planted in the first-stage regression (Table 4). The estimated size of the average effect of growing 10 kg of hybrid seed (the size of the FISP package in the survey year) on food group diversity is 0.04 units, which is small compared to that associated with growing hybrid maize at all (the binary variable). The magnitude of the coefficient for vitamin A diversity is almost exactly the same as for food group diversity. Most importantly, a greater scale of hybrid maize production is associated with more food group diversity (at 1 percent significance), more vitamin A diversity (at 5 percent significance), and a higher frequency of consuming foods from more diverse food groups (at 10 percent significance). Though the significance of the effect is weak, this last result was not visible when hybrid seed use was measured crudely as a binary variable.

Results of the ordered logit regression testing the impacts of growing hybrid seed on the frequency of consuming food that is fortified with vitamin A (sugar and Blue Band margarine) are shown in Table 7. The values of the dependent variable are (0, 1, 2). Planting hybrid maize seed has no observable impact on consumption from these food groups (the p-value for the binary variable is 0.11). As with the other dietary diversity indicators, larger total cultivated areas over the two growing seasons, higher asset values, cell phone and radio ownership, adult literacy, and higher long-term rainfall play positive roles in consumption of these items, which are luxury goods. Higher seed-to-grain price ratios are also positively associated with their consumption, perhaps reflecting more commercially oriented farming districts. The number of mature and older adults in the household offsets these effects, reflecting "more mouths to feed" by income-earners. The effect of higher long-term rainfall is positive.

Table 6: Impacts of Scale of Hybrid Use on Dietary Diversity

	Food Group Diversity	Vitamin A Diversity	Food Frequency
Hybrid seed planted (kg)	0.004***	0.029**	0.004*
	(0.001)	(0.015)	(0.002)
Female headship	0.106	0.089	0.323
	(0.123)	(0.145)	(0.205)
Literacy	0.127***	-0.003	0.307***
	(0.035)	(0.051)	(0.053)
Young adults	-0.120**	0.007	-0.260***
	(0.061)	(0.061)	(0.010)
Mature adults	-0.077	-0.064	-0.196**
	(0.048)	(0.060)	(0.078)
Older adults	-0.073	-0.117*	-0.195**
	(0.056)	(0.064)	(0.095)
Land size	0.093	-0.318	0.499**
	(0.134)	(0.407)	(0.218)
Assets	0.139***	0.017	0.262***
	(0.035)	(0.052)	(0.061)
Cell	0.376***	0.431***	1.068***
	(0.123)	(0.125)	(0.194)
Radio	0.353***	0.326**	0.162
	(0.125)	(0.133)	(0.207)
Seed-to-grain price	0.021	-0.016	0.039
	(0.013)	(0.021)	(0.025)
Bean price	9.14e-05	-0.000*	0.000***
	(6.67e-05)	(7.07e-05)	(0.000)
Cotton price	0.000**	0.001***	0.001**
	(0.000)	(0.000)	(0.000)
Sweet potato price	0.001**	0.000	0.001
	(0.000)	(0.000)	(0.001)
LT rainfall	0.002***	0.002***	0.004***
	(0.000)	(0.001)	(0.001)
5-year rainfall	0.002*	-0.005***	0.005**
	(0.001)	(0.002)	(0.002)
Planting season	-0.011	-0.031***	-0.026
	(0.010)	(0.010)	(0.017)
Nutrient availability	0.142**	0.083	0.081
	(0.068)	(0.082)	(0.121)
Constant	-3.191***	3.271**	-9.008***
	(1.235)	(1.645)	(2.088)
Observations	1,045	1,045	1,045
R-squared	0.185	NA	0.249

Source: Authors.

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Regression is second stage 2SLS for vitamin A diversity (R-squared not used).

Table 7: Ordered Logit Regression, Impact of Growing Hybrid Seed (Binary Choice) on the Frequency of Consumption of Vitamin A-Fortified Food

	Grow Hybrid (0,1)	Scale of Hybrid Use (kg)
Hybrid seed use	0.239	0.001
	(0.149)	(0.002)
Female headship	0.056	0.058
	(0.172)	(0.172)
Literacy	0.183***	0.191***
	(0.048)	(0.048)
Young adults	-0.121	-0.126
	(0.084)	(0.084)
Mature adults	-0.141**	-0.153**
	(0.065)	(0.067)
Older adults	-0.219***	-0.224***
	(0.075)	(0.075)
Land size	0.332*	0.320
	(0.187)	(0.205)
Assets	0.141***	0.143***
	(0.055)	(0.054)
Cell	0.874***	0.900***
	(0.145)	(0.145)
Radio	0.458***	0.473***
	(0.168)	(0.167)
Seed-to-grain price	0.064***	0.067***
	(0.018)	(0.019)
Bean price	3.40e-05	3.71e-05
	(9.72e-05)	(9.73e-05)
Cotton price	0.001***	0.001***
	(0.000)	(0.000)
Sweet potato price	0.000	0.000
	(0.000)	(0.000)
LT rainfall	0.001**	0.001**
	(0.001)	(0.001)
5-year rainfall	-0.003	-0.003
	(0.002)	(0.002)
Planting season	-0.002	-0.002
	(0.014)	(0.015)
Nutrient availability	0.040	0.044
	(0.093)	(0.093)
Constant (cut 1)	4.506**	4.606**
	(1.796)	(1.805)
Constant (cut 2)	5.207***	5.305***
Observations	1,045	1,045
Wald chi^2 (18)	160.20 (0.000)	

Source: Authors

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

7. CONCLUSIONS

Although much is known about maize production and also about household nutrition in Zambia, we are unaware of studies that relate use of maize hybrids to dietary diversity other than the analysis conducted by Kumar in 1994. In this paper, we tested the impact of growing hybrids on the dietary diversity of women and children in maize-growing households with baseline data collected in 2011 by HarvestPlus and its partners from over 1,000 households in the major maize-producing areas of Zambia.

We tested the potential endogeneity of growing hybrid seed and the scale of planting with instrumental variables methods. Our instrumental variables were subsidy receipt and membership in registered associations. Diagnostic statistical tests led us to fail to reject the exogeneity in three of the four dietary diversity indicators studied. This is as expected given that: production decisions precede consumption; farm households engage in a broad spectrum of agricultural and off-farm income-earning activities; and we have controlled for other observed factors related to hybrid seed use in the regression model.

We then estimated a sequence of dietary diversity equations (food group diversity, vitamin A diversity, and food frequency) with hybrid seed use treated as an exogenous variable and measured as a binary variable and in terms of kilograms planted. Our fourth dietary diversity equation, explaining the frequency of consumption of food fortified with vitamin A, was estimated with ordered logit regression.

Findings are also robust across econometric models, although the overall statistical strength of the regressions and individual coefficients vary. Growing hybrid seed, whether measured as a binary variable or in terms of kilograms, has a significant and positive effect on the numbers of food groups consumed by household members in the preceding 24-hour reference period, as well as the number of food groups that are sources of vitamin A, but not on the frequency of consumption from diverse food groups. Larger scale of hybrid seed use generates similar results but also has a weakly significant effect on the frequency index. Other major positive factors in dietary diversity include adult literacy, higher long-term rainfall and soil nutrient availability, total areas cultivated in both growing seasons, asset values, and cell phone and radio ownership.

One major implication of this result is that dietary diversity, consumption of vitamin A-fortified foods, and hybrid seed use are already interrelated among women in smallholder maize-growing households of Zambia. Related literature documents the close relationship often found between maternal diet and the diets of their children. Thus, we find that hybrid seed use does not counteract dietary diversity, as has often been hypothesized based on the argument that growing hybrids tends to promote crop specialization and drive out crops that serve as alternative food sources. This finding supports the strategy endorsed by HarvestPlus and its partners to promote the use of provitamin A maize hybrids in rural Zambia.

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APPENDIX

Table A.1: Food Groups as Elicited in the HarvestPlus Baseline Survey

Respondent should be the wife of the household head and/or mother of the household, otherwise respondent should be other female adult household member who is 15 years of age or older.

IA1	Food Item	IA2	IA3	IA4
		Did you consume [food item] in the last 24 hours?	Did you consume [food item] in the last 7 days?	How many times in the last seven days did you consume [food item]?
		1 = Yes >> IA4 2 = No>> IA3 -99 = Don't know/ remember	1 = Yes >> IA4 2 = No >> next item -99 = Don't know/ remember	Number of times
1	Maize			
2	Other cereals			
3	Beans and other pulses (such as cowpeas, etc.)			
4	Nuts and seeds			
5	Sugar			
6	Sweet potato, orange fleshed			
7	Other roots and tubers (Irish potatoes, cassava, white fleshed sweet potato, etc.)			
8	Fruits (mango, pineapple, guava, pawpaw, etc.)			
9	Wild fruits			
10	Eggs			
11	Milk, cheese			
12	Dark-green leafy vegetables			
13	Other vegetables (pumpkin, tomatoes, etc.)			
14	Fish and other seafood (shrimp, crab, etc.)			
15	Red meat (cow, goat, pig, sheep, pork, etc.)			
16	Animal liver, kidney, and other offals			
17	Poultry (chicken, duck, etc.)			
18	Blue Band margarine (vitamin A-fortified)			
19	Fats and oils (butter, other margarine, soybean, mustard, ghee, etc.)			

Table A.2: Nutrient Availability-Factor Rating for Modal Crop and Land Use Type

Diagnostic Factor	**Degree of Limitation**			
	Slight	Moderate	Severe	Very Severe
Organic carbon (%)	≥ 1.0	0.5-1.0	0.25-0.5	0.25
Base saturation (%)	50-100	35-50	15-35	<15
Soil reaction (pH)	5.5-7.5	5.0-5.5 or 7.5 -8.0	4.5-5.0 or 8.0-8.4	≤4.5 or ≥8.4

Table A.3: Impact of Growing Hybrid Maize Seed on Dietary Diversity, Poisson Model

	Food Group Diversity	Vitamin A Diversity
Grow hybrid	0.059***	0.095***
	(0.021)	(0.027)
Female headship	0.017	-0.006
	(0.023)	(0.030)
Literacy	0.024***	0.013*
	(0.001)	(0.008)
Young adults	-0.023*	-0.000
	(0.012)	(0.014)
Mature adults	-0.011	0.004
	(0.009)	(0.011)
Older adults	-0.013	-0.026*
	(0.010)	(0.014)
Land size	0.033	0.097***
	(0.023)	(0.032)
Assets	0.027***	0.020**
	(0.007)	(0.009)
Cell	0.068***	0.107***
	(0.025)	(0.027)
Radio	0.068***	0.089***
	(0.025)	(0.031)
Seed-to-grain price	0.004	0.002
	(0.002)	(0.003)
Bean price	1.73e-05	-2.01e-05
	(1.24e-05)	(1.45e-05)
Cotton price	7.11e-05**	0.000108***
	(3.38e-05)	(3.80e-05)
Sweet potato price	0.000**	0.000*
	(5.57e-05)	(7.45e-05)
LT rainfall	0.000***	0.000***
	(8.38e-05)	(0.000)
5-year rainfall	0.000	-0.001**
	(0.000)	(0.000)
Planting season	-0.002	-0.007***
	(0.002)	(0.002)
Nutrient availability	0.028**	0.041**
	(0.013)	(0.017)
Constant	0.044	0.695**
	(0.238)	(0.278)
Observations	1,045	1,045
Wald chi^2 (18)	160.20 (0.0000)	

Source: Authors.
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure A.1: Distributions of Vitamin A Diversity Scores, by Reference Period