The Impact of Hybrid Maize on Smallholder Livelihoods in Zambia:Findings of a Household Survey in Katete, Mkushi, and Sinazongwe Districts

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Petan Hamazakaza is principal scientist and Helen Kasalu is chief agricultural research officer, both of the Zambia Agriculture Research Institute, and based at Kabwe Research Station. Melinda Smale is professor of International Development, in the Department of Agricultural, Food, and Resource Economics, Michigan State University (MSU).

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Any views expressed or remaining errors are solely the responsibility of the authors.

Comments and questions should be directed to:

The Executive Director
Post Net 99
Indaba Agricultural Policy Research Institute
26A Middleway, Kabulonga,
Lusaka.
Landline: +260 211 261194;
Fax: +260 211 261199;
Email: kabaghec@iconnect.zm

INDABA AGRICULTURAL POLICY RESEARCH INSTITUTE TEAM MEMBERS

The Zambia-based Indaba Agricultural Policy Research Institute (IAPRI) research team is comprised of Chance Kabaghe, Thomas. S. Jayne, Stephen Kabwe, Rhoda Mofya Mukuka, Munguzwe Hichaambwa, Auckland Kuteya, Mary Lubungu, Nicole Mason, Brian Mulenga, Arthur Shipekesa, Nicholas Sitko, and Solomon Tembo. Michigan State University-based researchers associated with IAPRI are Margaret Beaver, Eric Crawford, Steven Haggblade, Chewe Nkonde, Melinda Smale, and David Tschirley.

EXECUTIVE SUMMARY

Maize plays a vital role in the livelihoods of the smallholder farmers in Zambia. The period following the 1991 economic liberalisation and Structural Adjustment Programme witnessed an influx of foreign based seed companies whose primary investment in the Zambian seed industry was in maize seed improvement and marketing. The crop has received considerable government attention over the years in terms of financial investment to support smallholder farmer access to seed and fertilizer. In this regard, government introduced the subsidized Farmer Input Support Programme (FISP) in 2002/03 and by 2010, about 1,210,520 resource constrained farmers had benefited from the programme.

This study was conducted in the three major maize-growing provinces of Zambia. In each province, a district was randomly selected. Sinazongwe, in Southern Province was selected to represent the marginal maize growing area that receives less than 700 mm of rainfall per year. In Eastern Province, Katete was selected to represent the moderate maize growing environment, with 800-1000 mm of precipitation per year. Mkushi district in Central Province was selected to represent optimal maize-growing conditions, with over 1000 mm of rainfall per year. In each district, a total of 10 villages were randomly selected and in each village, a random sample of 10 households was chosen for the quantitative survey. A total of 300 households were interviewed. The quantitative questionnaire was designed to capture information on a range of potential indicators relating to household maize production and its influence on livelihood strategies. Key components of the survey instrument included an inventory of agricultural and non-agricultural assets, household incomes and sources, agricultural inputs and sources, household social capital, and production and sales data for crops and livestock.

Key highlights from the study findings show that hybrid maize growers cultivated an average of 1.7 hectares (ha), as compared to 0.9ha for those who did not in the year preceding the survey (2010/11 season). Hybrid maize adopters are more endowed in terms of physical, social, and natural capital assets compared to non-adopters. FISP has played a key role in hybrid maize variety adoption in the last decade (2002/03 – 2011/12). Controlling for other factors, we find that subsidy receipt is strongly related to whether or not a farmer grows hybrid seed, but not to the amount planted.

Survey findings indicate that 59% of all the 300 farmers surveyed have received input support at one time or another, but 41% had never received input support. The distribution of the total number of years the households surveyed have received input support for maize production shows a high density around two years and two-thirds of farmers surveyed who grew maize hybrids in 2010/11 (65.2%) were members of farmer cooperatives.

The cumulative distribution of total income for non-hybrid maize growers shows values that are significantly lower than that of hybrid growers. The analysis shows significant differences in the count of all farm and non-farm activities with hybrid maize growers having an average of 2.33 of the 11 activities reported, as compared to only 1.81 for non-hybrid maize growers with a P-value of 0.0031. Maize contributes the largest percentage (26%) of income at household levels, followed by horticultural products (21.4%), and piecework at 10.5%. However, among the non-hybrid maize growers, piecework contributed the highest share (23.3%) to household income. Among other sources of income, only horticultural income is strongly associated with maize income suggesting that hybrid maize growers have more sources of non-covarying income, making them potentially more resilient to income shocks from any single source.

The probit regression demonstrates that the effect of years receiving the subsidy is strong in the decision to use hybrids (with a large magnitude), reflecting the limited financial capabilities of many smallholder maize growers and some path-dependence in use. District analysis show higher effects of hybrid maize seed use in Mkushi district, and the negative effect in Katete district (also with a large magnitude), compared to Sinazongwe. Access to market information, and literacy, are highly significant in the decision to plant hybrids. On the other hand, sex of household head, farm size, and draft power are not, although other analyses indicate that these are associated with the quantities of hybrid seed planted because they are related to scale of production. Numbers of livestock owned, on the other hand, figure strongly in the use of hybrid seed

Regressions show that planting hybrid seed increases the value of total household income among smallholder maize farmers by 64% on average, but has no significant effect on the richness and concentration of income sources when other factors are considered. However, a higher count and evenness of income shares from various sources is positively associated with household income, attesting to the importance of programs that support crop and income diversification among Zambian smallholders. Each additional kilogram (kg) of hybrid seed increases the maize sales share of total household income by 0.8 percentage points. Female-headed maize-growing households rely more heavily on maize for income than do male-headed households.

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ACRONYMS

ASP	Agriculture Support Programme
CFA	Control Function Approach
CFU	Conservation Farming Unit
CSO	Zambian Central Statistical Office
CIMMYT	*Centro Internacional de Mejoramiento de Maíz y Trigo* (International Maize and Wheat Improvement Center)
DFID	Department for International Development, U.K.
DoA	Department of Agriculture
FISP	Farmer Input Support Programme
FSP	Fertilizer Support Program
GoZ	Government of Zambia
ha	hectare
IAPRI	Indaba Agricultural Policy Research Institute
IOPV	Improved Open-pollinated Varieties
kg	kilogram
MSU	Michigan State University
NGOs	Non-governmental Organizations
OLS	Ordinary Least Squares
SLA	Sustainable Livelihoods Approach
SPIA	Standing Panel on Impact Assessment of the Consultative Group on International Agricultural Research
TOFAZA	Tobacco Free Association of Zambia
USAID	United States Agency for International Development
WVI	World Vision International
ZARI	Zambia Agricultural Research Institute
ZMK	Zambia Kwacha
ZNFU	Zambia National Farmers Union

1. INTRODUCTION

In Zambia, throughout the colonial period and following independence in 1964, smallholder farmers produced local maize largely for subsistence purposes and commercial farmers grew hybrid maize to feed laborers and miners in the Copper Belt (Howard and Mungoma 1997). To a greater extent than today, smallholder farming systems were characterized by mixed cropping, which offered a wider diversity of crop and livestock products. Depending on the region in this relatively land-abundant country, these systems embraced crops such as finger millet, bulrush millet, sorghum, groundnuts, cowpeas, pumpkins, paddy rice, local maize, beans, cassava, sweet potatoes, and bambara nuts (Howard, Chitalu, and Kalonge 1993). Maize assumed an economically important role in the economy during the colonial period; after independence, maize became the centerpiece of a social contract formed between the newly independent Government and the Zambian people (Smale and Jayne 2010).

From the 1970s, the commitment of the Government of Zambia (GoZ) to ensure a cheap staple food for urban populations led to major investments in state-managed systems to deliver improved maize seed and fertilizer at subsidized prices, combined with controlled grain prices and organized markets. When copper prices collapsed, policymakers turned their focus toward developing the unexplored potential of Zambia’s small-scale farmers (Eylands and Patel 1990). The GoZ, backed by donors, also made major investments in maize research and seed multiplication. An impressive number of maize hybrids and improved, open-pollinated varieties (IOPVs) were released throughout the 1980s, many of which were suited to the needs of smallholder growers in terms of yield stability and grain texture. Though fiscally unsustainable, the integrated system paid off in terms of sharply rising adoption curves and boosting national maize production.

Nonetheless, the system came at other costs. For example, between 1964 and 1991, Chizuni (1994) reports that maize production was encouraged throughout the country, even in regions which are not suitable for maize production. According to Scott (1995), the GoZ has never distinguished between agricultural development and social welfare. The consequence is that subsidies, hand-outs, and other *coercive* incentives undermined the development of a sense of self-reliance and more business-like approach to farmer decision-making.

By the mid-1980s, government subsidies to the maize sector consumed 17% of the total Zambian government budget (GoZ 1990). Under donor pressure, the GoZ pursued a Structural Adjustment Programme during the 1990s and most parastatal companies went bankrupt. The seed sector was one of the first to be liberalized. Zambia’s maize seed industry is today one of the strongest in eastern and southern Africa, with five major companies and a number of smaller-scale enterprises. Although fertilizer was a major focus of FISP, maize seed has also been a key component of the package delivered to farmers via registered farmer cooperatives.

The introduction of certified, improved maize seed, and particularly hybrids, changed the role that maize production, and agriculture in general, plays in the livelihoods of Zambian smallholder farmers. Several previous studies have shed light on this relationship. A detailed study led by Kumar (1994) and supported by the International Food Policy Research Institute, the University of Zambia’s Rural Development Studies Bureau, and the Zambian National Food and Nutrition Commission, explored the implications of maize hybrid adoption in Eastern Province of Zambia for gender relationships, resource allocation, income, food consumption, and nutrition. Among other findings, Kumar concluded that adoption was almost always associated with the expansion of ox-drawn cultivation. Nearly all farmers with over five hectares adopted hybrid maize, although adoption was also substantial on smaller-scale farms, where it was also more profitably produced. She found that marginal improvements in income from hybrid maize production deteriorated with farm sizes over four ha, reflecting labor and management constraints. Larger farmers also had a lower consumption of nutrients, perhaps as a consequence of specialization for market sales and substitution of purchased for home-produced food. Farmers continued to grow local maize for home consumption, selling hybrid maize as a cash crop. Women-headed households were less likely to adopt. Although women were heavily involved in maize production, they participated less in decision-making once hybrid seed was adopted.

Langyintuo and Mungoma (2008) showed that factors influencing the adoption and use intensity of improved hybrid maize varieties differed between resource-endowed and resource-constrained households, perhaps as a reflection of risk-bearing ability. The authors defined these groups in terms of various forms of capital, in accordance with the livelihoods approach.

A more detailed report by Langyintuo et al. (2005), which was based on the field survey, showed that 78% of the well-endowed households adopted improved maize varieties on an estimated 49% of their maize areas. In contrast, 58% of the poorly-endowed households adopted improved maize varieties on only 15% of their maize area. The authors also noted dis-adoption of improved maize varieties (especially hybrids), which they attributed to irregular, limited sources of cash. The well-endowed owned more physical assets such as oxen, which are crucial for maize production on a larger scale, owning more, as well as more diverse livestock.

A recent study by Kalinda et al. (2010), conducted in Monze and Kalomo districts, documents the range of livelihood strategies pursued by households and their capital endowments, grouped according to human, natural, physical, financial, and institutional or social capital. As elsewhere, even in these drought-vulnerable areas, maize, including local, IOPV, and hybrid types, occupies roughly 60% of cultivated area in the two districts. Farmers perceived hybrid maize as the riskiest of maize types and crops with respect to yield variation, but also the most profitable. When crop yields were higher with hybrid maize, most households reported they would buy assets. The authors found that the probability of growing and amount of improved seed grown is significantly related to the size of the farm holding and participation in farmer organisations. Human capital (education, labor supply) were not significant determinants; male headship was.

In terms of farm sizes, a study by TOFAZA and ZARI (2011) in Central, Eastern, and Southern Provinces of Zambia revealed that land ownership is a critical component in agricultural production and enterprise diversification. This study further elaborates that land size in most cases pre-determines the extent to which a household is able to diversify its agricultural enterprises including taking up new innovations and crop varieties.

In this paper, we test the relationship between hybrid seed use and the livelihoods of smallholder farmers in Zambia with a combination of descriptive statistics and an applied econometrics framework. We use the concepts of the livelihoods framework, and particularly the asset pentagon, to specify our regression model. We define the livelihood outcomes of adoption in terms of total household income and the diversity of household income sources. We measure diversity in terms of: a) the count of income sources; b) the share of income sources; and c) the Herfindahl index of income sources, which summarizes both the count and the evenness across income sources. We base our analysis on a detailed dataset of 300 households sampled in the three districts of Mkushi, Katete, and Sinazongwe. The study districts are located in the three major maize- growing provinces of Central, Eastern, and Southern, respectively. Data were collected in the same areas surveyed in 2003-04 by Langyintuo et al. (2005). As compared to the earlier study, we also consider the effects of the FISP on use of hybrid seed.

In the next section, we summarize our research methods, including data collection and the econometric strategy we employ to test hypotheses. Descriptive analyses of capital endowments of surveyed households and their income sources are presented in the fourth section. Section 5 reports regression results. In the final section, we draw conclusions and policy implications, also proposing future research directions.

2. DATA SOURCE

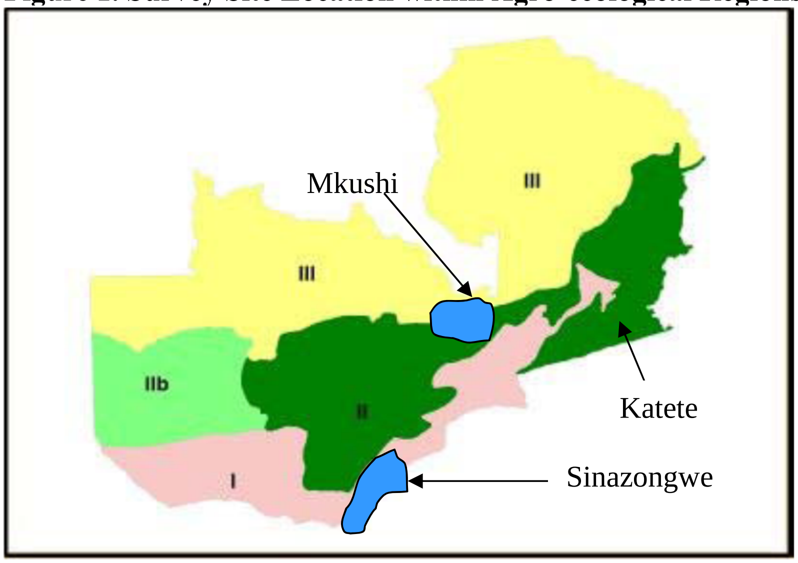
The countryside of Zambia is classified into three agro-ecological regions which are delineated on the basis of agro-climatic conditions, including rainfall patterns, temperature, farming systems and soil types. The nation is divided administratively into nine provinces: namely, Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, Northwestern, Southern, and Western Provinces.

The study was conducted in the three major maize-growing provinces of Zambia: Southern, Central and Eastern provinces. In each province, a district was selected at random. Sinazongwe, in Southern Province, is a marginal maize growing area that receives under700 mm of rainfall per year, located in region I. In Eastern Province, in region II, Katete represents a moderate maize-growing production environment, with 800-1000 mm of precipitation per year. Mkushi district in Central Province includes commercial farms and represents optimal maize-growing conditions, with over 1000 mm of rainfall per year. Mkushi district straddles regions II and III (Figure 1).

In a preliminary screening exercise, the survey team found high attrition rates in the previous sample drawn in 2003. As advised by Zambian Central Statistical Office (CSO), the team conducted a new household listing in each of the 30 villages, recording the name, age, and sex of household head, number of years the household has been resident in the village, and the type of maize the household intended to grow in the 2011/12 season.

A statistician from the CSO joined the survey team for the household listing, identifying the geographical location of the household with a Global Positioning System and the Standard Enumerator Area to which the household belongs according to the most recent Zambian census, conducted in the same year. Only smallholders were listed. In the Zambian context, smallholder farmers are defined as those farmers that cultivate less than 20 ha of land.

Figure 1. Survey Site Location within Agro-ecological Regions of Zambia



Source: Authors.

Table 1. Selected Villages by District, 2011/12 Season

Districts		
Katete	**Mkushi**	**Sinazongwe**
1. Malata	11. Lukunka	21. Sianyuka
2. Mbalane	12. Kasangwa	22. Siajamba
3. Azeleguze	13. Mukulaulo	23. Bulima
4. Chilembwe	14. Mutongola	24. Siankwazi
5. Kachipu	15. Chitambo	25. Muvwali
6. Mthunya	16. Mapapa	26. Siatulonga
7. Kholowa	17. Kalwele	27. Kanego
8. Saukani	18. Chanfuko	28. Kaumba
9. Chinsichi	19. Shumbwa	29. Malabali
10. Kalumbi	20. Machiko	30. Sinakaimbi

Source: Authors.

In each district, 10 villages were randomly selected (Table 1).

Systematic random sampling with replacement was applied to select households from the village list frame. A total of 10 households per village were selected to achieve an overall sample of 300 households for the entire survey in the three districts.

The formal questionnaire was administered in face-to-face interviews with the household head. The questionnaire was designed to capture information on a range of potential indicators relating to household maize production and its influence on livelihoods strategies. Key components of the survey instrument included household demographic information, an inventory of agricultural and non-agricultural assets, household incomes and sources, agricultural inputs and sources, household social capital, and production and sales data for crops and livestock.

Data were collected by one survey team comprising a supervisor and five enumerators in the period March and April 2012, at the close of the 2011/12 growing season. Enumerators were trained agricultural technicians and ZARI research staff, with years of field experience.

3. RESEARCH METHODS

3.1. Livelihoods Concepts

The conceptual basis of our analysis is the well-known livelihoods framework[1]. As defined by Ellis (2000), a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. O'Donnell (2004) has argued recently that the livelihood framework can provide a clear basis for understanding how technologies such as hybrid maize can impact on various aspects of livelihoods in many different ways at household level.

This approach leads us to emphasize, in our empirical model, the influence of asset endowments on hybrid maize adoption, and taking account of their effects on adoption, their impacts on income and income diversification. In accordance with the livelihoods framework, households are regarded as possessing five types of assets (an asset pentagon) that are essential to the pursuit of livelihoods: human capital, natural capital, physical capital, financial capital, and social capital. In broadest terms, human capital consists of the skills, knowledge, ability to labour, and good health, which are important to pursue livelihood strategies. Natural capital consists of the natural resource stocks from which livelihoods are derived (e.g., land, water, wildlife, biodiversity). Physical capital includes basic infrastructure (transport, shelter, energy, communications, and water systems), production equipment, and tools that enable households to maintain and enhance their relative level of wealth. Financial capital includes cash and other liquid resources (e.g., savings, credit, remittances, pensions, etc.). Social capital comprises the social resources people draw upon in pursuit of livelihoods such as networks, membership in groups, exchange relations, and access to wider institutions in society. For descriptive and analytical purposes, we define these assets operationally in terms of the Zambian rural context and the variables included in our survey instrument. More about our capital variables is presented in the results section.

As livelihood outcomes of hybrid seed adoption, we use several indicators related to income. First, we consider total household income from farm and non-farm sources in the year preceding the survey. Second, we explore the diversity of household income sources. We measure diversity in three ways: a) the count of income sources; b) the share of income sources; and c) the Herfindahl index of income sources, which summarizes both the count and the evenness across income sources.

Diversity indexes as utilized in the ecology literature (Magurran 1998) are quantitative measures that generally reflect two underlying features of a population. The first is richness, or the number of types (such as species or in our case, income-earning activities). In a simply count indicator of richness, each unit has equal weight. A second concept is proportional abundance, or equitability. Indicators of proportional abundance express how evenly the units of analysis (individuals of a species, or households) are distributed among types.

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[1] In a 2003 Working Paper published by the Overseas Development Institute, Solesbury reports that in the 1997 White Paper on international development, DFID made the sustainable livelihoods approach (or SLA), a core principle of its strategy for pro-poor policy making. The concept of SLA first appeared in research literature in the 1980s, and has since become an influential paradigm for operationalizing field research and rural development policy.

In this study, we are interested in income-earning activities, including both farm sources (crops and livestock) and non-farm sources (remittances, petty trade, self-employment). We measure richness as a count over sources of income.

As an equitability or evenness indicator, we have chosen the Herfindahl index, which is defined as $H=\Sigma\alpha_i^2$, where α_i is a proportion or share represented by each type of the unit under analysis.

The Herfindahl index (also known as the Herfindahl-Hirschman index) has been extensively used by economists (e.g., Albert O. Hirschman) to analyze the extent of competition among firms in an industry, calculated in terms of market shares. The index assigns a heavier weight to firms with more market power, and can, thus, be used as an indicator of the concentration of sales in analysis of monopolistic or oligopolistic behavior in anti-trust lawsuits.

The Herfindahl index ranges from 1/n to 1, where n is the number of income sources. The Herfindahl index in economics is equivalent to the Simpson index in the ecology literature. Applied to household income, the Herfindahl index is the sum of squared income shares among income-earning activities undertaken by household members. The higher the index, the more inequitable the distribution of income among sources.

3.2. Econometric Strategy

The objective of our econometrics analysis is to examine the relationship between growing hybrid seed and household livelihoods, expressed in terms of total income and the diversity of income sources. Since hybrid seed use could be endogenous to adoption decisions, biasing regression results, we test for its endogeneity. In the sections that follow, we describe variables we used and econometric approaches in greater detail.

3.2.1. Explanatory Variables

According to the concepts presented above, the determinants of the decision to use hybrid seed are the five core types of assets, or building blocks, of livelihoods: human capital, natural capital, physical capital, and financial and social capital. In turn, adoption of hybrid seed affects total income and the diversity of income sources, still controlling for capital assets. Variable definitions are shown in Table 2.

Human capital is measured by the sex of the household head, the literacy of the household head, and the number of active male adults in the household. Earlier research in Zambia and elsewhere has consistently found differences in use of improved maize inputs (seed, fertilizer) between male- and female-headed households (Kumar 1994), although the subsidy program appears to affect this relationship (Smale and Mason 2012). The number of active male adults is a variable that is pre-determined in the cropping season (unlike household size, which includes the number of dependents and young children), and an indicator of labor supply. Farming experience refers to labor quality. Education is an important element of human development and is a pre-requisite to knowledge and ability to apply formal skills. Farmers who have never received formal education or those who leave school at primary level in Zambia have problems of reading and writing English (the official language).

Table 2. Definition of Variables

Variable	Definition
Dependent	
Grow hybrid	1=planted hybrid seed in 2011/12, 0 otherwise
Hybrid seed planted	Kgs of hybrid seed planted in 2011/12
Income	Logarithm of all household income earned from all farm and non-farm sources in 2010/11 (i.e., year preceding survey)
Income concentration	Herfindahl index=sum of squared income shares of income sources recorded in the survey, ranging from 1/n to 1
Income richness	Count of income sources recorded in survey, ranging from 1 to 11
Income share	11 variables measuring share of income sources (maize, cotton, horticulture, livestock, groundnut, other crops; remittances, petty trade, self-employed, piecework, other non-farm income).
Explanatory	
Subsidy years	Years that household has received input subsidies for maize production, ranging from 1 to 11
Headship	1=male household head, 0=female
Male adults	Number of male adults 16-59 years in household
Literacy	Head is can read and write in English=1, else=0
Draft	Factor score for draft animals (see text)
Market information	Factor score for market information (see text)
Katete	1=Katete, 0=Mkushi orSinazongwe
Mkushi	1=Mkushi; 0=Katete or Sinazongwe
Farm size	Total hectares of farm land to which household had access in 2011
Farm size squared	$(\text{farm size})^2$
Livestock	Number of livestock owned (excluding fowl)
Social intensity	Ratio of number of persons who are members of any village association to all persons in the village

Source: Authors.

Consequently, this aspect undermines their ability to participate effectively in development programs including agricultural related interventions as well as acquiring formal skills to pursue different livelihood options. We used literacy (ability to read and write in English) as the explanatory variable, measure as achievement of at least a primary school level of education.

Natural capital includes total farm area, and a squared term, to express the notion that the impact of farm size may decrease after a certain area. Our review of the literature about hybrid maize adoption in Zambia (Kumar 1994; Langyintuo and Mungoma 2008; Kalinda et al. 2010; TOFAZA and ZARI2011) suggests a strong relationship between farm size and the likelihood of hybrid seed use. In addition, we know that the amount of seed planted is a function of the scale of the maize area, which may be, in turn, related to total farm size.

To incorporate the role of physical capital, we applied principal components analysis with varimax rotation to reduce the number of asset variables and the multicollinearity problems that result in regression analysis. Two factors had eigenvalues above 1. Variables loading most on the first included the number of oxen and draft animals, carts, and plows. Variables loading most heavily on the second were the number of bicycles, radios, and televisions. We termed the first factor *draft* and called the second *market information*. A separate variable for numbers of livestock owned, excluding poultry and other fowl, was also included.

Financial capital is measured by the number of years the household has received input subsidies for maize production. As reported by the hybrid maize growers we surveyed, FISP was the primary source of purchased inputs (fertilizer and seed). We consider the agricultural inputs support program (FSP/FISP) as the primary source of financial capital, although the membership in a registered farmers' cooperative which facilitates access to this program is also a major element of social capital. In the context of maize production and particularly use of improved maize seeds, associated fertilisers and other inputs such as herbicides, farmer cooperatives remain a life line for smallholder farmers.

More generally, we view social capital analysis from the perspective of the intensity of community based organizations to which the study populations in the three districts are affiliated. The Focus Group Discussions conducted by the research team (Hamazakaza et al. 2013) in the sites also pointed out the role that the external environment, and particularlynon-governmental organizations (NGOs), have played in terms of indirectly promoting hybrid maize production through conservation agriculture innovations since the early 2000s. The conservation agriculture innovations promoted by the NGOs (e.g., Zambia National Farmers Union (ZNFU), Conservation Farming Unit (CFU), Agriculture Support Programme (ASP), Plan International, World Vision International (WVI), etc.) used hybrid maize as a test crop and demonstrated the high yield potential of these varieties with appropriate cultural practices.

In addition to farmer cooperatives, households reported that their members were affiliated with women's clubs, NGOs, and commercial entities. Each of these may facilitate the access of their members to maize inputs, either directly through the organization or indirectly, through networking and informal exchange outside its formal structure. In view of the non-collateral nature of the maize input loans sought by the small-scale farmers, affiliation to these institutions is critical if they are to access inputs in time—especially among those farmers who are economically vulnerable.

We measured the intensity of social capital as the ratio of the total number of persons in sampled households who are members of any village association to the total number of persons sampled in the village. We interpret the variable as expressing the intensity of social capital in the villages surveyed, which is exogenous to the individual household.

District dummy variables reflect a number of important fixed factors, including the farming system and agroecology, or natural capital, as well as historical features related to settlement and language group, and density of market and services infrastructure. Availability of a high number of well-developed commercial farmers and a relatively well developed market and services infrastructure in Mkushi compared to Katete and Sinazongwe districts is a key variable that may to a great extent influence hybrid maize adoption in the district compared to the other two. Commercial farmers in Mkushi are engaged in hybrid maize seed production and, hence, their proximity to the survey areas may influence the uptake of hybrid maize uptake by the smallholder farmers.

In Katete, the cultural setting in terms of maize variety preferences is still very much inclined to the flint local maize types similar to the old improved variety bred in the U.S., Hickory King. Culturally the most common and preferred mode for maize meal processing involves on-farm pounding. In this context, farmers in Katete prefer the flint varieties which are more suitable for such a process as compared to the dent or semi-dent types which are more common among hybrids and better suited to industrial processing.

Sinazongwe district is typical of a drought prone district in Zambia where the Ministry of Agriculture in collaboration with ZARI and the International Maize and Wheat Improvement Center (CIMMYT) have promoted early-maturing maize varieties to escape drought spells during the cropping season. Most of the varieties in this category are IOPVs with flint-type or semi-dent grain texture. Infrastructure development is relatively poor in Sinazongwe, particularly the road and poorly developed market infrastructure.

Dependent variables include adoption, income and income diversity. Adoption is measured in two ways: 1) a binary variable measuring use (1) and non-use (0), and a continuous variable (kgs planted) which has zero observations when the binary variable is equal to zero.

Total income is the sum of all income from farm and non-farm income sources in the year (2010/11) preceding the survey, and has been logged because its distribution is highly skewed. As explained above, income diversity is measured by the Herfindahl index (income concentration) and the count of income sources (income richness). We also consider the shares of each of the 11 sources of income measured in the survey instrument. Total income is a continuous variable. The Herfindahl index ranges from 1/n to 1, with a large number of values at 1. Income richness ranges from 1 to 11. The shares are choice variables that are censored at zero; farm households may choose to grow or earn zero amounts from some sources. The structure of the dependent variables has ramifications for the regression methods we use to estimate the models, which are summarized next.

3.2.2. Livelihoods Impacts Model

The objective of our econometrics analysis is to examine the relationship between growing hybrid seed and household income, expressed in terms of total income, income shares, and diversity indicators. In this section, we describe the variables we used and econometric approaches.

The potential endogeneity of hybrid seed use in livelihood outcome regressions is a concern. If it is endogenous, then the unobserved error terms that affect hybrid seed use are correlated with those that affect livelihood outcomes, and a single-equation, ordinary least squares regression could produce biased coefficient estimates. The control function approach (CFA) can be used to test the endogeneity of an explanatory variable in a non-linear model. As in a two-stage instrumental variables model, the CFA requires an instrumental variable to be used in the first stage, reduced form estimation of seed subsidy receipt. The instrumental variable, which is not included in the second-stage estimation of the structural equation, should be correlated with receipt of the seed subsidy but not with the amount of hybrid seed planted when other covariates are considered, except via the seed subsidy. In the second stage, the structural model is estimated with the observed endogenous variable and the residual from the first stage (the estimated error term) as explanatory variables. The test of endogeneity is the statistical significance of the coefficient of the residual, estimated with bootstrapped standard errors. The control function approach is described in early work by Blundell and Smith (1989), further developed by Wooldridge (2010), and has been applied recently to analyses of fertilizer and seed subsidy receipt in Zambia by Mason and Ricker-Gilbert (forthcoming) and Smale and Mason (forthcoming). We use years of maize subsidy receipt as an instrumental variable.

To test the effects of growing hybrid seed on household livelihood outcomes while controlling for potential endogeneity, we applied two-stage, instrumental variables regression

(IV2SLS) for income and income richness (both continuous variables dependent variables), and the CFA for income concentration and all income shares (censored variables with both upper and lower limits). We also compared ordinary least squares (OLS) and Poisson regressions for the income richness outcome, but found them to be similar. In the IV2SLS case, the first stage regression was the binary variable predicting hybrid seed use and the instrumental variable was seed subsidy receipt, which affects income only through adoption. In the CFA approach, while the binary variable can be used to test for potential endogeneity, the residual of the probit regression cannot be used to control for endogeneity in the second stage. When a variable was found to be endogenous, the residual was estimated from a first stage regression with kgs of hybrid seed as the dependent variable.

Unlike in the CFA, the test for endogeneity is part of the procedure for estimating IV2SLS regression. Standard model diagnostics include tests of a) the relevance of the instrument set; b) homoskedasticity, and c) endogeneity of the adoption variable. Model diagnostics for (a) include i) the evaluation of the joint F-test for excluded instruments in the first stage regression; ii) the Sargantest for over-identifying restrictions; and iii) the Anderson correlation coefficient, which provides a test for the weakness (under-identification) of instruments. Rejection of the null hypotheses supports evidence that instruments are correlated with the endogenous regressor. Failure to reject the null hypothesis in the Sargantest indicates that the extra instrumental variables are exogenous in the structural equation. The Pagan-Hall test is employed for the null hypothesis of homoskedasticity (b). The null hypothesis of exogeneity is evaluated with a Wu-Hausman test.

In both instrumental variables approaches, failure to reject the null hypothesis of exogeneity results in single-equation estimation with the variable in question entered among other exogenous determinants.

4. RESULTS

In this section, we begin by using descriptive statistics to compare users and non-users (also referred to as adopters and non-adopters) of hybrid maize seed by components of the asset pentagon (human capital, natural capital, physical capital, financial capital and social capital). We also compare livelihood outcomes between average users and non-users of hybrid seed. In the second subsection, we present the findings of the regression analyses.

4.1. Descriptive Statistics

Nearly three-quarters (73%) of the 300 maize-growing households we surveyed planted hybrid seed in the 2010/11 cropping season (i.e., season preceding survey year). Hybrid maize growers planted an average of 19.9 kgs of seed.

Three-quarters (75%) of maize-growing households headed by men grew hybrid seed in the survey year, as compared to about two-thirds (64%) of those headed by women. Given our relatively small sample size (300 households), this difference was statistically significant only at 10% with a Pearson Chi-squared test. Mean household sizes were larger among adopters (7.22) than among non-adopters of hybrid maize seed, and the difference of means was statistically significant at 1% with a two-tailed t-test. In addition, hybrid maize growers are clearly better endowed in terms of the number of economically active, male adults who can provide labor resources (Table 3). There are no significant differences in household composition in terms of men or women over 60 years of age, adult women (16-59), or female children (under 16 years). Hybrid growers also have more male children. On the other hand, there is no meaningful or statistically significant difference in average age, literacy, or experience of the household head between households that grew and did not grow hybrid maize seed. Literacy rates do appear to have a meaningful difference between household heads who planted hybrid seed (27%) and those who did not (20%).

As expected, adopters are more well-endowed in terms of natural capital than non-adopters. Survey data confirm that the average total farm area to which hybrid maize growers had access was two times larger (10.5ha/household compared to 5.7ha/household) than that of farmers who did not plant hybrid maize seed in the survey seasons. Similarly, in terms of land utilisation for maize production, farmers who grew hybrids cultivated an average of 1.7ha, as compared to 0.9ha for those who did not in the 2010/11 season.

Table 3. Human Capital Characteristics of the Study Households, by Use of Maize Hybrids

	Planted hybrid		Did not plant hybrid		p-value
	Mean	Std. Error	Mean	Std. Error	
Age of household head (yrs.)	46.4	1.01	45.8	1.85	0.767
Experience as head (yrs.)	19.47	0.94	19.72	1.88	.898
Literacy (yes=1, no=0)	0.27	0.0298	0.198	0.0445	0.216
Number of male adults (16-59 yrs.)	1.48	0.09	1.04	0.11	.006
Household size	7.22	0.27	5.83	0.37	.005

Source: Authors. P-values refer to two-tailed t-tests.

Both differences are statistically significant at less than 5%, despite the large variation in the sample. Kolmogorov-Smirnov tests also confirm statistically significant differences, and that farm sizes are smaller for non-adopters across the full range of values for the two groups.

Physical assets facilitate crop production, and as noted long ago in the study by Kumar (1994), ownership of oxen, ploughs, and carts are strongly associated with use of inputs such as improved seed and fertilizer. Overall, the comparison of asset endowments confirms that maize growers who plant hybrid seed tend to be significantly better-endowed in terms of most types of physical assets than are maize farmers who do not use hybrid seed (Table 4).They are more likely to own bicycles, televisions, and radios, in addition to productive assets such as oxen and oxcarts. One-third of hybrid maize growers (33.5%) and only 23.5% of non-hybrid growers owned at least one pair of oxen. Statistically, significant differences were not apparent for tractor ploughs or cultivators.

Turning to financial capital, survey data indicate that 59% of the all 300 farmers surveyed have received input support at one time or another, and 41% had never received input support.

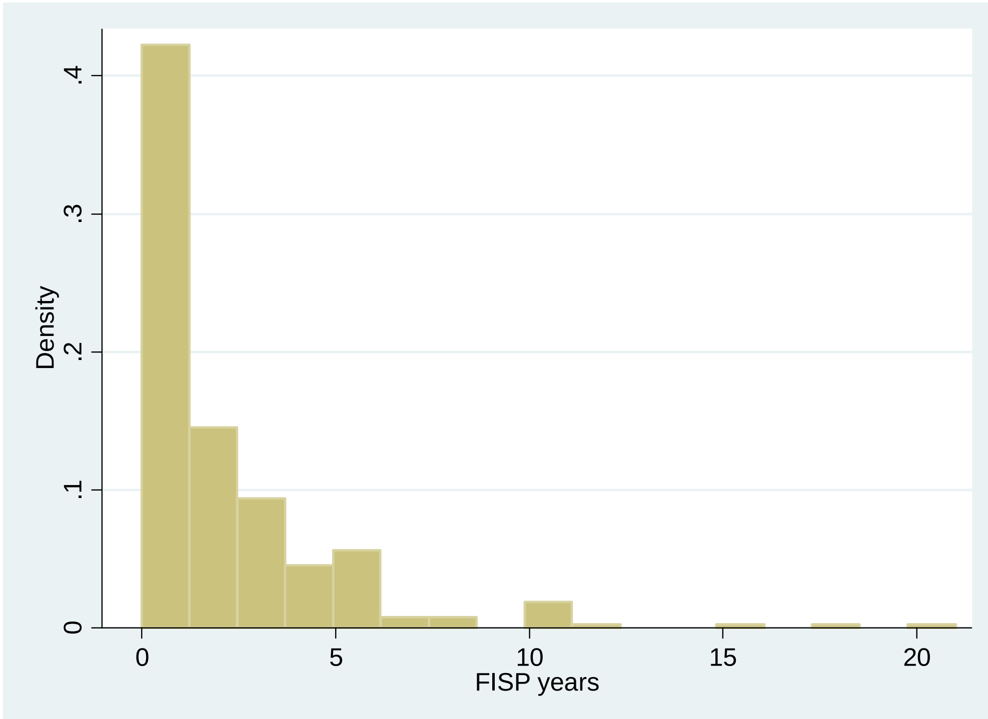
The distribution of the total number of years the households surveyed have received input support for maize production shows a high density around two years (Figure 2). The histogram also displays a steady decline in number of years for households that have received support from FISP above two years. Outlier values above 10 years (five observations) referred to sources of free or subsidized seed outside the FISP. In terms of hybrid maize production and variety adoption, these findings support the assertion that most farm households have not consistently received FISP support over the past decade.

Table 4. Physical Capital Characteristics of the Study Households (Numbers Owned), by Use of Maize Hybrids

Number of units		Planted hybrid	Did not plant hybrid	t-test (p-value)
Bicycle	Mean	0.945	0.617	
	Std. Error Mean	0.050	0.0757	0.001
Television	Mean	0.269	0.037	
	Std. Error Mean	0.039	0.0211	0.000
Radio	Mean	0.777	0.395	
	Std. Error Mean	0.047	0.057	0.000
Cultivator	Mean	0.059	0.0123	
	Std. Error Mean	0.018	0.0123	0.134
Tractor plough	Mean	0.0182	0.00907	
	Std. Error Mean	0.0123	0.0123	0.723
Oxen	Mean	0.579	0.0678	
	Std. Error Mean	0.296	0.0644	0.018
Donkeys	Mean	0.505	0.0571	
	Std. Error Mean	0.321	0.0604	0.070
Oxcart	Mean	0.136	0.0249	
	Std. Error Mean	0.0370	0.0275	0.026

Source: Authors.

Figure 2. Sample Distribution of Number of Years Household Has Received FISP Support



Source: Authors.

In view of the economic vulnerability of the smallholder farmers in Zambia, the low number of years of FISP support for the vast majority of farmers suggests that many households have not only benefited inconsistently but may have also grown hybrid seed irregularly.

There is clearly some path-dependence in hybrid seed use that is related to benefiting from FISP. Among the FISP beneficiaries who have received FISP over the last 10 years, 18.6% reported as having only benefited from the programme once. About one-third (30.5%) have received FISP support in two seasons, and approximately one-fifth (19.8%) have benefited in three seasons. Three-quarters (74%) of farmers who grew hybrid maize in 2010/11 had received input support at one time or another, as compared to only 17% of those who did not plant hybrid maize in that season. Hybrid maize growers in 2010/11 had benefited from FISP support for an average of 2.67 years, as compared to only 0.272 years among farmers who did not. This difference was highly significant (1%).

As shown in Table 5 below, it is evident that nearly two-thirds of farmers surveyed who grew maize hybrids in 2010/11 (65.2%) were members of farmer cooperatives. A total of 242 individuals among the sampled households were affiliated to the different institutions at community level that offer input support to crop production including maize. However, farmers who did not plant hybrids were also more likely not to be affiliated with any club related to agricultural activities (61.7%, as compared to only 18%).

Table 6 below summarizes the parameters we used to measure the intensity of social capital. Based on the sample data, we estimate that 11.8% of the population is affiliated to some form of agricultural, community-based organisation.

Table 5. Household Institutional Affiliation, by use of Maize Hybrids

	Did not plant hybrid		Planted hybrid	
	count	%	count	%
Farmer cooperative	15	18.5	144	65.2
Women club	8	9.9	20	9.1
NGO affiliated	4	4.9	16	7.2
Commercial entity	4	4.9	1	0.5
Not affiliated to any club	50	61.7	40	18.1
Total	**81**	**100**	**221**	**100**

Source: Authors.

Table 6. Proportion of Households Affiliated to Agricultural Organizations in Sample Parameters

	Total
Total estimated sampled households in survey areas	300
Total sample population	2,053
Number of household members affiliated to farmer organizations in sample	242
Intensity measurement	0.1179

Source: Authors.

In terms of livelihood outcomes, the major income sources at household level in the year preceding (2010/11) the survey period comprised of maize grain sales, cotton sales, groundnut sales, petty trading, piecework, fruits and vegetable sales, livestock sales, remittances, other crop sales, self-employment, and other sources. Out of the eleven major income sources, maize remains the most important source of income among the hybrid maize seed growers whose annual average income from maize grain sales in 2010/11 season was the Zambia Kwacha (ZMK)2,679,791 compared to only ZMK33,599 for non-hybrid maize growers (Table 7). The mean total household income for the preceding year was nearly five times as high among hybrid maize growers (5,359,452 ZMK) compared to farmers who grew no hybrid maize in that season (1,129,574 ZMK). The independent samples test of the difference in average total annual income between hybrid maize growers and the non-growers leads us to reject the null hypothesis that the means for annual income are equal for the two farmer categories at less than 1%, with unequal variances. Horticultural income, income from livestock and groundnuts, as well as income from remittances and self-employment were also significantly different, and higher, among farmers who planted hybrid maize. It is noteworthy that these sources of income would not be expected to be correlated with maize income. Pearson correlation coefficients are significant only between horticultural income and maize income. This finding supports the hypothesis that hybrid maize growers have not only more diversified income sources, but these provide more resilience to shocks from any single source.

Table 7. Annual Household Income by Source, 2010/11 Season (ZMK)

Income Sources	Planted hybrids		Did not plant hybrids		Significance	
	Mean	Std. Error Mean	Mean	Std. Error Mean	F (variance)	t test (difference of means)
Maize Grain Sales	2,679,791	1,488,946	33,599	14,232	0.099	0.077
Horticultural products	609,415	113,519	106,667	32,609	0.000	0.000
Cotton Sales	298,452	72,004	327,350	135,868	0.896	0.842
Livestock products	304,283	83,765	87,469	27,342	0.005	0.015
Groundnut Sales	25,177	8,519	4,875	3,014	0.006	0.025
Remittances	83,670	28,499	25,625	10,747	0.022	0.058
Other Crop Sales	113,909	27,181	69,074	32,696	0.172	0.361
Self Employment	450,324	117,371	61,325	29,480	0.000	0.001
Petty Trading	243,545	100,028	159,321	77,815	0.305	0.624
Other sources	169,132	60,520	72,469	29,834	0.067	0.340
Paid Employment	429,595	140,439	189,247	65,583	0.045	0.307
Total Income	5,359,452	1,528,407	1,129,574	1,743,289	0.057	0.008

Source: Authors.

We also conducted a two-sample Kolmogorov–Smirnov test to determine if there are any differences in the underlying distribution of income between hybrid maize and non-hybrid growers. The Kolmogorov-Smirnov test of equality of distributions (Table 8) shows that the distribution of total income for non-growers is significantly lower across the full range of values than that of hybrid growers at a significance level of 1%.

With respect to our diversity indicators, the counts over numbers of crop and livestock activities were not significantly different between the hybrid and non-hybrid maize growers. Mean values of the richness of crop activities were almost the same (1.96 and 1.94), as were numbers of livestock activities, which corresponds to number of types reared (1.31 and 1.15) for farmers who planted hybrid maize and those who did not, respectively. Clearly, these are low values overall. However, the counts over all farm and non-farm income sources were statistically different between the two groups of maize growers. Statistically, the analysis shows significant differences in the count of all farm and non-farm activities between hybrid and non-hybrid maize growers with a P-value of 0.0031. Those who planted hybrid maize pursued an average of 2.33 of the 11 activities reported, as compared to only 1.81 among those who did not.

In Table 9 below, the Herfindahl indices of 0.671 and 0.733 for hybrid and non-hybrid maize growers respectively suggest poorly distributed income sources for either group, and as a consequence, some vulnerability to income risk. In our study, the index ranges from the inverse of the number of income sources (0.09) to 1. If two sources of income represented the same share, the index would be equal to 0.5. An index above 0.25 is considered to be high in studies of collusion in U.S. industries. The P-value of 0.0569 confirms statistical differences between the two farmer groups, with higher concentration of income among non-hybrid growers.

Maize contributes the largest percentage (26%) of income at household levels followed by horticultural products (21.4%) and piecework at 10.5%. However, among the non-hybrid maize growers, piecework contributed the highest share (23.3%) to household income. Other important income sources based on their share contribution to household income were horticultural products (15.7%), petty trade (11.4%), cotton (10.6%), and livestock (9.8%). Statistically, there were significant statistical differences in income share contributions between hybrid and non-hybrid maize growers for piecework and maize grain income sources at 95% confidence level.

Table 8. Two-sample Kolmogorov-Smirnov Test for Distribution of Total Annual Income, by Use of Maize Hybrids

Smaller group	Did not plant hybrid	Planted hybrid	Combined K-S
D	0.4271	0.0000	0.4271
P-value	0.0000	1.000	0.000
Corrected			0.000

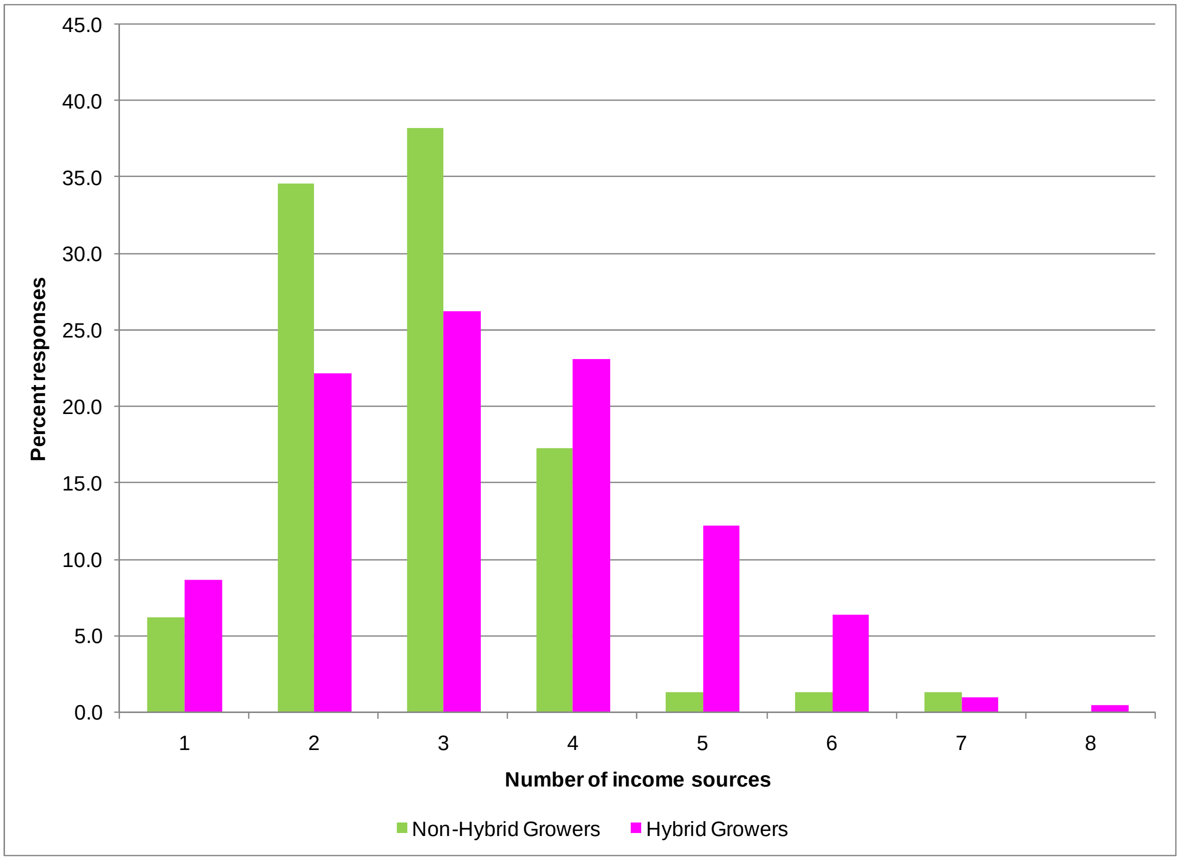
Source: Authors, based on survey data.

Table 9. Diversity of Income Sources, by Use of Maize Hybrids

Indicator of income diversity		Planted hybrid	Did not plant hybrid	t-test of difference of means (P Values)
Richness				
Count of crop activities	Mean	1.963801	1.938272	
	Std. Error Mean	0.0532201	0.0792435	0.7990
Count of livestock activities	Mean	1.307692	1.148148	
	Std. Error Mean	0.0649458	0.0995532	0.1958
Count of all farm and non-farm activities	Mean	2.330317	1.814815	
	Std. Error Mean	0.0954419	0.1166814	0.0031
Concentration				
Herfindahl	Mean	0.6709042	0.7334045	
	Std. Error Mean	0.0170443	0.0275224	0.0569
Shares				
Maize	Mean	0.2596266	0.0422066	
	Std. Error Mean	0.0235999	0.0183553	0.0000
Horticulture	Mean	0.2143219	0.1565282	
	Std. Error Mean	0.0241818	0.0354094	0.2029
Cotton	Mean	0.0628614	0.1058356	
	Std. Error Mean	0.0141297	0.0288185	0.1410
Livestock	Mean	0.0713701	0.097664	
	Std. Error Mean	0.0137979	0.02752	0.3520
Groundnuts	Mean	0.0107356	0.0073636	
	Std. Error Mean	0.0031586	0.0051108	0.5783
Other crops	Mean	0.0406516	0.032016	
	Std. Error Mean	0.0080702	0.0158169	0.5988
Self-employment	Mean	0.0744928	0.0674083	
	Std. Error Mean	0.0172658	0.0256726	0.8273
Petty trade	Mean	0.0641227	0.1143982	
	Std. Error Mean	0.0142034	0.032029	0.0994
Piecework	Mean	0.1053098	0.2332927	
	Std. Error Mean	0.018494	0.0451142	0.0020
Remittances	Mean	0.0440287	0.0660562	
	Std. Error Mean	0.0115229	0.0269717	0.3800
	Mean	0.0524789	0.0772306	
Other income sources	Std. Error Mean	0.132942	0.0289025	0.3783

Source: Authors, based on survey data.

Figure 3. Richness of Income Sources by Farmer Type



Source: Authors, based on survey data.

Figure 3 shows higher income diversity among hybrid maize growers with a significant number realizing income from more than three sources. Generally, the spread of income sources was more normally distributed among hybrid grower maize growers compared to non-growers who were more limited to four sources or fewer.

4.2. Econometric Results

First-stage regression results, which depict the adoption decision, are shown in Table 10. Coefficients are marginal effects (average partial effects), and standard errors are adjusted for village clusters.

The effect of years receiving the subsidy is strong in the decision to use hybrids, reflecting the limited financial capabilities of many smallholder maize growers and some path-dependence in use. Male headship bears little relation to whether hybrid seed is grown. Relative to Sinazongwe, district effects are strongly negative for Katete in the adoption decision, but positive for Mkushi. Farmers in Mkushi have easy access to hybrid seed due to their proximity to commercial farms; those in Katete are known to prefer local maize types because of their consumption preferences. Access to market information is important. Sex of household head, draft power, farm size, and adult male labor are statistically insignificant in the decision to plant hybrids (although they are significant in regressions of quantities planted, because they are related to scale).

Table 10. First-stage Probit Regression Explaining Hybrid Seed Use

	Marginal effects	Robust Std. Err.	P>z
Subsidy years	0.155	0.0217	0.000
Sex of household head	0.0843	0.0586	0.151
Active male adults	0.0000912	0.0180	0.996
Literacy	0.139	0.0376	0.000
Draft	0.00921	0.0352	0.793
Market information	0.0501	0.0229	0.028
Katete	-0.2095	0.0598	0.000
Mkushi	0.132	0.0745	0.076
Farm size	-0.00338	0.00533	0.526
Farm size squared	0.0000209	0.0000486	0.667
Livestock	0.00849	0.00340	0.013
Social intensity	0.587	0.520	0.260
Log pseudo likelihood = -97.936			
Wald chi2(12) = 71.49			
Prob > chi2 = 0.0000			
Pseudo R2 = 0.434			
Adj. Standard errors (33 village clusters)			

Source: Authors.

Numbers of livestock owned, on the other hand, figure strongly in the use of hybrid seed. As hypothesized, literacy is strongly and positively related to the decision to use hybrids, but the intensity of social capital in a village is not statistically significant. It is noteworthy that the number of years receiving the subsidy has the largest positive effect in terms of magnitude, and location in Katete, the largest negative effect.

Diagnostic tests for the instrumental variables regression of hybrid seed use and income result in strong support for the instrumental variable, years of subsidy receipt (F value significance of 0.000 for the instrument and Chi-squared significance of 0.000 for the Anderson canon. corr. statistic). We failed to reject the hypothesis that growing hybrid seed is exogenous in household income (Wu-Hausman F-statistic with p-value= 0.89254). We found similar results for concentration and richness of income sources.

Hybrid seed use has a strong effect on the value of household income, raising it by an average of 64% (Table 11).Other factors with positive effects on household income are access to draft animals, agricultural implements, and market information. Unexpectedly, literacy is negatively associated with total income when other factors are considered. Male headship and the number of active male adults are weakly but positively associated with total household income. Relative to Sinazongwe, other factors held constant, households in Katete appear to have earned less income in the year preceding the survey. Farm size in and of itself is of no statistical significance in explaining income variation, and nor is the number of livestock owned.

Table 11. OLS and Tobit Regressions Effects of Hybrid Seed Use on Income and Income Diversity

	Income (ln) (OLS)			Richness (OLS)			Concentration (Tobit)		
	Coef.	Robust Std. Err.	P>t	Coef.	Robust Std. Err.	P>t	Marginal Effects	Robust Std. Err.	P>t
Grow hybrid	0.644	0.181	0.001	0.083	0.148	0.580	0.00721	0.0480	0.881
Sex of household head	0.407	0.246	0.107	0.291	0.166	0.088	-0.0518	0.0544	0.342
Active male adults	0.108	0.064	0.098	0.016	0.049	0.739	0.00252	0.0116	0.829
Literacy	-0.298	0.147	0.051	0.202	0.181	0.273	0.00144	0.00145	0.322
Draft	0.263	0.0794	0.002	-0.0528	0.102	0.611	0.0224	0.0235	0.341
Market information	0.367	0.0659	0.000	0.0182	0.0857	0.833	0.00685	0.0181	0.706
Katete	-0.992	0.305	0.003	-0.417	0.339	0.228	-0.00476	0.101	0.963
Mkushi	-0.0110	0.242	0.964	1.09	0.320	0.002	-0.278	0.0657	0.000
Farm size	0.00183	0.00590	0.759	-0.00470	0.0101	0.644	-0.000438	0.0014704	0.766
Farm size squared	-0.0000241	0.0000346	0.492	0.0000158	0.0000522	0.765	0.00000755	0.00000767	0.326
Livestock	0.0107	0.0107	0.325	0.0355	0.0104	0.002	-0.00703	0.00178	0.000
Social intensity	1.62	1.94	0.410	-3.68	1.73	0.042	1.57	0.392	0.000
Constant	13.3	0.403	0.000	1.85	0.258	0.000	0.713	0.0750	0.000
F(12, 32) = 24.11, Prob > F=0				F(12, 32) =7.17, Prob> F=0.0000			F(12, 229) = 7.37, Prob > F=0		
R-squared = 0.41				R-squared = 0.28			Pseudo R-squared = 0.24		

Source: Authors.

However, we found that hybrid seed use was not a statistically significant factor in either of the income diversity regressions. Few variables are statistically significant in our income diversity regressions, with the exception of district effects, which reflect farming system characteristics. Location in Mkushi is positively related to richness, and negatively related to concentration among income sources, compared to farming in Sinazongwe. Livestock owned is associated positively with richness, counteracting concentration among income shares; village social intensity demonstrates the opposite effects.

We then added the diversity indexes as explanatory variables to test the relationship between income diversification and income levels, controlling for other explanatory variables. In the interests of space, these regressions are not shown here. Because these are metrics constructed over choice variables, rather than choice variables themselves, they can be treated as exogenous determinants of total income values. A major finding is the more diverse the income sources, in terms of richness and evenness, the higher the total value of household income among maize-growing smallholders.

Share regressions showing significant effects of hybrid seed use are shown in Table 12 and include only maize, horticulture, cotton, and piecework. Hybrid seed use was not a significant factor in groundnut, livestock, remittance, self-employed, salaried, petty trade income, other crop or other non-farm income sources.

The statistical significance of the residual from the first-stage regression explaining hybrid maize use attests to its endogeneity in maize income share. To control for endogeneity in the maize share regression, following Wooldridge (2010), the kgs of hybrid seed planted was used as the dependent variable in the reduced form, first-stage regression, which included the maize seed subsidy receipt as an instrument. The residual from that regression was added as an explanatory variable in the second-stage, structural regression. Findings suggest that each additional kg of hybrid seed increases the maize sales share of total household income by 0.8 percentage points (maize share ranges from 0 to 1). The only other significant variables in the regression are male headship, which reduces the maize share, and location in Mkushi, which raises the average share by 38 percentage points. In other words, female-headed maize-growing households rely more heavily on maize for income than do male-headed households.

With respect to other crops, however, there is no statistical support of endogeneity, and regressions were re-estimated without residuals. Using maize hybrids is positively associated with household income shares from horticultural crops (30%), but negatively related to cotton income shares (19%). Farm households growing hybrid maize also have lower income shares from piece work, suggesting that their labor is more systematically allocated to farm and non-farm tasks. Piece work is typically associated with households that have fewer resources, and must sell their labor to meet daily needs and cope with unforeseen circumstances.

In these regressions, as in the maize share regression, few of the other explanatory variables are statistically significant. Nonetheless, these are worth noting. For example, access to draft power and ownership of livestock are negatively associated with the share of horticultural sales in total household income, suggesting that farmers with these assets grow field crops and sell livestock products instead of producing vegetables, which is relatively labor-intensive and requires more marketing arrangements, so that market information is also a significant covariate. Other factors held constant, households with access to larger landholdings can easily add this activity to their other income-earning activities. Male headship is strongly associated with the importance of cotton sales in total household income. Location in Mkushi, relative to Sinazongwe, has a negative influence, conforming to farming systems.

Table 12. Effects of Growing Hybrid Maize on Income Shares from Maize, Horticulture, Cotton, and Piecework

	Maize share*			Horticulture share			Cotton share			Piecework share		
	APE	Robust Std. Err.	P>t	APE	Robust Std. Err.	P>t	APE	Robust Std. Err.	P>t	APE	Robust Std. Err.	P>t
Grow hybrid seed	0.0088	2.6700	0.006	0.3035	0.1289	0.0190	-0.1911	0.1178	0.1060	-0.3466	0.1348	0.0110
Residual	-0.0187	0.0096	0.053									
Sex of household head	-0.2776	0.1068	0.009	0.1247	0.1004	0.2160	0.5290	0.1192	0.0000	0.1330	0.1758	0.4500
Active male adults	-0.0365	0.0376	0.332	-0.0074	0.0288	0.7980	-0.0560	0.0461	0.2250	0.0038	0.0424	0.9280
Literacy	-0.1354	0.1059	0.201	0.0010	0.0032	0.7460	-0.0019	0.0064	0.7650	-0.0077	0.0042	0.0680
Draft	-0.1044	0.0913	0.253	-0.1028	0.0349	0.0040	-0.0305	0.0809	0.7070	0.1017	0.0708	0.1520
Market information	-0.0582	0.0602	0.334	-0.1022	0.0406	0.0130	-0.1142	0.0827	0.1690	0.0563	0.0627	0.3700
Katete	-0.1513	0.1308	0.247	0.2384	0.1644	0.1480	0.0720	0.4412	0.8710	0.0764	0.2359	0.7460
Mkushi	0.3836	0.1621	0.018	0.0434	0.1293	0.7370	-0.9532	0.4764	0.0470	0.0036	0.2613	0.9890
Farm size	-0.0043	0.0030	0.153	0.0075	0.0044	0.0870	0.1516	0.0358	0.0000	-0.0165	0.0126	0.1940
Farm size squared	0.0000	0.0000	0.202	0.0000	0.0000	0.1640	-0.0048	0.0014	0.0010	0.0000	0.0001	0.9330
Livestock	-0.0041	0.0050	0.415	0.0083	0.0037	0.0240	0.0191	0.0054	0.0000	-0.0088	0.0100	0.3810
Social intensity	-0.0496	0.6113	0.935	-0.0723	1.3063	0.9560	-0.2196	2.2531	0.9220	0.5045	1.7696	0.7760

Maize share*	Horticulture share	Cotton share	Piecework share
F(13, 228)= 23.62	F(12, 229) = 3.88	F(12, 229) = 18.45	F(12, 229) = 2.80
Prob > F = 0.0000	Prob > F = 0.0000	Prob > F = 0.0000	Prob > F = 0.0014
Log pseudo likelihood=-136.05	Log pseudo likelihood = -167.25	Log pseudo likelihood = -85.60	Log pseudo likelihood = -152.11
Pseudo R2=0.2703	Pseudo R2 = 0.0682	Pseudo R2 = 0.2352	Pseudo R2 = 0.0782

St. Errors adjusted for village cluster

Source: Authors. *Hybrid seed use is endogenous only in the maize share equation, and the explanatory variable in the structural equation is kgs of hybrid seed use. In all other equations, the explanatory variable is binary.

Farm size affects the share of this cash crop positively, as does livestock ownership. The only other factor that is statistically significant in the piecework regression is literacy. The more likely it is that the household head is literate, the lower the share of household income earned through piecework because the head has better access to other productive resources.

5. CONCLUSION

In this study, we have employed a combination of descriptive statistics and econometrics to explore the relationship of hybrid seed use and livelihoods among smallholder maize growers in three districts of the major maize-producing provinces of Zambia. We have considered livelihood outcomes in terms of overall household income and the diversity of income sources, defined in terms of the richness (count) of source and evenness (Herfindahl index, which measures concentration) of income shares. We also examined the effect of hybrid seed use on the income shares for each category of income.

The conceptual framework that guided our choice of explanatory variables in the econometric model is the livelihoods framework, and particularly the asset pentagon. We employed factor analysis to condense a range of asset variables into fewer explanatory variables. We estimated a double hurdle adoption model, testing it against the Tobit alternative, and tested for the endogeneity of the number of years receiving a seed subsidy in hybrid seed use. We then tested the effects of hybrid seed use on livelihood outcomes.

The Fertilizer Input Support Programme has played a key role in hybrid maize variety adoption in the last decade (2002/03 – 2011/12). The FISP positive influences in terms of increased adoption rate for the improved hybrid maize seed has had far reaching impacts in terms of improving the household livelihoods as maize is and remains predominantly the major source of income among the smallholder farmers in Zambia. Over half of farmers surveyed had received input support at one time or another, but the average was only two years and a mere 10% received the subsidy in the survey year.

However, regardless of the subsidy, use rates are high for hybrid seed in the three districts of study, including nearly three-quarters of smallholders maize growers. Controlling for other factors, we find that subsidy receipt is strongly related to whether or not a farmer grows hybrid seed, but not to the amount planted. Factors that determine are generally distinct from those that determine the kg of hybrid seed planted, suggesting that the underlying decision-making processes may be different. Interestingly, male headship is an insignificant factor, although the number of active male adults is more significant in the scale of hybrid seed grown. District effects and market information are significant in both. Draft power and farm size are important for the scale of planting, while livestock ownership and literacy are key in whether the household grows hybrid seed or not.

Among human capital characteristics we measured, only the number of active male adults and household size differed significantly between farmers who planted and did not plant hybrid seed. Major differences were apparent in terms of most types of physical capital, and financial capital, which we measured in terms of participation in the FISP program. Non-hybrid growers were not only far less likely to be a member of a farmer cooperative, but far less likely to be affiliated with any agriculturally-related club in the village at all.

In terms of livelihood outcomes, indices of crop and livestock enterprise diversification are not significantly different between the hybrid maize users and non-users at the mean, but differences in the total count of activities and the concentration among income shares are highly significant. The value of annual income is significantly different between the two groups for maize, horticulture, groundnuts, remittances, and self-employment. Among these other sources of income, only horticultural income is strongly associated with maize income—suggesting that hybrid maize growers have more sources of non-covarying income, making them potentially more resilience to income shocks from any single source. As expected, maize income shares are several times greater for hybrid maize growers. At the mean, only the share from piecework is higher among farmers who did not plant hybrid seed. Overall, non-hybrid maize users show more vulnerability with regard to livelihoods. This could be attributed to the limited diversification of combined farm and non-farm related income sources compared to hybrid maize seed users.

Growing hybrid maize seed is associated with total household incomes that are 64% higher, although it is not a significant factor in either regression predicting the diversity of income sources. On the other hand, when we enter these indices as explanatory variables in the income regression, the concentration among income shares reduces total household income and richness increases it. Controlling for other factors, hybrid seed use is of major significance in explaining income shares from maize, horticulture, cotton, and piecework. Female headship strongly reduces the share of income earned from maize, while location in Mkushi augments it. As expected, piecework and income shares from maize are negatively related, as are cotton and maize shares. Income shares from horticulture and maize are associated positively.

6. POLICY IMPLICATIONS

Survey findings confirm that maize production still remains the most important enterprise in terms of income generation for the smallholder farmers in agro-ecological regions I and II of Zambia. This dependency on one major crop for household income, which is further dependent on government support in terms of input subsidies, places smallholder households in a very vulnerable situation. Diversification of income sources that do not co-vary is a potential means of reducing income risk about smallholder farmers. Not all smallholder farmers are en route to becoming full-time, commercial farmers. Income diversification can also ease the transition out of agriculture into other occupations.

There is no doubt that hybrid maize growers are among the relatively advantaged, and that the input subsidy program has improved access to hybrid seed among smallholder farmers in Zambia. However, years of subsidy receipt may have contributed to growing disparities between farmers who are repeatedly included in the program and those who are not. This is a subject for further, careful, research using mixed qualitative and quantitative methods. Strengthening farmer cooperatives is key in terms of facilitating farmer access to government supported input support programmes, but other forms of social capital should be encouraged in order to broaden mechanisms for inclusion in income-generating activities.

The design of the FISP pack, particularly choice selection, should take into account the prevailing farming systems for a particular region. The adoption of the improved varieties being promoted and distributed through the input support programmes is highly influenced by the farmer variety preferences in a region. Crop, as well as variety diversification, should be promoted as a potentially beneficial strategy to support farmer livelihoods.

Farmer support should go beyond just seed and fertilizer support if at all such inputs are to contribute to the household livelihood improvement in the long term. The effective utilization of inputs such as fertilizers and seeds is strongly associated with the asset endowments of farmers in terms of agricultural implements.

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