The Strategic Value of Crop Diversification in Zambia

by

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B.S., The University of Zambia, 2011
M.S., Kansas State University, 2016

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

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Abstract

This study examines the profitability of crop diversification in Sub-Saharan Africa. Crop diversification means growing different crops or using different cropping systems. It has been shown to provide risk management advantages and to lead to cost reduction in the presence of scope economies. Some countries and economic development organizations are, therefore, promoting crop diversification. However, crop diversification has been shown to be associated with a reduction in productivity and profitability due to foregone efficiency benefits from economies of scale. As a result, some countries, such as Rwanda, have adopted crop specialization policies.

In examining the effects of crop diversification on farm performance, previous research has employed various indices to quantify diversification. These indices are based on the number of crops grown and their relative abundance. Although the indices provide a good aggregate measure of diversification, they also assume homogeneity in diversification strategies among farmers who have the same number and relative abundance of crops even though the crops grown may be different. Using indices, therefore, ignores differences in economies of scope among heterogeneous or homogeneous crop combinations and their related profitability. It would seem that prior research has not explored the issue of crop diversification adequately because of crop diversification's definitional constraints.

Against this backdrop, the research problem that this study seeks to address is premised on the fact that different crop combinations may be associated with different performance outcomes. Therefore, this study recognizes diversification not in number of crops, but the types of crops in a farmer's production 'portfolio'. We call these portfolios farm enterprise structures. An enterprise structure is a combination of unique crop enterprises that make up the farm. The specific research question that the study addresses is: To what extent do enterprise structures influence profitability? The main objective of the study is to identify combinations of enterprise structures and their related profitability. Differences in enterprise structure profitability could improve our

understanding of existing cropping patterns and help to identify ways of strategically design enterprise structures to achieve higher profitability given farmer's realities.

We use secondary data from Zambia's 2015 Rural Agricultural Livelihood Survey (RALS). RALS is a country-wide survey of agricultural producers with a sample size of 7,934 randomly selected households. We utilize the Gaussian/Ordinary Least Squares (OLS) regression model to test the significance of the effect associated with adopting different enterprise structures, and to examine their contributions to profitability.

The results show statistically significant differences in demographic, socio-economic and production characteristics among farmers pursuing different enterprise structures. The results also show regional variations in the distribution and profitability of enterprise structures. This is understandable because of differences in regional agro-ecological conditions. The results further show that enterprise structures significantly influence profitability to varying degrees, suggesting that some crop portfolios may have higher profitability than others even though they may have the same number of crops. Diversification recommendations based on enterprise structures are, therefore, likely to be more effective than those based on indices.

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Dedication

To Chansa, Ufya and Towani. For the love and support you have given me during my PhD journey.

Chapter 1: Introduction

1.1 Background

This study examines the profitability of crop diversification in Sub-Saharan Africa (SSA). Crop diversification has been used to mean growing different crops or using different cropping systems (Fowler and Mooney 1990). It has been shown to provide several benefits for farmers. It can reduce income uncertainty (Guvele 2001), increase yield stability (Makate et al. 2016), lead to cost reduction in the presence of scope economies (Rahman 2009a), increase incomes (Pingali and Rosegrant 1995; Van den Berg et al. 2007; Arslan et al. 2018), bring about nutritional diversity (Lin 2011) and reduce the likelihood of being poor (Michler and Josephson 2017). It has also been shown to bring more spatial and temporal biodiversity on the farm (Makate et al. 2016), improve soil fertility as well as control for pests and diseases (Lin 2011). As such, crop diversification is being promoted as a climate smart agricultural strategy (Rahman 2009; Maggio, Sitko, and Ignaciuk 2018; FAO 2018; Renard and Tilman 2019; IPCC 2019). Climate smart agriculture (CSA) is an integrated approach for addressing the interlinked challenges of food security and climate change with the aim of increasing productivity, enhancing resilience and reducing emissions (World Bank, 2017).

Countries and multilateral development organizations are making investments in crop diversification as a CSA technique. For example, eight out of the 31 SSA countries that have submitted National Adaptation Programs of Action (NAPA) to the United Nations Framework Convention on Climate Change (UNFCCC) have projects dedicated to promoting crop diversification (Giuseppe, Sitko, and Ignaciuk 2018). The World Bank is also supporting projects such as the US$61.40 million Agricultural Productivity and Diversification project (PADA) in Benin aimed at promoting crop diversification (World Bank 2019b). In 2018, the World Bank doubled its investment on climate adaption (World

Bank 2018; Reuters 2018). Part of this investment will go towards the financing of climate-smart agricultural techniques like crop diversification in 20 countries (World Bank 2018).

Policy discourse on crop diversification has also been of interest in the international development community. The Food and Agriculture Organization (FAO) has programs dedicated to supporting countries with evidence-based policy advice on climate-smart agricultural techniques, like crop diversification. In 2019, World Bank Africa, the International Center for Tropical Agriculture (CIAT), FAO and the Indaba Agricultural Policy Research Institute (IAPRI) collaborated to produce a report entitled Productive Diversification in African Agriculture and its Effects on Resilience and Nutrition (PRODIVA). One of the goals of PRODIVA was to provide policy direction on the use of crop diversification for improving resilience outcomes. The latest report from the Intergovernmental Panel on Climate Change also emphasizes land-use strategies like crop diversification for climate change adaptation (IPCC 2019).

Despite its stated advantages and support emanating therefrom, crop diversification has been shown to be associated with lower profitability and productivity compared to specialization (Blank 1990 Chavas 2004; Ross et al. 2016). As farmers increasingly distribute their physical, human and management resources across more crop enterprises, they forego economies of scale benefits from specialization (White and Irwin 1972; Purdy, Langemeier, and Featherstone 1997; Ignaciuk et al. 2018). Specialization allows farmers to adopt production practices that reflect their comparative advantage more closely leading to higher productivity and profitability (Ricardo 1821; Kurosaki 2003). Because of the disadvantages of diversification, some scholars have argued that diversification at landscape level (community, regional or national level) may provide superior outcomes to farm-level crop diversification (Kahane et al. 2013; Klasen et al.2016; World Bank 2019a). The basis of this argument is that diversification at the landscape level allows farmers to reap the economies of scale benefits from specializing while affording their communities access to a diversified food supply, income streams and employment opportunities required for nutrition, resilience and higher incomes (World Bank 2019a).

The disadvantages of diversification have also prompted some countries, such as Rwanda, to implement policies aimed at promoting farm level specialization (GoR, 2005). Rwanda's Land Use Consolidation policy (LUC) requires farmers to grow a single priority crop that has been identified by the country's Ministry of Agriculture based on local growing conditions (GoR, 2005; Nyamulinda et al. 2014). The rationale of the LUC policy is that farm and regional crop specialization will provide economies of scale resulting in overall improved efficiency and sustainability (Nyamulinda et al. 2014). Zimbabwe and Benin are other SSA countries that have decided to promote crop diversification at a regional and national level (Zimbabwe Ministry of Agriculture 2012; ZEF, FARA, and INRAB 2017).

Given the bifurcated policy directions on crop diversification, how may policymakers and farmers make decisions about diversification? In an effort to address this question, previous research has tried to examine the impact of crop diversification on farm performance outcomes. Performance outcomes have included production efficiency (Llewelyn and Williams 1996; Coelli and Fleming 2004; Haji 2006; Rahman 2009; Manjunatha et al. 2013), risk management (Smale et al. 1998; Di Falco and Chavas 2009;Just and Candler 1985; Maggio, Sitko, and Ignaciuk 2018; Arslan et al. 2018) and income or profitability (Di Falco et al., 2010; Maggio, Sitko, and Ignaciuk 2018; Arslan et al. 2018). In doing so, different indices have been used to quantify crop diversification. The most common indices that have been used to specifically examine the effect of diversification on income or profitability include the following:

1. The Herfindahl index (Pope and Prescott 1980; Llewelyn and Williams 1996; Purdy, Langemeier, and Featherstone 1997; Ogundari 2004; Culas and Mahendrarajah 2005; Manjunatha et al. 2013; Li, Bellotti, and Komarek 2016). Let $p_i = \sum_{i=1}^{k}\left(\frac{A_i}{\sum_{i=1}^{k} A_i}\right)$, where A_i is the land area allocated to each crop or income

contributed by each crop. The Herfindahl index is calculated as ${p_i}^2$. It is based on the number of crops grown and their relative abundance in the crop portfolio. Using the Herfindahl index, Manjunatha et al. (2013) showed that crop diversification significantly improves farm profit in India.

2. The Simpson index of diversification (Di Falco and Perrings 2003; Mofya-Mukuka and Hichaambwa 2016; Arslan et al. 2018). The Simpson index is the inverse of the Herfindahl index. It is calculated as 1- ${p_i}^2$. Like the Herfindahl index, it is based on the number of crops grown and their relative abundance in the crop portfolio. Measuring crop diversification using the Simpson index, Arslan et al., (2018) showed that a one unit increase in the crop diversification index increases per capita income by 11% in Zambia.

3. The Margalef index (Di Falco and Chavas 2009; Di Falco, Bezabih, and Yesuf 2010). Given that S is the number of crops grown by a household, N is the total number of crops in the sample and ln is the natural logarithm, the Margalef index is measured as $\frac{S-1}{\ln N}$. The Margalef index is based on the number of crops grown. Using the Margalef index, Di Falco et al., (2010) showed that a one unit increase in crop diversification increases farm profitability by 42.3levs/ha (about US$ 23.7/ha) in Bulgaria.

Other crop diversification indices that have been used in the literature (although not specifically to evaluate the impact of crop diversification on income or profitability) include:

4. The entropy index (Pope and Prescott 1980; Culas and Mahendrarajah 2005). The entropy index is calculated as $\sum_{i=1}^{k} p_i \, log \frac{1}{p_i}$. It is also based on the number and relative abundance of crops.

5. Index of maximum proportion (Pope and Prescott 1980; Culas and Mahendrarajah 2005). The index of maximum proportion is the ratio of land area allocated to the

main crop to its total crop area. It is calculated as $Maxp_i$ where i =1, 2…n (Culas and Mahendrarajah 2005). The index of proportion is based on the relative abundance of the main crop grown.

6. The Ogive index (Coelli and Fleming 2004; Ogundari 2004; Rahman 2009). It is calculated as: $\sum_i^{N_i}\left[\frac{(Y_i-{}^1/_{N_i})^2}{{}^1/_{N_i}}\right]$ where N_i is the number of the i[th] crop grown and Y_i is the land area or revenue share occupied by the i[th] crop; (4) Number of crops grown (Pope and Prescott 1980; Culas and Mahendrarajah 2005). The Ogive index also does not go beyond the number and relative abundance of crops.

Because the indices of crop diversification are largely based on the number of crops grown and their relative abundance in the crop portfolio, they do not take into account the potential differences in the type of crops grown. Their underlying assumption is that a farmer who specializes in producing crop A has the same diversification strategy as a farmer who specializes in producing crop B, *ceteris paribus*. Similarly, they assume that a farmer who diversifies into producing crop A and B has the same diversification strategy as a farmer who diversifies into producing crop C and D, given that the proportion of the two crops in the portfolio is the same for both farmers. Further, the indices assume that a farmer who grows crop A and B as a mixed crop has the same diversification strategy as a farmer who grows crops A and B as monocrops. (Mixed cropping is a cultivation practice in which two or more different crops are grown simultaneously in the same field/plot. On the other hand, monocropping involves growing a single crop in a given plot (CSO and MAL 2015)).

In reality, the specific crops involved in diversification decisions may result in different strategic outcomes. Because of the differences in economies of scope between crops, diversifying into crop A and B may have different profitability outcomes from diversifying into crop C and D. Similarly, specializing in a low value crop such as sorghum may result in a different profitability outcome from that of specializing in a cash crop like cotton. The agronomic and market characteristics of each crop determine its compatibility in the portfolio and also influence its contribution to profitability.

Each crop can be considered as a unique enterprise. An enterprise is a sub-business unit under common control. Because of differences in production requirements and strategic use, a maize monocrop can be considered to be a different enterprise from a cotton monocrop or a maize and groundnut mixed crop, for example. The combination of the various enterprises on the farm is the enterprise structure of the farm. For example, a farm that specializes in maize production has a maize enterprise structure; a farm that diversifies into a maize monocrop and cotton monocrop has a maize/cotton enterprise structure while a farm that diversifies into a maize monocrop and a maize and groundnut mixed crop has a maize/maize*groundnut enterprise structure, where maize/cotton means maize monocrop and cotton monocrop, and maize*groundnut means maize and groundnut mixed cropping.

Acknowledging the uniqueness of enterprise structures among farmers may improve our understanding of existing cropping patterns and their influence on profitability. It may also present an opportunity to structure more effective and pragmatic recommendations for practitioners and policy-makers. This approach allows us to address the challenge presented by Maggio et al., (2018), "*…the abstract nature of the index is difficult to translate into useful policy action.*"

1.2 Research Problem

Due to the monolithic framework that has been used to explore the economic effects of diversification, the literature has failed to provide an effective perspective on the strategic benefits of crop diversification. Previous literature has largely considered crop diversification to be synonymous with the production of multiple crops. As such heterogeneity in strategy among specialized or diversified farmers has not been fully exploited to understand existing cropping patterns and to identify superior strategies.

1.3 Research Question

Based on the foregoing problem, this research seeks to address the following question: To what extent do enterprise structures influence farm profitability?

1.4 Research Objectives

The overall objective of the study is to identify the existing crop enterprise structures and their related profitability. The specific objectives are as follows:

i. Evaluate the distribution of crop enterprise structures in the study area and establish the characteristics of farmers adopting them.

ii. Determine the effect of enterprise structures on the profitability of crop production while controlling for farmer characteristics.

iii. Compare the profitability of farmers who have different proportions of crops in an enterprise structure.

iv. Determine the effect of the Simpson index on profitability and compare the results to the effect of enterprise structures on profitability.

1.5 Overview of Methods

Objective (i) is achieved by analyzing the distribution of households implementing the different enterprise structures and testing for statistical differences in characteristics. Objective (ii) is achieved by employing the OLS regression model to test the effect of adopting different enterprise structures on farm profitability in each agro-ecological zone. Objective (iii) is achieved by statistically comparing the mean profitability of farmers who are using the same enterprise structure but have different proportions of the individual crops in that enterprise structure. This comparison is carried out for all enterprise structures that have a sample size of at least 30 households in each agro-ecological zone. Objective (iv) is achieved by using the OLS regression model to test the effect of the Simpson index of diversification on profitability. Conclusions from the results of using the Simpson index are then compared to those of using the enterprise structure.

1.6 Outline of the Dissertation

Chapter 1 has described the importance of crop diversification and provided an overview of the challenges presented by the current state of knowledge on crop diversification. It also highlighted the research problem, question and objectives motivating the measurement of crop diversification from a strategic perspective of crop enterprises in a farm's portfolio.

In Chapter 2, the pertinent literature on crop diversification and profitability is explored, reviewed, synthesized and presented. This literature presents the rationale for diversification based on economies of scope. It also provides an exploration of the history of diversification in economics and the origin of the use of diversity indices, their limitations and broader applications. For example, we examine diversification as it relates to investment in finance literature and how portfolio analysis rather than indices has been the key framework for investment in finance. We draw lessons from the literature to inform our reconceptualization of diversification in agriculture.

Chapter 3 presents the methods employed in the study. This includes a discussion of the study area and data employed in the study. We also present the theoretical framework, as adapted from the theory of economies of scope, as the foundation of the study. The conceptual model highlights the key variables in the study and how these are conceptualized to affect profitability. Under the empirical framework, we discuss the assumptions necessary to use the Gaussian model and how our data and model motivate its adoption.

The results are presented and discussed in Chapter 4 and implications from the results are presented in Chapter 5. In Chapter 4, we present the descriptive statistics and results of empirical estimation. The implications and policy recommendations emanating from the results are presented in Chapter 5.

Chapter 2: Literature Review

This chapter explores previous research on diversification. It begins by introducing the concept of economies of scope, showing how diversification is reasonable when synergy in inputs or outputs exist. The chapter then steps back in history to examine the origin and evolution of the concept of diversification in Economics and of the use of indices to measure diversification. This historical background provides a strong foundation on which to explore the measurement and use of diversification. The chapter also includes a review of portfolio analysis as an alternative way of looking at the concept of diversification. It also provides a description of the theory of scale economies as an alternative cost saving theory to scope economies. The chapter ends by synthesizing the gaps in literature with a new proposed approach of using enterprise structures in analyzing the effect of crop diversification on profitability.

2.1 Economies of Scope in Diverification

The rationale behind diversification is anchored in the theory of economies of scope. Economies of scope exist when it is less costly to combine production of goods rather than producing them separately (Panzar and Willig 1981). In the presence of scope economies, diversification may result in cost savings. This cost saving may be in form of reduced production costs or reduced risk.

A sufficient condition for a multiproduct cost function to exhibit overall economies of scope is that cost complementarities between products should exist (Baumol, Panzar, and Willig 1982). Cost complementarities (synergies) imply that the marginal cost of producing any one product decreases with increases in the quantities of all other products (Baumol, Panzar, and Willig 1982). Cost complimentaries may arise from producing goods that share inputs. For example, a farmer who intercrops two agronomically compatible crops, can save on land, fertiliser, labor, water and soil nutrient costs. On the other hand, intercropping two incompatible crops that require different agronomic conditions and production management systems may result in lower yields, higher productions cost and overall lower returns.

Economies of scope is also important when diversifying for risk management purposes. Synergy among assets in a portfolio may affect the variance of returns for the portfolio as a whole. For example, in financial investment decisions, stocks that compliment each other will result in lower portfolio variance. That is, given two securities (assets), A and B, the variance of a portfolio containing A and B can be expressed as:

$$\sigma_{AB}^2 = W_A^2\sigma_A^2 + W_B^2\sigma_B^2 + 2W_AW_B\sigma_{AB} \quad (1)$$

Where σ_{AB}^2 is the variance of the portfolio, W_A and W_B are the weights of the two assets measured as the proportion of the total portfolio in the assets A and B, σ_A^2 and σ_B^2 are the variances of assets A and B, respectively while σ_{AB} is the covariance between A and B. When the covariance between A and B is negative, the variance of the portfolio will be lower than the sum of variances of the individual assets. When the covariance between asset A and B is positive, the portfolio variance will be higher than the sum of variances of the individual assets. Therefore, when the assets are negatively related, it is less costly (in terms of risk) to combine the assets together in a portfolio. However, when the assets are positively related, it is more costly to combine the individual securities into a portfolio. Economies of scope can be said to exist when asset A and B are negatively related while diseconomies of scope can be said to exist when asset A and B are positively related.

Diversification decisions, whether for higher returns or for risk management, may therefore be associated with economies of scope. Although the literature on diversification for risk management is mostly seen to be independent from the literature on diversification for profitability or cost saving, the foundation for both of this literature is rooted in the same concept of scope economies. A more detailed elucidation of the theory of economies of scope is presented under the theoretical framework in Chapter 3.

2.2 Origin of the Concept of Diversification in Economics

Empirical research on diversification in investment decisions may be traced to the seminal work of Harry Markowitz (1952). Markowitz showed that as the number of assets in a portfolio increased, the portfolio variance and average portfolio return decreased. He therefore argued that an investor's goal is not only to maximize expected return but also to minimize variance. Based on the twin-objectives of maximizing expected returns and minimizing variance, Markowitz developed the mean-variance framework to help investors in identifying the best portfolio. The best portfolio under the mean-variance framework is the portfolio that has the highest return and minimum variance.

Because portfolio variance is dependent on the correlation between securitities (securities that are negatively correlated will have a lower portfolio variance compared to securities that are positively correlated), Markowitz emphasized that the adequecy of diversification did not solely depend on the number of the different securities held, but also on the relationship (synergy) between the different securities in the portfolio. Securities that result in lower variance can be said to be more synergistic than those that do not. Markowitz's portfolio selection theory involved considering each security as being unique from another. That is, a portfolio with securities A and B would be different from a portfolio with securities C and D.

In agriculture, the seminal work of Heady (1952) launched agricultural economics' conceptualization of diversification. Heady (1952) examined the effects of two forms of diversification on income variability: (1) diversification by increasing land area to more crops; and (2) diversification by reallocating existing land area to more crops. Using experimental data from Fort Hays in Kansas for the period between 1910 and 1950, Heady compared the variance associated with the following crop portfolios:

i) 100 acres of Wheat alone
ii) 100 acres of Milo alone
iii) 100 acres of Barley alone

iv) 200 acres: 100 acres for Wheat and 100 acres for Milo

v) 200 acres: 100 acres for Wheat and 100 acres for Barley

vi) 200 acres: 100 acres for Milo and 100 acres for Barley

vii) 100 acres: 50 acres for Wheat and 50 acres for Milo

viii) 100 acres: 50 acres for Wheat and 50 acres for Barley

ix) 100 acres: 50 acres for Milo and 50 acres for Barley

Portfolios (iv) to (vi) represent diversification by addition of land resources while portfolios (vii) to (ix) represent diversification by reallocation of land resources. Heady repeated the experiment using data on corn, oats, hay and wheat in Iowa between 1910 and 1950. His results suggested that diversification by reallocation resulted in lower variance than diversification by increasing land allocation.

Like Markowitz (1952), Heady (1952) did not base his analysis on the number of crops in a portfolio. Therefore, the portfolios (i) to (iii) represent three different specialization portfolios although they have the same number and relative abundance of crops. Similarly, portfolios (iv) to (ix) are not homogenous, even though they have the same number and relative proportion of crops. In line with Markowitz (1952), Heady gave emphasis to the synergy (degree of correlation) between crops in determining the effectiveness of crop diversification for variance reduction.

Following Heady (1952), early research on diversification in agriculture focused on comparing average returns and income variability of different crop combinations and determining optimal proportions of land area to be allocated to each crop (Castle 1954; Carter and Dean 1960; Stovall 1966; Johnson 1967; Blank 1990). For these early researchers, diversification was much more than the number of crops grown and their relative abundance in the portfolio. It was about finding the optimal allocation of resources to unique crops when constructing a portfolio.

Recent work on crop diversification has largely used indices to measure crop diversification (Di Falco and Chavas 2009; Rahman 2009; Manjunatha et al. 2013; Arslan et al. 2018). These indices have ignored the importance of synergy in crops. Based on indices, portfolio (i) to (iii) in Heady's research are homogenous. Similarly, portfolio (iv) to (ix) are the same.

2.3 Diversity Indices

An index of diversity was first introduced by Fisher, Corbet and Williams in 1943. Following a series of numerical processes, they found that the number of butterfly species and the total number of butterflies in a sample were related. As the total number of butterflies increased, the number of butterfly species converged to a constant value. They referred to this constant value as an index of diversity. The index of diversity represented the 'richness of species' and was defined as the increase in the number of species obtained by increasing the size of a sample by *e* (2.718). The index of diversity could be calculated whenever the number of species and the sample size was known. One of the shortfalls of the index of diversity was that it was not independent of the sample size and could therefore not be generalized. In 1949, Simpson improved upon the index of diversity by proposing a measure of diversity that was based on population constants. Simpson's measure of concentration/diversity was based on the proportion of individuals in various groups. It is the foundation of the modern day Simpson index of diversification.

In 1945, a German economist called Hirschman, developed an index to measure the economic power of a large country trading with a small country. The index was calculated as the square root of the sum of squares of the market share of each country based on the number of countries and volume of trade that a country engaged in. The index was 100 when a country's trade was monopolized by another country and it approached zero as the number of countries that a country engaged in trade with approached infinity. Using the index, Hirschman showed that the exports of small countries tended to be more concentrated than their imports which could allow large countries to use trade to exercise their economic power. That is, if a country has an important share of another country's exports, it can artificially secure or maintain a similarly dominating position in its imports under unchecked national sovereignty.

Later in 1950, Orris Herfindahl rediscovered Hirschman's index without prior knowledge of Hirschman's work. The goal of Herfindahl's research was to find out whether the steel industry in the United States had become more or less monopolistic between 1898 and 1948. Herfindahl's index was a square of the index developed by Hirschman. To provide a summary measure of concentration based on the number and relative abundance of firms in the steel industry, Herfindahl developed an index calculated as the sum of squares of the market share of each market participant. Using the index, he showed that the steel industry had become more competitive during the period. Because the index was independently discovered by Hirschman and Herfindahl, it is usually referred to as the Herfindahl-Hirschman index (HHI) in economics.

Adelman (1969) proposed a numbers-equivalent interpretation of the Herfindahl index, which could be applied in any market. The numbers-equivalent measure of the Herfindahl index was simply the reciprocal of the Herfindahl and is identical to the Simpson index. As such, the Herfindahl and the Simpson index have similar characteristics.

The Shannon index has its origin in communication theory. It was introduced by Claude Shannon in 1948 to quantify entropy or the degree of surprise in a string of texts. Shannon studied the way in which information contained in messages was degraded during transmission. He showed that predicting which letter would be next in a string of text was more difficult as the number of letters increased and their proportional abundance in the string of interest became more equal. The Shannon index was extended and applied in the study of biological diversity by ecologists (MaCarthur (1955) and Margalef (1958)). Thus, it has many variants such as the Shannon-Weiner index, the Shannon-Weaver index, and the Shannon entropy index, which are popular in the ecology literature.

The early use of indices was for measuring industry or regional concentration (Hirschman 1945; Herfindahl 1950). Although the Shannon index was originally used in communication theory and ecology, it was later applied to economics by Garrison and Paulson (1973), who used it to measure the geographical concentration of economic activity in the Tennessee valley. Harkbart and Anderson (1975) also used the Shannon index to calculate economic diversification for the period between 1940 and 1960 in the state of Wyoming. Like the Herfindahl, the Shannon index was applied for industry analysis.

The work of Berry (1971) introduced the use of indices to firm-level diversification. Using the Herfindahl index, Berry calculated diversification indices for 460 industrial corporations in the United States between the year 1960 and 1965. The Herfindahl index was based on the ratio of the firm's output in each industry to the firm's total output in all industries in which the firm invested. Berry then tried to establish the relationship between firm diversification and growth by regressing firm growth (measured as the percentage increase in total assets of the firm between 1960 and 1965) on the diversification index. He found that diversification led to firm growth if the firm invested in at least 4 industries.

Citing Berry's use of the Herfindahl index, Pope and Prescott (1980) applied the Herfindahl index in estimating the effect of farm size on diversification for a cross-sectional sample of over 1,000 crop farms in California. Pope and Prescott also employed the entropy index, the index of maximum proportion, and the number of crop enterprises as additional measures of diversification. The indices were calculated based on the land area allocated to the different crops as well as on the proportion of income contributed by each crop. Pope and Prescott found that farm size had a positive and statistically significant effect on diversification, showing that larger farms tended to be more diversified.

Pope and Prescott's work formed much of the foundation on which the use of diversification indices to relate crop diversification and farm characteristics/ performance has been based. These studies have included Purdy, Langemeier, and Featherstone (1997), Ogundari (2004), Culas and Mahendrarajah (2005) and Li, Bellotti, and Komarek (2016) who have employed the Herfindahl index to measure crop diversification. Other studies include Di Falco and Perrings (2003), Mofya-Mukuka and Hichaambwa (2016) and Arslan et al. (2018) who have used the Simpson index to measure diversification; Culas and Mahendrarajah (2005) who used the entropy index and the index of maximum propotion; Coelli and Fleming (2004), Ogundari (2004) and Rahman (2009) who used the Ogive index as well as Smale et al. (1998) and Di Falco and Chavas (2009) who used the Margalef index.

2.4 Limitations of Diversification Indices

The key characteristics of the indices of diversification is that they only take into account the richness and evenness of categories in a sample. Richness is the number of different categories of units in a sample while evenness is the distribution of relative weights between the different categories (Tabner 2007). Because they are dependent on only the number of categories and their relative weights, they do not account for many other factors that make the categories to be different. The scientists who developed these indices mostly highlighted their limitations and the situations in which they would not be ideal.

For example, in recognizing the limitations of his index, Herfindahl (1950, p. 52) explicitly stated that his index would to some extent, misrepresent situations whose outcome was actually dependent on many factors. In his review of the Herfindahl index, Adelman (1969) acknowledged that two different industries could have the same index, asserting that the index could not capture the real structure of the industry and the factors determining its behavior.

In the ecology literature, diversity indices have been criticized as representing a 'reductionist analysis' that over-simplifies highly complex biological communities to simple measures (Green 1979; Ludwig and Reynolds 1988). Lima-Junior, Cardone, and Goitein (2006), for example, concluded that, because the indices were not detailed enough to account for habitat complexity and heterogeneity, they ignored species identification and role in the community.

In the crop diversification literature, indices have proven to be a useful aggregation mechanism. As such, their limitations have not be fully addressed to enrich our understanding of diversification. Our review of the agriculture diversification indices literature shows that their use ignores complex mechanisms and heterogeneity in crops that could be important for understanding strategic choices decision-makers make about how they construct their choices and solutions.

A few attempts to provide a better measure of crop diversification have been made. One such attempt is by Giuseppe, Sitko, and Ignaciuk (2018). Rather than measuring crop diversification as an index, they measured it as the combination of crops from different crop groups (legumes, staples, cereal, cash crop). They examined the determinants and impacts of a maize–only crop portfolio compared to a maize/legume portfolio, a maize/staples portfolio, a maize/cash crop portfolio, a maize/legume/staples portfolio, a maize/legume/cash crop portfolio as well as a maize/legume/staples/cash crop portfolio in a cross-sectional sample of farmers in Zambia. Using a multinomial endogenous treatment effect model, they found that relative to the maize-only portfolio, other portfolios had neutral or positive effects on maize productivity and neutral or negative effects on income variability. They also found that portfolios that had legumes resulted in better outcomes. Although their approach accounts for heterogeneity in crop groups, it assumes that all crops in a particular crop group are similar based on their agronomical characteristics. Given that the focus of their paper was to examine the effect of these crop portfolios on maize productivity, their categorization was adequate for their purpose. However, for a more complete understanding of the effects of crop diversification, a more detailed dissaggregation of crops is required.

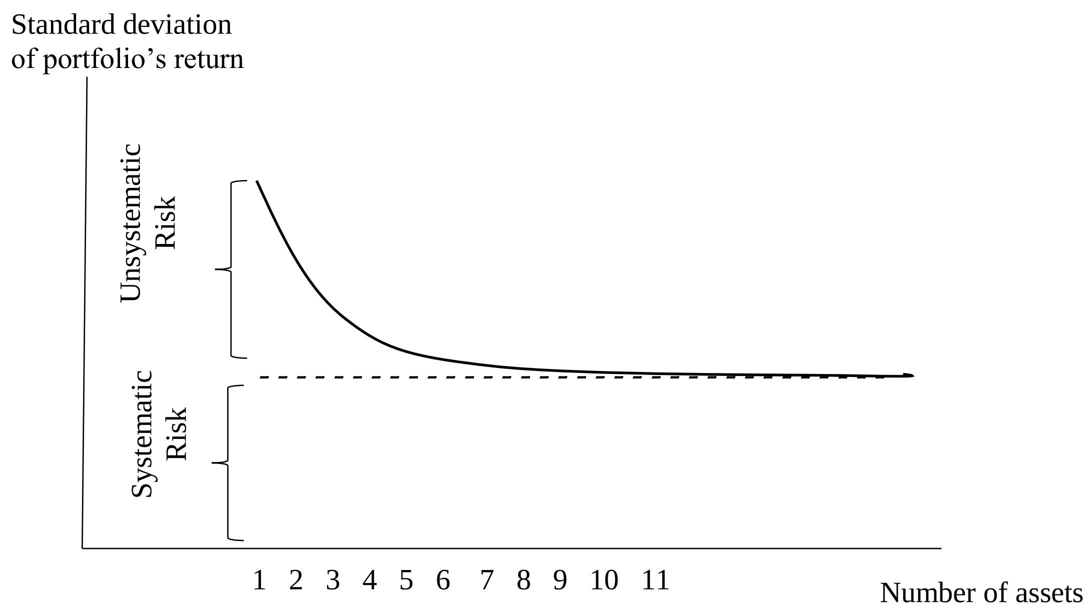
2.5 Portfolio Size Decisions

In the finance literature, diversification indices have not been popular. Besides Woerheide and Persson (1993) who explore whether diversification indices would be satisfactory measures of diversification in finance, diversification indices have largely not been adopted in investment decisions. In looking at the extent of diversification, the finance literature used the number of securities as a measure of portfolio size to give an idea of adequacy in extent of diversification decisions. Establishing an optimum portfolio size (level of diversification) has been shown to be important for investors to get maximum benefits from their portfolio. Diversifying below the optimal level of diversification can provide fewer diversification advantages while diversification beyond the optimal level can increase portfolio risk and cost (Lynch and Rothchild 2000).

While discussing the importance of correlation between securities in a portfolio, Markowitz (1959) indirectly addressed the issue of portfolio size (pages 112-116). He illustrated that the variance of a portfolio reduces as the number of securities increases. However, Evans and Archer (1968) were the first to attempt to establish an optimal portfolio size of stocks for investors. They examined how the variance of returns for randomly selected portfolios changed as the number of securities in the portfolios increased. Because the securities were randomly selected, there was no intention to select the most synergystic securities in their study. Their goal was to establish the optimal number of securities to be included in a portfolio. The motivation for their research was that if the costs associated with a portfolio was a function of the number of securities held, then the number of securities in a portfolio was important for portfolio selection.

Evans and Archer analyzed the marginal reduction in portfolio variance resulting from successive increases in securities under the assumptions that the investor is a random buyer of common stocks, dividends from securities are not reinvested and that equal dollar amounts are invested in each security in the portfolio. Using data on 470 of the securities listed in the Standard and Poor's Index for the year 1958, they randomly selected one security from the 470 secuties and this became the portfolio with one security, then they randomly selected two securities from the 470 securities and this became the portfolio with two securities. They repeated this process for 40 portfolios. Then they regressed the standard deviation of the returns on the inverse of the portfolio size using a least squares regression. The standard deviation was used as a measure of unsystematic risk, which is the risk that affects a few of the securities. The alternative to unsystematic risk is systematic risk which affects all securities, each to the same degree.

Figure 2. 1 Diversification Reduces Unsystematic Risk



Source: (Ross et al. 2016)

Evans and Archer (1968) found that the relationship between standard deviation and portfolio size took the form of a rapidly decreasing asymptotic function as shown in Figure 2. 1. They showed that the standard deviation decreased with succesive increases in the number of securities until the number of securities reached about 10. They concluded that a portfolio size of 10 randomly selected securities was enough to diversify away unsystematic risk. In line with Evans and Archer, Fisher and Lorie (1970) later showed that roughly 80% of the achievable reduction in dispersion is obtained by holding eight stocks.

Later in 1987, Meir Statman contradicted Evans and Archer's widely adopted conclusion. Rather than looking only at the marginal cost (standard deviation) of diversification, Statman (1987) also considered the marginal benefit (expected returns) of diversification to arrive at his conclusion. He considered the optimal portfolio size to be the one at which the margical cost of diversification was equal to the marginal benefit and showed that a well-diversified portfolio of randomly selected stocks must include at least 30 stocks for borrowing investors and at least 40 stocks for lending investors.

Evans and Archer (1968), Fisher and Lorie (1970) and Statman (1987) provided a range of the number of securities to include in a portfolio under the assumption that the investor is randomly selecting securities of equal dollar amounts. That is, the investor is not deliberately chosing stocks based on their synergystic effect on risk. However, they acknowledged that although the number of securities provided a range for adequate diversification, it was not enough to guide portfolio selection. Citing an earlier study by Jacob (1974) who showed that an investor could reduce unsystematic risk with fewer securities if the securities were cautiously chosen, Statman (1987) cautioned that the number of securities was not the sole determinant of the level of diversification.

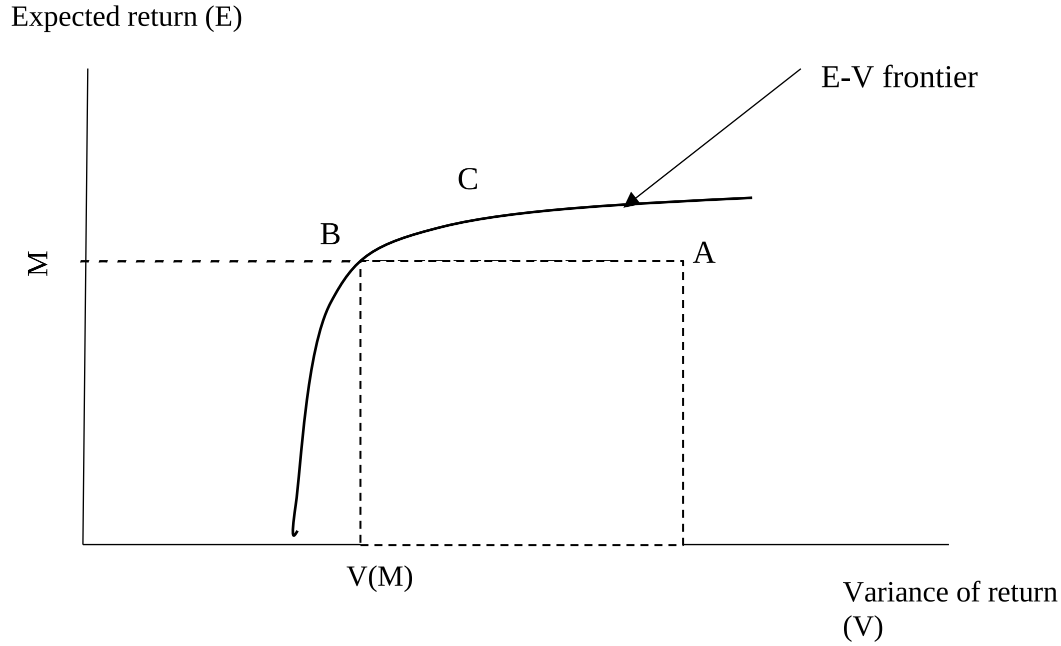
Besides portfolio size, portfolio selection decisions are based on the relationship between specific securities. The relationship between securities determines the level of synergy that can be achieved by adding the securities in one's portfolio. Securities whose returns have a stronger negative relationship can be said to be more synergistic as they will lead to lower variance thereby providing higher risk management benefits for investors. Because, in reality, investors do not always invest equal dollar amounts in randomly selected securities, portfolio selection is also concerned about finding the proportional allocation of wealth across carefully selected securities or portofolios to maximize returns and minimize variance.

2.6 Portfolio Selection

Following Markowitz's portfolio theory of 1952, models and tools have been developed to help in the identification and selection of optimal portfolios. The main framework that has been used to examine the risk and return in portfolio selection is the mean – variance or Expected return – Variance (E-V) model shown in Figure 2. 2. The E-V model summarizes choice under uncertainty using the first two moments (mean and variance) (Markowitz 1952; Markowitz 1959; Chavas 2004). The E-V model shows that, as variance reduces due to increased diversification, so does expected returns. An optimal portfolio is assumed to be the one that maximizes expected return and minimizes variance (Markowitz 1952; Markowitz 1959; Sharpe 1963; Chavas 2004). That is, the stocks with the highest synergy result in the lowest variance but highest returns.

To identify an optimal portfilio from a list of viable portfolios, an investor begins by eliminating all inefficient portfolios in the E-V model. If a portfolio is inefficient, then there exits some other portfolio with either higher average return and no more variance, or with lower variance and no less return (Markowitz 1959; Chavas 2004). For example, given portfolios A, B and C in Figure 2. 2, portfolio A is inefficient since it has higher variance but equal returns compared to portfolio B. After eliminating inefficient portfolios, the investor compares the various combinations of expected return and variance of the efficient portfolios. If a portfolio is efficient, it means that it is impossible to obtain a greater expected return without incurring greater variance and it is impossible to obtain a smaller variance without giving up some expected return (Markowitz 1959; Chavas 2004). In Figure 2. 2, portfolio B and C are efficient portfolios while portfolio A is inefficient relative to portfolio B.

Figure 2. 2: E-V Frontier



Source: Chavas 2004

The optimal portfolio from among efficient portfolios can be identified using linear, non-linear or dynamic programming, or Monte Carlo techniques (Markowitz 1959; Chavas 2004). The optimal portfolio will always correspond to a point M on the E-V frontier (Figure 2). In agriculture, several researchers have used linear and non-linear prgramming techniques to identify optimal crop portfolios (Carter and Dean 1960; Stovall 1966; Johnson 1967; Collins and Barry 1986; Blank 1990b; Turvey, Baker, and Weersink 1993).

Apart from selecting individual assets to form a portfolio, investors may also try to select an already diversified portfolio from among existing portfolios in the market. For example, an investor may need to select a mutual fund from among the various mutual funds in the market. A mutual fund is a collection of stocks, bonds and other securities. To select a portfolio from among several portfolios, the investor uses the principles of the E-V framework to identify efficient portfolios and to choose the portfolio that gives the best combination of average returns and variance.

The finance literature shows that economies of scope from the complimentary relationship among stocks is important when making diversification decisions. More complimentary stocks can lead to lower variance and/or higher returns. Similarly, in crop diversification, complimentary crops can lead to lower variance and/or higher returns. Because economies of scope depend on cost complimentaries, not all crop combinations can result in cost savings. Therefore, it is to be expected that benefits from crop diversification will depend on the specific crops, not number of crops, that are being grown together. The diversification index approach to measuring crop diversification ignores cost complimentaries among crops and is therefore likely to provide incomplete guidance regarding crop selection in diversification decisions.

2.7 Economies of Scale

While the presence of economies of scope may encourage the production of a variety of crops to save on costs, a closely related concept of economies of scale may encourage the production of one crop to cost save. Gains in economies of scale is sometimes argued to be the reason for the adoption of specialization policies (GoR, 2005; Nyamulinda et al. 2014).

Economies of scale exist if increasing output leads to a decrease in average cost. For a single output firm, economies of scale exist if $\frac{Average\ cost\ (AC)}{Marginal\ cost\ (MC)} > 1$ while diseconomies of scale exist when $\frac{AC}{MC} < 1$. In a multiproduct firm, there exists two types of economies of scale: (1) Multiple product scale economies (MPSE) and (2) Product specific scale economies (PSE). MPSE measures cost changes for simultaneous increaeses in all outputs while PSE measures cost changes for a single output holding all others fixed (Moss and Featherstone 1994). PSE are present if the per unit cost of producing an output declines as the output increases (Moss and Featherstone 1994).

For a multiproduct farm, PSE are measured by incremental cost. Define the incremental cost of producing y_i as:

$$\left(IC(y_i)\right) = c(Y) - c(Y - y_i) \tag{2}$$

where, $Y = (y_1, .. y_i, .. y_n)$, $y_i = (0, \dots, y_i, \dots 0)$ so that $Y - y_i = (y_i, \dots, 0, \dots y_n)$. $c(Y)$ is the cost of producing all outputs while $c(Y - y_i)$ is the cost of producing all but y_i.

The average incremental cost $AIC(y_i) = \frac{IC(y_i)}{y_i}$ (3)

and $PSE_i = \frac{AIC(y_i)}{\partial c / \partial y_i}$ (4)

PSE exist if $PSE_i > 1$.

$$MPSE = 1 - \sum \frac{\partial c(Y)}{\partial y_i} \cdot \frac{y_i}{c(Y)} \tag{5}$$

MPSE exist when $MPSE > 0$. When MPSE exist, a farm can reduce average cost by increasing the amount of all outputs proportionally, keeping the mix of outputs unchanged (Pokharel and Featherstone 2019).

Given that $\widetilde{MC} = \sum \widetilde{MC}_l = \sum \widetilde{y}_l \frac{\partial c}{\partial y_i}$ and that $\alpha_i = \frac{\widetilde{MC}_l}{\widetilde{MC}}$, where $\sum \alpha_i = 1$, MPSE can be decomposed into PSE and economies of scope (EOS) as follows:

$$MPSE = 1 - \frac{1 - EOS}{\sum \alpha_i PSE_i} \tag{6}$$

Therefore, in a multi-product firm, the presence of scope economies may magnify MPSE (Pokharel and Featherstone 2019). Consequently, a firm does not need to be specialized in order to enjoy economies of scale. In the presence of MPSE, a diversified firm can achieve both economies of scope and scale. Specialization is therefore only reasonable in the absence of economies of scope and MPSE.

2.8 Summary of Review

In summary, the review of previous literature shows that although the number of crops in a portfolio can provide a reasonable range of the extent of diversification, it is not enough to guide diversification decisions. The review also suggests that while diversification indices provide a good aggregate measure of diversification, they also over-simply reality and may therefore not provide adequate information for understanding the complex processes that decision makers are faced with when making diversification decisions.

A much more detailed approach to diversification decisions is captured through portfolio analysis which considers not only the number but also the types of assets in a portfolio and their relationship with each other. A more synergistic relationship among assets may result in lower portfolio variance and/or increased portfolio return. In a cross sectional study of crop diversification, the effect of synergy among crops can be examined through the relationship between crop portfolios and portfolio returns. In longitudinal data, the effect of synergy among crops can be examine, both through the relationship between crop portfolios and portfolio returns and the relationship between crop portfolios and portfolio variance.

Portfolio analysis may involve choosing individual securities to add to a portfolio or choosing an already diversified portfolio from among several portfolios. In this study, we extend the investment idea of choosing a porfolio from among already diversified portfolios to agriculture. Therefore, rather than looking at a farmer as a decision maker who is choosing individual crops to grow in a particular season, we examine the farmer as a decision-maker who is choosing which crop portfolio to use in a given season.

Differences between investment in the financial market and in agriculture exist. In particular, while a given portfolio of stock in the financial market gives the same return for each investor, in agriculture, the return from a given crop portfolio may be different for different farmers. This is because the return on the crop portfolio is dependent on several other factors desides the synergy among crops. Other factors such as differences in soil and climatic conditions, differences in proportions of individual crops as well as differences in farm management practices may result in different returns from the same crop portfolio.

In this study, we recognize these differences between financial markets and agricultural production. As such, in examining the effects of crop enterprise structures on returns, we carefully control for differences in production practices and farmer characteristics. We also examine the effects of crop diversification in each agro ecological region to account for differences in environmental conditions. Further, because the study uses cross sectional data, we focus our analysis on the effect on crop diversitication on returns in one agricultural season. This study, therefore, does not capture synergy effects from crop diversification on variance of returns. The effect of crop diversification on variance would be more plausibly examined using longitudinal data, as earlier stated. Finally, because differences in crop proportions may affect returns from a crop portfolio, we statistically test for differences in returns from farmers who have the same crop portfolio but different proportions of the individual crops.

Chapter 3: Methods

This chapter presents the methods that have been employed in this study. It provides a thorough description of the study area and data used in the study. It also explains the theoretical foundation of this study and expounds on the expected relationship between key variables in the study. The Chapter also presents the empirical framework for the analysis.

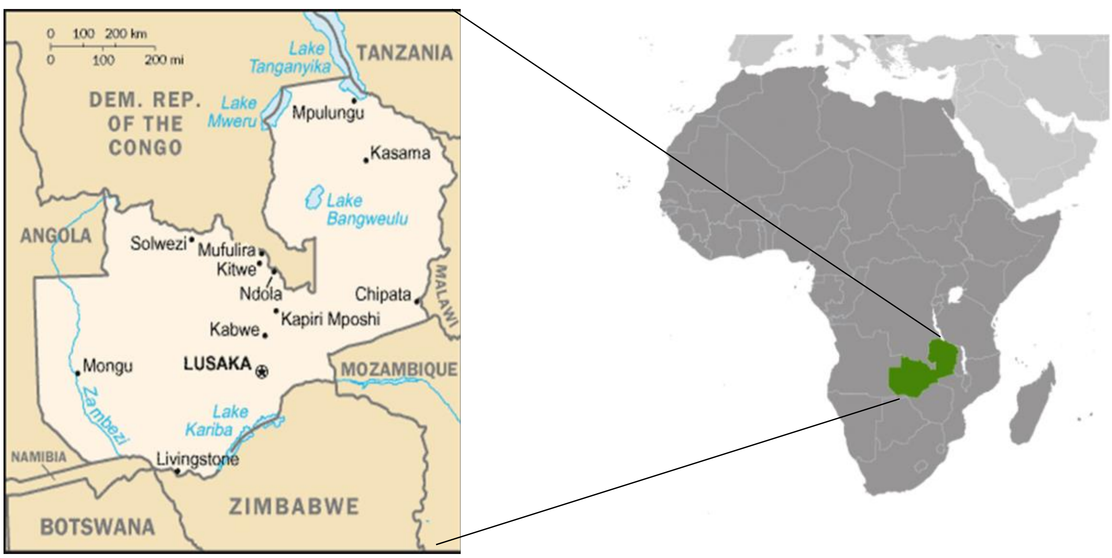
3.1 Study Area: Zambia

Zambia is a landlocked country located between latitudes 8°and 18° South and longitudes 22° and 34° East in Southern Africa. It is bordered by the Democratic Republic of Congo to the north, Tanzania to the north-east, Malawi to the east, Angola to the west and Mozambique, Zimbabwe, Botswana and Namibia to the south (CSO 2012). The country has a total surface area of 752, 618 square kilometers of which 47% is arable land (Ministry of National Development Planning 2017).

Zambia has an estimated GDP of US$26.72 billion, to which the agricultural sector contributes about 3% (World Bank 2019c). Agricultural development has been recognized as one of the important pathways of boosting economic growth and reducing poverty in rural areas (Ministry of National Development Planning 2017). The agricultural sector employs nearly 54% of the population (World Bank 2019c). With only 15% of the country's arable land under cultivation (Ministry of National Development Planning 2017), having 60% of the water in southern Africa and being surrounded by eight countries, Zambia's agriculture is seen to have the potential for increased production and trade, which can propel the country's development (CSO 2012).

As with the rest of SSA, Zambia's agriculture is heavily reliant on rainfall, making it highly vulnerable to climatic variations. One of the adaptation strategies that the Zambian government has outlined in its National Climate Change Response Strategy (NCCRS) is enhancing farming systems that encourage crop diversification (Government of the Republic of Zambia 2010). Crop production has mainly been focused on maize which is the country's staple food crop. Maize is grown by almost 90% of agricultural households throughout the country (CSO 2016). Besides maize, other key crops include groundnuts, cassava, sweet potatoes, mixed beans, seed cotton, sunflower, millet, soybean, rice, sorghum, Bambara nuts, cowpeas and tobacco. The country's policy direction on crop diversification is to encourage the production of these other key crops.

Figure 3. 1: Map of Zambia in Africa



Source: CIA, 2011

Zambia is divided into 10 administrative provinces: Central, Copperbelt, Eastern, Luapula, Lusaka, Muchinga, North-Western, Northern, Southern and Western provinces. These administrative provinces fall into four agro-ecological zones (AEZs): AEZ I, AEZ II a, AEZ II b and AEZ III. AEZ I covers the dry areas of the Gwembe, Lusemfwa and Luangwa valleys of Southern, Eastern and Western Provinces (Donovan et al. 2002). It constitutes 12% of total land area of the country. The region lies between 300 and 900 meters above sea level. Its annual rainfall is between 600 to 800mm and mean daily temperatures are between 20-38˚C, and is characterized with frequent dry spells

(Christiansen 2008). Its growing season is about 80 to 120 days. it's soil type ranges from slightly acidic loamy and clayey soils to acidic sandy soils, which are associated with soil erosion, limited soil depth, poor water holding capacity and poor structure. Major crops in this region are maize, sorghum, groundnuts, cowpeas and pumpkins (CSO 2016).

AEZ IIa and AEZ IIb cover much of central Zambia and stretch across Central, Southern, Lusaka and Eastern provinces. AEZ IIa comprise of the plateaus of Eastern, Lusaka and Southern Province while AEZ IIb encompasses the Kalahari plateau and the Zambezi flood plains of Western Province. AEZ IIa and AEZ IIb (which together form AEZ II) constitute 42% of Zambia's total land area. They have an elevation of between 900 to 1300 meters above sea level, and contain the most fertile soils, with mean annual rainfall of between 800 to 1,000mm and mean daily temperatures of between 23-25^{o}C (Christiansen 2008). The growing season in these zones is between 100 to 140 days. AEZ IIb covers only the flood plains of AEZ II. Because of its conducive production conditions, AEZ II has the largest number of commercial farmers. Major crops in these regions include maize, soybeans, cotton, tobacco, beans, groundnuts, sorghum and sunflower (CSO 2016).

The northern-most part of the country is in AEZ III, and stretches across Northern, Luapula, Copperbelt, Northwestern and parts of Central province. Its altitude is between 1,100 and 1,700 meters above sea level. AEZ III constitutes 46% of the country's land area. This region receives between 1,000 to 1,500mm of annual rainfall and has the longest growing season of between 120 to 150 days. Average daily temperatures range between 16-20^{o}C (Christiansen 2008). Its soils are highly weathered and leached, with low nutrient content and high acidity. Although the region receives more than enough rainfall, the production of crops may be constrained by the low number of sunshine days. Main crops in this region include cassava, maize, sweet potatoes, millet and beans (CSO 2016).

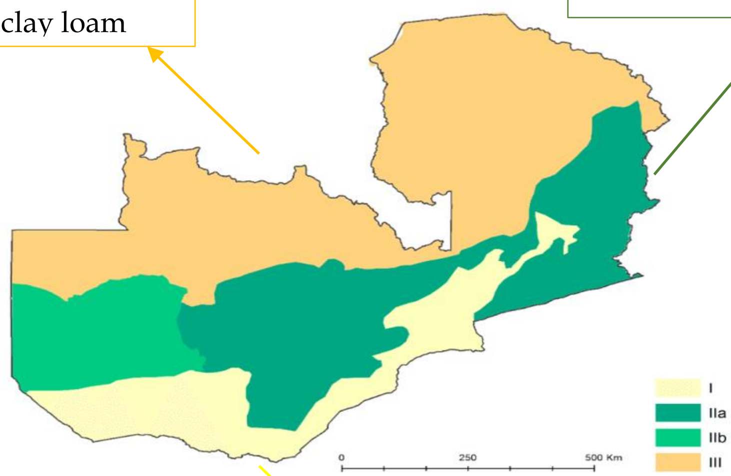
Figure 3. 2: Zambia's Agro ecological Zones

AEZ III

- 1000-1500mm annual rainfall.
- 120 – 150 day growing season.
- Soil has low nutrient content and acidic.
- Deep soils, sandy clay loam

AEZ IIa

- 800-1000mm annual rainfall.
- 100 – 140 day growing season.
- Fertile soil.



AEZ IIb

- 800-1000mm annual rainfall.
- 100 – 140 day growing season.
- Zambezi flood plains and Kalahari plateau.
- Loamy to sandy soils

AEZ I

•600 – 800mm annual rainfall.
•80 – 120 day growing season.
•Frequent dry spells.
•Poor soil structure.
•Loamy to clay soils

Source: Christiansen 2008

3.2 Data

We use secondary data from the 2015 Rural Agricultural Livelihoods Surveys (RALS) in Zambia. RALS is a survey designed to obtain comprehensive information on Zambia's small- and medium-scale farmers. The RALS sample is, therefore, based on households cultivating less than 20 hectares. The aim of the survey was to study options for improving crop production and marketing, and food consumption among small and medium scale farmers. The survey was designed and implemented by the Indaba Agricultural Policy Research Institute (IAPRI), the Central Statistical Office and the Ministry of Agriculture in Zambia.

The 2015 RALS is a follow up panel survey to the 2012 RALS. Both surveys are based on Zambia's 2010 population census sampling frame. The 2015 RALS had a sample size of 7,934 households randomly sampled using a two-stage stratified sample design. The first stage involved identifying the Primary Sampling Unit (PSU). A PSU is defined as one or more Standard Enumeration Areas (SEAs) with a minimum of 30 agricultural households. The second stage involved identifying agricultural households from a list of all households and stratifying those agricultural households into three categories on the basis of area planted, presence of specified specialty crops and livestock. Thereafter, systematic sampling was used to select 20 agricultural households across the three strata in each PSU. The RALS 2015 covered a total of 476 PSUs, across all the 10 provinces of Zambia.

Population weights to correct for over- and under-sampling in the 2015 survey were generated. The generation of weights was based on sampling probabilities at the first stage of the sampling process (the selection of SEAs) and probabilities for the second stage (selecting households). The weights of the sample are equal to the inverse of the probability of selection. Given that ${P^1}_{hi}$ is the first stage sampling probability of a SEA i ,

a_h is the number of SEAs selected in district h, M_{hi} is the size of the i^{th} SEA in district h and $\sum_{i=1}^{N_h} M_{hi}$ is the total size of district h, the probability of sampling a SEA is given as:

$$P^1{}_{hi} = \frac{a_h M_{hi}}{\sum_{i=1}^{N_h} M_{hi}} \tag{7}$$

And the first stage sampling weight (W_{hi}) is calculated as:

$$W_{hi} = \frac{1}{P^1{}_{hi}} \tag{8}$$

The second stage selection probability of the household ($P^2{}_{hi}$) is calculated as:

$$P^2{}_{hi} = \frac{n_{hi}}{N_{hi}} \tag{9}$$

Where N_{hi} is the total number of agricultural households listed in the i^{th} SEA of district h. The second stage sampling weight (W_{hi}) is calculated as:

$$W_{hi} = \frac{1}{P^1{}_{hi} P^2{}_{hi}} \tag{10}$$

A non-response adjustment factor was also applied to the household weights. For more details about the RALS survey design, see Chapoto et al., (2016).

The RALS 2015 collected detailed information about crop production in the 2013/14 agricultural season. This agricultural season extends from 1st October 2013 to 30th September 2014 (CSO and MAL 2015). The survey included field level data on crops grown, monocrop and mixed crop fields, production practices, and input use. The inputs captured in the survey include hired labor, fertilizer and seed. Detailed information for seed acquisition is however limited to six Feed-the-Future Initiative focus crops. These are: sunflower, soybeans, groundnuts, sweet potato, cassava and maize. The survey also includes data on fertilizer and seed acquisition through the Farmer Input Support program, on ownership of agricultural assets and marketing of agricultural produce for the May 1st, 2014 to April 30th, 2015 marketing season. Marketing data includes information on prices received for the crops sold.

3.3.1 Measurement of Key Variables

3.3.1.1 Profitability

The dependent variable in this study is farm profitability, which is measured using the gross margin per hectare and gross margin per total variable costs. Gross margin is calculated as crop revenue less variable costs. To measure crop revenue (value of crops produced), we multiply the quantity of each crop harvested by the average market price of the crop. This allowed crop revenue to be imputed for all households, including those that did not sell their production.

Cassava was a specialty crop in the survey. Its output data were not based on what the household actually harvested but rather on the amount the household would have harvested if it had decided to harvest its entire mature cassava field. The instruction to enumerators with respect to cassava was:

"Find out the number of 50kg bags of raw cassava that the household could have harvested from this field if it had decided to harvest the entire field…"(CSO and MAL 2015, p. 53).

Thus, the revenue for cassava is based on the assumption that the household harvested all its mature cassava. In reality, households in Zambia may harvest their mature cassava as and when need arises. They leave some of the mature cassava in the field as a way of storing it for future use.

To measure gross margin, we subtract fertilizer cost and cost of hired labor from crop revenue. Ideally, gross margin should be crop revenue less all variable costs which include seed cost, fertilizer cost, cost of labor, cost of agrochemicals and related transport costs. In this study, we do not have data on cost of agrochemicals, therefore, the cost of agrochemicals is not accounted for in our measure of profitability. Further, we exclude seed costs because the RALS collected data on seed acquisition for only a handful of specific crops (sunflower, soybeans, groundnuts, sweet potato, cassava and maize), which are the key crops for USAID's Feed the Future Initiative in Zambia (CSO and MAL 2015). To avoid bias in estimating the seed cost and, therefore, gross margin for other crops that are not part of the Feed the Future Initiative, we entirely exclude seed cost in our estimation of total variable costs.

The two costs that we include in our measure of total variable costs are fertilizer purchase cost and their related transportation cost, as well as the cost of hired labor. To measure expenditure on fertilizer acquisition, we sum the total cost of basal and top fertilizer bought from government or commercial sources. Although the survey did not explicitly collect data on the cost of fertilizer bought through the government subsidy program, we were able to estimate this cost using the market price of fertilizer. Under the government subsidy program, farmers pay about 35% of the cost of fertilizer (Jumbe, Kaiyatsa, and Mason 2018). By applying the 35% to the cost of fertilizer, we were able to get an estimate of expenditure on fertilizer bought under the government subsidy program.

Bearing in mind that our analysis is based on financial activity over a specific period of time, we follow the accounting approach used in the profit and loss financial statement to measure revenue and costs. The cost of fertilizer that we use in the study is, therefore, not the cost of fertilizer that the household used during the 2013 to 2014 agricultural season, but rather the cost of fertilizer that the household bought. Cost of fertilizer bought and cost of fertilizer used may be different in cases where a household had carry-over fertilizer stock from the previous season, received fertilizer gifts or stored some of the fertilizer purchased for the following season.

The other variable cost that we include is the cost of hired labor. The RALS data did not include sufficient information on the use of family labor. As such, our estimate of the cost of labor is essentially the cost of hired labor. Although family labor may be argued to be an additional cost paid by the household in terms of the opportunity cost of time, we focus on the household's cost of hired labor to avoid measurement error in the estimation of non-pecuniary costs and benefits related with family labor.

Finally, to account for differences in scale of operation, we use gross margin per hectare, calculated as gross margin divided by hectares planted, and gross margin per total variable costs, calculated as gross margin divided by total variable costs, as our measures of profitability. The formulas employed in calculating gross margin per hectare are as follows:

$$Crop\ revenue(ZMW) = \sum_{i=1}^{n}(Price_i\ *\ Quantity\ harvested_i) \quad (11)$$

$$TVC\ (ZMW) = \left(fertilizer\ cost + fertilizer\ transport\ cost + cost\ of\ hired\ labor\right) \quad (12)$$

$$Gross\ margin\ (ZMW) = Crop\ revenue - TVC \quad (13)$$

$$Gross\ margin\ per\ hectare\ (ZMW/ha) = \frac{Gross\ Margin}{hectares\ planted} \quad (14)$$

$$Gross\ margin\ per\ total\ variable\ costs\ (ZMW) = \frac{Gross\ Margin}{TVC} \quad (15)$$

Where TVC means Total Variable Costs. During the 2013-2014 agricultural season, the exchange rate between the Zambian kwacha (ZMW) and the US dollar ($) was ZMW6.4 to $1 (Exchange-rates.org 2019). We estimate the effect of enterprise structures on gross margin per hectare, controlling for demographic, socio-economic and production variables.

3.3.1.2 Enterprise structure (EP)

The EP is constructed from the individual crops that a household grew. The proportion of households growing the different crops in Zambia is presented in Table 3. 1. Table 3. 1 shows that the most popular crop is maize, grown by 93% of households. Groundnuts are grown by 52% of households while cassava is grown by 28% of the households. Irish potato, velvet beans, paprika, sugarcane and sesame are grown by less than 0.5% of households.

Table 3. 1: Distribution of Households growing the Different Crops (N = 7683)

S/N	Crops grown in 2013/14 Agricultural Season	Number of households growing the crop (Unweighted)	Percentage of households growing the crop
1	Maize	7,145	93%
2	Groundnuts	3,993	52%
3	Cassava	2,181	28%
4	Seed cotton	1,215	16%
5	Mixed beans	1,119	15%
6	Sweet potato	1,023	13%
7	Sunflower	958	12%
8	Soybeans	636	8%
9	Millet	581	8%
10	Rice	421	5%
11	Sorghum	269	4%
12	Bambara nuts	207	3%
13	Cowpeas	146	2%
14	Burley tobacco	67	1%
15	Virginia tobacco	60	1%
16	Popcorn	58	1%
17	Irish potato	23	0%
18	Velvet beans	7	0%
19	Paprika	1	0%
20	Sugarcane	1	0%
21	Sesame seeds	1	0%

Source: Author's Analysis

The individual crops presented in Table 3. 1 were either grown as monocrops or mixed crops. Considering monocrops and mixed crops of the same crops to be different enterprises, we isolated 95 unique crop enterprises in the sample. Table 3. 2 presents the most popular enterprises, defined those that were selected by at least 0.5% of the households. The distribution of all 95 enterprises is presented in Appendix A.

The data show that monocropping is more common than mixed cropping in Zambia. The top twelve enterprises are all monocrops. The most popular monocrop is the maize monocrop, which is used by 84.15% of households, followed by groundnuts (45.86% of households) and cassava (28.66% of households). Among the mixed crop enterprises, the cassava*groundnut enterprise is the most common with 2.66% of households having this enterprise. It is followed by the maize*cassava (1.77% of households), millet*cassava (1.72%), maize*mixed beans (1.63%) and maize*groundnut enterprise (1.55%).

Table 3. 2: Distribution of the Most Popular Enterprises (N = 7,393)

	Enterprise	Unweighted Number of households growing the crop	Weighted number of households	Percent of Households (%)
1	Maize	6,767	1,177,529	84.15
2	Groundnuts	3,876	641,682	45.86
3	Cassava	1,894	401,050	28.66
4	Sweet potato	1,020	200,595	14.34
5	Mixed beans	1,070	195,067	13.94
6	Seed cotton	1,195	162,191	11.59
7	Sunflower	944	137,554	9.83
8	Millet	485	96,864	6.92
9	Soybeans	618	93,371	6.67
10	Rice	437	66,244	4.73
11	Sorghum	264	46,408	3.32
12	Bambara nuts	219	45,184	3.23
13	Cassava*Groundnuts	170	37,176	2.66
14	Maize*Cassava	126	24,774	1.77
15	Millet*Cassava	101	24,117	1.72
16	Maize*Mixed beans	130	22,768	1.63
17	Maize*Groundnuts	117	21,710	1.55
18	Cowpeas	95	17,652	1.26
19	Cassava*Sweet Potato	87	16,652	1.19
20	Burley tobacco	86	14,541	0.04
21	Cassava*Mixed beans	63	12,874	0.92
22	Maize*Pumpkin	68	11,702	0.84
23	Popcorn	55	11,097	0.79
24	Virginia tobacco	58	7,235	0.52

* = mixed crop

Source: Author's Analysis

The enterprises are the building blocks of the enterprise structure. The enterprise structure (EP) is the collection of all the individual enterprises on the farm. Based on the 95 enterprises, we identified 33 EPs that had a sample size of at least 30 households. These are presented in Table 3. 3.

Table 3. 3: Enterprise Structures with a Sample Size of at least 30 Households (N = 4895)

SN	Group	Number of Households Using the Enterprise Structure
1	Maize	953
2	Maize/Groundnut	755
3	Maize/Groundnut/Cotton	340
4	Maize/Cassava	310
5	Maize/Groundnut/Sunflower	260
6	Maize/Cotton	226
7	Maize/Cassava/Groundnut	208
8	Maize/Groundnut/Sweet potato	189
9	Maize/Groundnut/Beans	139
10	Cassava	124
11	Maize/Groundnut/Cotton/Sunflower	124
12	Maize/Sweet potato	116
13	Maize/Sunflower	102
14	Maize/Beans	98
15	Maize/Cassava/Groundnut/Beans	89
16	Maize/Groundnut/Soybean	83
17	Maize/Soybean	77
18	Maize/Cassava/Rice	74
19	Maize/Cassava/Beans	58
20	Maize/Rice	52
21	Maize/Cassava/Groundnut/Sweet potato	49
22	Maize/Groundnut/Soybean/Sunflower	46
23	Maize/Cassava/Sweet potato	45
24	Maize/Millet	45
25	Maize/Cotton/Sunflower	44
26	Maize/Sorghum	43
27	Cassava/Groundnut	42
28	Maize/Cassava/Groundnut/Beans/Sweet potato	39
29	Maize/Groundnut/Cotton/Rice	36
30	Maize/Groundnut/Millet	36
31	Maize/Groundnut/Rice	33
32	Maize/Groundnut/Cotton/Soybean/Sunflower	30
33	Cassava/Rice	30

Source: Author's Analysis

All the 33 EPs consisted only of monocrop enterprises. Thus, the enterprises in the 33 EPs can also be viewed as individual crops. The 33 EPs were all varying combinations of maize, groundnuts, cassava, mixed beans, seed cotton, sunflower, sweet potatoes, soybeans, rice, millet and sorghum (the 11 most popular crops grown in Zambia as presented in Table 3.1 above). The data show that 30 of the 33 EPs consist of maize supporting existing evidence that Zambia is a maize-centric country.

3.3 Theoretical Framework

This study is conceptualized based on the theory of economies of scope in diversification. The underlying theory behind the concept of economies of scope is as follows:

Suppose a firm is producing m outputs using n inputs. The firm chooses inputs to maximize profits as shown in the optimization problem below. Given that y_i is output for good i, p_i is the price of output i, x_j is the quamtity of input j and w_j is its price, Y is a vector of outputs $(y_1, y_{i,\ldots\ldots}, y_m)$ and X is a vector of inputs $(x_1,\ x_j, \ldots, x_n)$, a firm maximizes

$$\max \sum_{i=1}^{m} p_i\, y_i - \sum_{j=1}^{n} w_j x_j \qquad (16)$$

$$\text{s.t } Y_i = f(X) \qquad (17)$$

Solving this optimization problem, we find the optimal input levels (x_{i}^{*}). These optimal input levels can then be used to determine the cost function, $c(y_i, p_i)$ for a firm producing one output and the cost function, $c(Y, P)$ for a firm producing m outputs.

Economies of scope exist if:

$$\sum_{i=1}^{m} c(y_i, p_i) > c(Y, P) \qquad (18)$$

Or if:

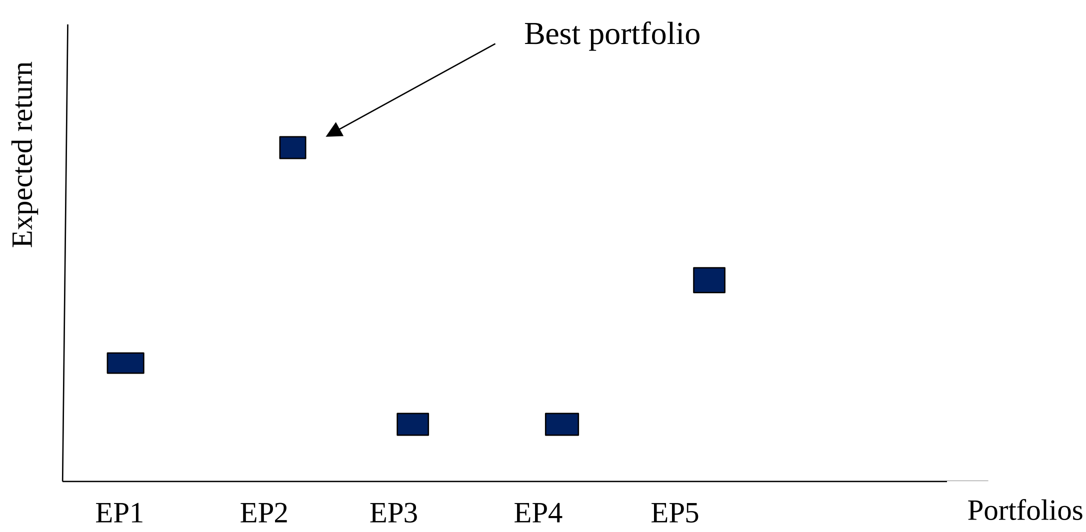
$$\frac{\sum_{i=1}^{m} c(y_i,p_i) - c(Y,P)}{c(Y,P)} > 0 \qquad (19)$$

That is, it is less costly to combine production of goods rather than producing them separately (Panzar and Willig 1981).

Crop portfolios differ in the extent of scope economies because of differences in cost complimentarities among crops in the portfolios. That is, production of the different crops in a portfolio may share inputs (i.e., land, fertilizer, moisture, sunlight, soil nutrients, labor, machinery, knowledge etc) to varying extents. The greater cost saving and/or higher productivity from producing certain crop portfolios results in higher return (profitability) than others.

The portfolio with the highest return is the one that provides the highest benefit from scope economies. Given a set of crop portfolios, a farmers will choose the portfolio with the highest expected returns. For example, as shown in Figure 3. 3, a farmer who has five different crop portfolios (EP1, EP2, EP3, EP4 and EP5) to choose from for a given growing season, will select EP2 because it has the highest expected return.

Figure 3. 3: Selection of Portfolio with the Highest Expected Return



Source: Author's Analysis

3.3 Conceptual Model

In this study, we are interested in examining the relationship between profitability and enterprise structure. We conceptualize that enterprise structures affect profitability. Therefore, we model profitability as a function of the enterprise structure, demographic characteristics, socio economic variables and production variables as follows:

$$\pi_i = f(EP, X) \tag{20}$$

where π is profitability, EP is the enterprise structure variable and X is a vector of explanatory variables. Because of the influence of climatic and soil conditions on the adoption and profitability of enterprise structures (Schurle and Tholstrup 1989; Mishra, El-Osta, & Steele, 1999; Barry, Escalante, and Bard 2001; Poon and Weersink 2011), we estimate separate models for each agro ecological location i. The framework supporting the conceptual model is presented in Figure 3.4.

3.3.1 Independent Variables

The variables that affect profitability have widely been studied in agriculture. Based on previous literature, we identify variables that are also consistent with the theoretical foundation of this study. The vector of explanatory variables in this study therefore includes (1) demographic characteristics such as gender, age, education and household size; (2) socio-economic variables such as wealth, access to subsidies and farm size; and (3) production characteristics which include the use of fertilizer and improved seed and practicing crop rotation.

1. Demographic Variables

i) Gender - which represents differences in production choices between male and female farmers because of differences in access to institutional services and opportunities (The World Bank 2008).

ii) Age - which is related to farming experience (Omiti et al. 2009) and has been shown to positively affect profitability (Mishra, El-Osta, & Steele 1999; Purdy, Langemeier, and Featherstone 1997).

iii) Household Size - a proxy for the production and consumption situation facing the household (Moraka 2001).

iv) Education - which has been shown to influence productivity and management ability (Randela, Alemu, and Groenewald 2008).

2. Socio-economic Variables

v) Asset Value - a proxy for wealth (Pope and Prescott 1980). Better endowed farmers are able to adopt more profitable capital intensive cropping systems

vi) Subsidy – which may reduce the out of pocket expenditure on production cost and/or increase revenues from production.

vii) Farm size - because larger farms may enhance income through high production and economies of scale (Poon and Weersink 2011).

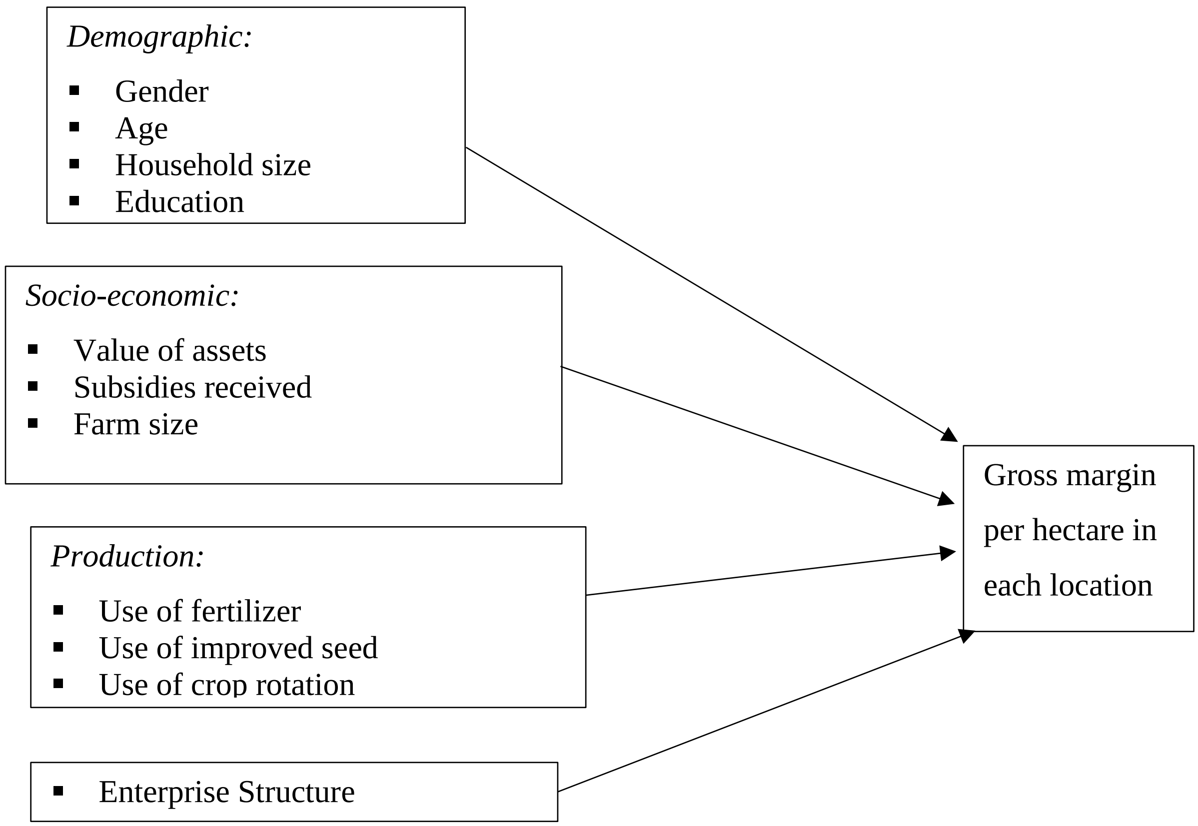
3. Production Variables

viii) Use of fertilizer – a yield enhancing input

ix) Use of improved seed – which has also been shown to improve yields

x) Use of crop rotation – which helps to control for weeds, pests and diseases and also replenish soil nutrients leading to a reduction in input costs (Davis et al. 2012; Helmers, Yamoah, and Varvel 2001).

Figure 3. 4: Factors Influencing Farm Profitability



Source: Author's Analysis

Table 3. 4: Description of Variables

Variables	Description of Variable	Type of Variable
Dependent Variable		
Gross margin per hectare	total crop revenue less total variable costs per hectare	Continuous
Independent variables		
Enterprise Structure	Combination of enterprises that make up the farm	Categorical
Age	Age of household head in years	Continuous
Gender	1 if household head is male, 0 otherwise	Categorical
Education	Years of education	Continuous
Household size	Number of household members	Continuous
Value of Assets	Total value of agricultural assets in ZMW	Continuous
Subsidy	Amount of subsidy received in ZMW	Continuous
Farm size	Total land area owned (hectares)	Categorical
Fertilizer per hectare	Amount of fertilizer applied per hectare in kg/ha	Continuous
Improved seed	Proportion of cultivated area planted with improved seed	Continuous
Crop rotation	Use of crop rotation between the previous and current growing season (1=Yes, 0 = No)	Categorical
Agro ecological zone I	1 if the farm is located in agro ecological zone I, 0 otherwise	Categorical
Agro ecological zone II a	1 if the farm is located in agro ecological zone II a, 0 otherwise	Categorical
Agro ecological zone II b	1 if the farm is located in agro ecological zone II b, 0 otherwise	Categorical
Agro ecological zone IIII	1 if the farm is located in agro ecological zone III, 0 otherwise	Categorical

Source: Author's Analysis

3.4 Empirical Framework

To achieve our second objective, we estimate Ordinary Least Squares (OLS) regression models for each of the four regions in the study area. In estimating $y = X\beta + u$, where y is the dependent variable, X is an n by k matrix of independent variables and u is the error term, the classical assumptions needed for the OLS/Gaussian regression model include the following:

(i) $E(u|X) = 0$, where E is the expectation operator. This assumption implies exogeneity of explanatory variables.

(ii) $Variance\ (u|X) = E(uu'|X) = \sigma^2 I_n$, where σ^2 is the variance and I_n is an identity matrix. This assumption implies homoscedasticity and no autocorrelation between error terms.

(iii) $rank\ (X) = k$. $\text{cov}(X_i, X_j) = 0 i \neq j$ This implies no multicollinearity between independent variables.

(iv) X is a stochastic or non-stochastic matrix.

(v) $u \sim N(0, \sigma^2 I_n)$, That is, the u vector has a multivariate normal distribution.

When the classical assumptions hold, the Gauss-Markov theorem states that OLS has the smallest variance in the class of linear, unbiased estimators (Wooldridge 2003). Given that $\hat{\beta}$ is an estimator of the true coefficient β, linearity implies that $\hat{\beta} = AY$ meaning that the regression is linear in parameters. Unbiasedness means that $E(\hat{\beta}) = \beta$. The variance of the estimator $(\hat{\beta})$ which is given by $\sigma^2(X'X)^{-1}$is the smallest variance (most efficient). Under the Gauss-Markov theorem, $\hat{\beta}$ is the best, linear unbiased estimator (BLUE) of β.

Besides being a BLUE estimator, other reasons that motivate the use of OLS when classical assumptions hold, include: (1) ease of computation; and (2) providing an optimal linear prediction of the dependent variable, making it more robust compared to other estimation methods (Greene 2008).

In exploring the effect of enterprise structure on farm profitability, we estimate an OLS regression and test if classical assumptions hold in each of the models. The model that we estimate is:

$$\pi = \beta_0 + \beta_1 EP + \beta_i x_i + u \tag{21}$$

where π is the farm gross margin per hectare or gross margin per total variable costs, EP is the enterprise structure variable which is a categorical variable of up to 33 different groups, x_i is a control variable i .

We test for heteroscedasticity using the Breusch-Pagan test and the White test. Using both tests, we fail to reject the null hypothesis of no heteroscedasticity. Under heteroscedasticity, OLS is unbiased but inefficient. As such, the hypothesis tests (t-tests and F-tests) may be inaccurate. To correct for heteroscedasticity, we transform our linear model to a semi-log model by using the log of profitability as our dependent variable. We also use White's robust standard errors in our models as a remedy for heteroscedasticity.

Multicollinearity occurs when two or more independent variables are linearly correlated. To test for multicollinearity in our regression models, we first examine the partial correlation coefficients between our independent variables. We observe low correlation among our variables. However, we also use a statistical procedure called the variance inflation factor (VIF) to further test for multicollinearity. The VIF shows how the variance of an estimator is inflated in the presence of multicollinearity (Gujarati and Porter 2003). The VIF is calculated as: $VIF = \frac{1}{1-r_{ij}^2}$

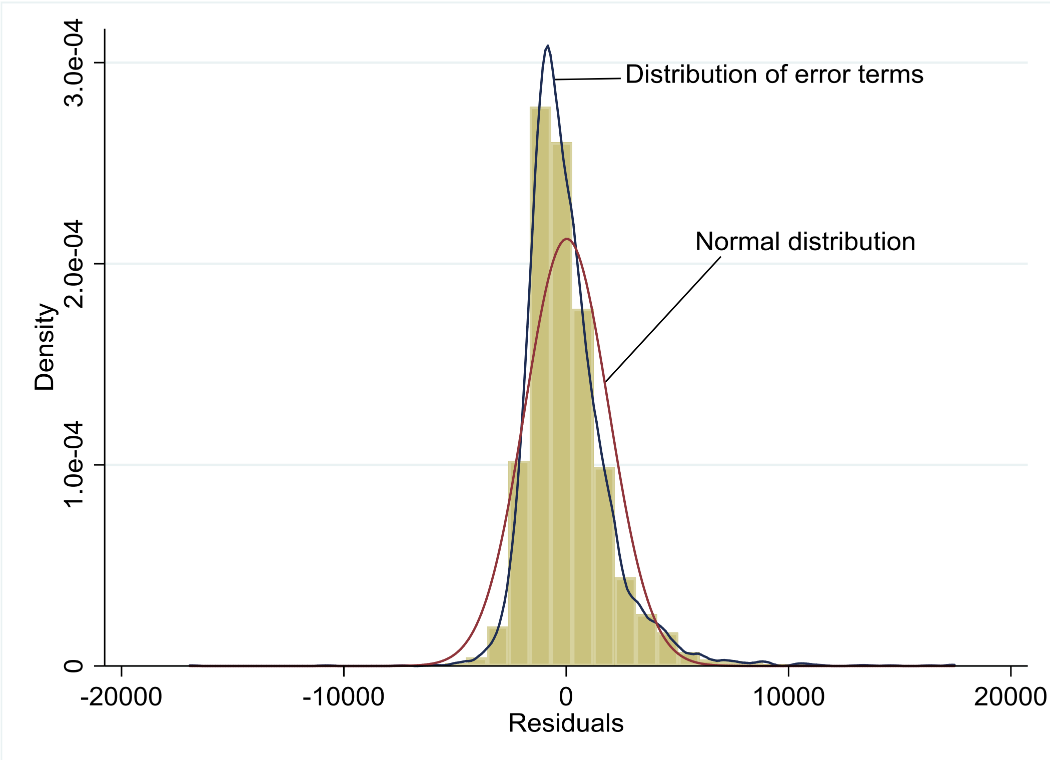
where r_{ij} is the coefficient of correlation between regressors x_i and x_j. In the absence of multicollinearity, the VIF is 1 and as collinearity between x_i and x_j increases, the VIF approaches infinity. As a rule of thumb, a VIF of more than 10 indicates the presence of multicollinearity (Gujarati and Porter 2003). In our models, we find that the highest VIF is 3.97. We, therefore, conclude that there is no evidence of multicollinearity in the models.

Endogeneity implies that there is correlation between the explanatory variable and the error term. It could arise from omitted variable bias, simultaneity and/or errors in variables (Wooldridge 2003). In the presence of endogeneity, OLS is biased and inconsistent. The Hausman test for endogeneity involves regressing the endogenous variable on the instrumental variables and getting the residuals from this estimation. The residuals are then added as another explanatory variable in the regression of the dependent variable on the endogenous variables. If the coefficient on the residual is statistically different from zero, then the null hypothesis of no endogeneity cannot be rejected.

Given that our variable of interest in equation (1) is a categorical variable of 33 unique enterprise structures, we face the challenge of testing for endogeneity of the enterprise structure variable in this study. Accounting for endogeneity would require that the 33 enterprise structures are collapsed into a single measure, such as an index of diversification. Since the goal of the study is to take advantage of the heterogeneity in the different enterprise structures, we proceed by estimating the enterprise structure as a dummy variable of 33 unique categories. This approach comes at a cost of not being able to account for endogeneity. In the presence of endogeneity, our study would only provide suggestive results (Michler and Josephson 2017).

Assumption (iv) is achieved because the vector of independent variables in our models is deterministic. In addition, our models are linear in parameters and error terms, thereby satisfying linearity. Although the normality assumption is not required for estimation, it is necessary for hypothesis tests using the t-test and F-test to be valid (Gujarati and Porter 2003). Therefore, we test for the normality of error terms in our models. Using the full sample, error terms in model (1) are distributed as shown in Figure 3. 5. The data shows that the distribution of residuals from model (1) closely follow a normal distribution. We also use statistical tests for normality, that is, the Jacque-Bera test and the Shapiro-Wilk test. The normal distribution of error terms implies that hypothesis tests from OLS are likely to be valid in this study.

Figure 3. 5: Testing the Normality Assumption



Source: Author's Analysis

3.4.1 OLS Model specification

Having established that OLS estimation is likely to be valid in this study, we proceed to specify the empirical model that will be employed in this study. For each of the j =1, 2, 3 and 4 regions, we estimate the following model:

$$ln\pi_{ij} = \beta_{oj} + \beta_{1j}EP_j + \beta_{2j}Age + \beta_{3j}Gender + \beta_{4j}Household\ size + \beta_{5j}Education + \beta_{6j}Value\ of\ assets + \beta_{7j}Subsidies + \beta_{8j}Farm\ size + \beta_{9j}Fertilizer + \beta_{10j}Improved\ seed + \beta_{11j}Crop\ rotation \quad (22)$$

where π_{ij} is the gross margin per hectare or gross margin per total variable costs of farmer i in region j and EP_j is a dummy variable of enterprise structures in region j. The enterprise structures examined in each region are those that are adopted by at least 30 households.

Model (22) is selected based on the Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC) for model selection. While the R^2 provides an alternative measure of goodness of fit, it does not penalize enough for additional parameters such that in large samples, irrelevant regressors may be included in the model (Cameron and Trivedi 2005). The AIC and BIC, on the other hand, have a penalty that is large enough to exclude irrelevant regressors but not relevant ones. Given that k is the number of regressors and N is the sample size, the AIC and BIC are defined as:

$$AIC = -2 * \ln(likelihood) + 2 * k \tag{23}$$

$$BIC = -2 * \ln(likelihood) + \ln(N) * k \tag{24}$$

The goodness of fit of the model is measured by $-2 * \ln(likelihood)$ while the complexity of the model is measured by $2 * k$ or by $\ln(N) * k$ (Cameron and Trivedi 2005). The model with the lowest AIC or BIC is the most preferred. Based on the AIC and BIC, we selected Model (22).

Chapter 4: Results and Discussion

This chapter presents the descriptive statistics of the sample and the results of the empirical estimation. It begins by presenting summary statistics on the full sample of 7,393 farming households in the data. Thereafter, it focuses in on 4,895 farmers who used any of the 33 enterprise structures (hereafter EPs), showing the ways in which farmers adopting each of these EPs are different from each other. Results of the empirical estimation based on these 4,895 farmers are then presented. The results of the empirical estimation of the effect of crop diversification on profitability using the enterprise structure approach are compared to those in which an index of diversification is used.

4.1 Descriptive Statistics

Table 4.1 presents summary statistics on the data. The results show that, on average, farmers are making a gross margin per hectare of ZMW2,485.09/ha. Of all the households in the sample, 76% were male-headed households. This result closely follows official findings from Zambia's 2013-2014 Post-Harvest Survey (PHS) which shows that 77.3% of agricultural households were male-headed households in the 2013-2014 agricultural season (CSO 2016). The average age of the household head in our sample is 48.04 years and the average number of years of education is 5.80 years. This is also in line with the findings from the 2013-2014 PHS which showed that the majority of household heads were in the age group of between 35-39 years and had completed primary education (7 years). The results show that the average household size is 6.63 members which is also close to the findings from the 2013-2014 PHS that show that most of the households had between 4 and 6 household members.

In terms of socio-economic variables, the results show that the average value of agricultural assets owned by households is ZMW677.68 and on average, an agricultural household received ZMW275.48 in subsidies from the government's Farmer Input Support Program (FISP). In terms of farm size, the results show that majority of the farmers own less than 2 hectares of land, with 72% of the farmers being in the category of small farms (own between greater than 0 and 1.99 hectares of land). The medium farms of between 2 and 4.99 hectares represent 21% of the sample while the large farms of between 5 and 19.99 hectares make up 7% of the sample.

Table 4.1: Summary Statistics on the Sample (N= 7,393, Weighted N = 1,399,331)

Variable	Mean	Std. Dev.	Min	Max
Dependent variable				
Gross Margin per hectare	2485.09	1942.53	-15062.3	36286.78
Demographic variables				
Male	0.76		0	1
Age	48.04	15.27	16	105
Household size	6.63	2.80	1	30
Years of Education	5.80	3.84	0	19
Socio-economic variables				
Value of assets	677.68	4,046.67	0	160,100
Amount of subsidy	275.48	692.50	0	19,470
Small farm (0-1.99 hectares)	0.72		0	1
Medium farm (2 - 4.99 hectares)	0.21		0	1
Large farm (5 - 19.99 hectares)	0.07		0	1
Production variables				
Kgs of fertilizer per hectare	111.81	130.15	0	1,275
Improved seed	0.56		0	1
Crop rotation	0.48		0	1
Geographical location (Number of farms)				
AEZ I	0.08		0	1
AEZ II a	0.40		0	1
AEZ II b	0.08		0	1
AEZ III	0.43		0	1

Exchange rate: $1= ZMW6.4 (Exchange-rates.org 2019)

Source: Author's Analysis

The production characteristics of farmers in the sample show that the average quantity of fertilizer applied by each household is 111.81 kg/ha. This is also close to the national average fertilizer application rate of between 100.7 to 120.7 kg/ha as reported by Chapoto and Chisanga (2016). Chapoto and Chisanga (2016) also report that nationally, 62% to 72% of rural households use improved seed, irrespective of crop. Findings in this study show that 76% percent of farmers used improved seed. To account for variability among households who used improved seed, we computed the proportion of area planted on which households used improved seed. The results show that, on average, households used improved seed on 56% of the land area planted. With respect to crop rotation, 48% of households reported rotating cereals with nitrogen fixing crops between the 2013 and 2014 agricultural seasons.

In terms of agro-ecological location, the results show that the majority of farmers are located in AEZ IIa and III, with 40% and 43% of the farmers in the sample being located in these zones, respectively. This result could be attributed to the large surface areas of regions AEZ II and III (42% and 46% of the country's surface area, respectively (ZAMSEED 2019)) which allow them to accommodate more households.

4.1 Enterprise Structures with at least 30 Households

The 33 EPs that were adopted by at least 30 households are the focus of the empirical estimation in this study. The threshold of 30 households is selected because, as a rule of thumb, 30 is the minimum sample size required for a sample to be considered "large" for purposes of drawing statistical inferences based on the normal distribution (Hogg, Tanis, and Zimmerman 2015). Focusing our empirical analysis on 33 EPs reduces our sample size from 7,393 to 4,895.

To simplify the nomenclature of the EPs, we use the following abbreviations to represent crops:

i. Mz - Maize
ii. Gn – Groundnuts
iii. Cs – Cassava
iv. Ct – Seed cotton
v. Sp – Sweet potato

vi. Mb – Mixed beans (beans)
vii. Sb – Soybeans
viii. Sf – Sunflower
ix. Ml – Millet
x. Sg - Sorghum
xi. R – Rice.

Table 4.2 shows that the most common form of diversification involves growing two or three crops. Of the 33 EPs, two involve specialization, 12 EPs involve diversification with two crops, 12 EPs involve diversification with three crops, five EPs involve diversification into four crops and two EPs involve diversification with five crops. EPs that involve more than five crops and those that involve mixed cropping are not popular in the country as they did not meet the threshold of being used by at least 30 households. An advantage of the use of the EP over an index of diversification is that it clearly separates farms that have the same level of diversification based on the index. For example, the farmers specializing in maize are separated from those who are specializing in cassava.

Table 4.2 also shows that the top five most popular EPs ((1) Mz; (2) Mz/Gn; (3) Mz/Gn/Ct; (4) Mz/Cs; and (5) Mz/Gn/Sf)) represent more than 50% of households in the sample. The results further show that all but three EPs contain maize. The majority of all the EPs also contain groundnuts and/or cassava. That is, 30 EPs contain maize, 17 contain groundnuts and 11 contain cassava.

Table 4.2: Names of Enterprise Structures and Percentage of Households Using them

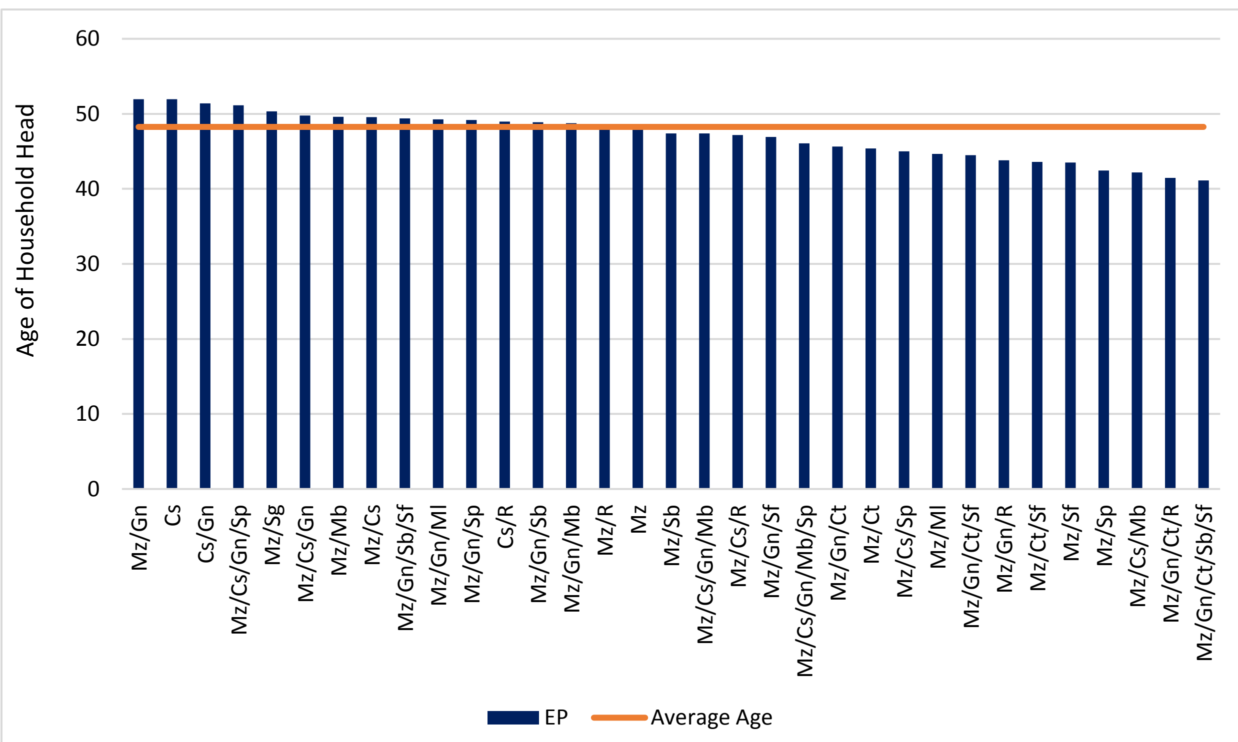
Enterprise Structure (EP) Name	Abbreviated Enterprise Structure Name	Percentage of Households using the EP
Maize	Mz	19.47
Cassava	Cs	2.53
Maize/Groundnuts	Mz/Gn	15.42
Maize/Cassava	Mz/Cs	6.33
Maize/Cotton	Mz/Ct	4.62
Maize/Sweet potato	Mz/Sp	2.37
Maize/Sunflower	Mz/Sf	2.08
Maize/Mixed beans	Mz/Mb	2.00
Maize/Soybeans	Mz/Sb	1.57
Maize/Rice	Mz/R	1.06
Cassava/Groundnuts	Cs/Gn	0.86
Maize/Sorghum	Mz/Sg	0.88
Cassava/Rice	Cs/R	0.61
Maize/Millet	Mz/Ml	0.92
Maize/Groundnuts/Cotton	Mz/Gn/Ct	6.95
Maize/Groundnuts/Sunflower	Mz/Gn/Sf	5.31
Maize/Cassava/Groundnuts	Mz/Cs/Gn	4.25
Maize/Groundnuts/Sweet potatoes	Mz/Gn/Sp	3.86
Maize/Groundnuts/Mixed beans	Mz/Gn/Mb	2.84
Maize/Groundnuts/Soybeans	Mz/Gn/Sb	1.70
Maize/Cassava/Rice	Mz/Cs/R	1.51
Maize/Cassava/Mixed beans	Mz/Cs/Mb	1.18
Maize/Groundnuts/Rice	Mz/Gn/R	0.67
Maize/Cassava/Sweet potatoes	Mz/Cs/Sp	0.92
Maize/Cotton/Sunflower	Mz/Ct/Sf	0.9
Maize/Groundnuts/Millet	Mz/Gn/Ml	0.74
Maize/Cassava/Groundnuts/Mixed beans	Mz/Cs/Gn/Mb	1.82
Maize/Groundnuts/Cotton/Sunflower	Mz/Gn/Ct/Sf	2.53
Maize/Groundnuts/Cotton/Rice	Mz/Gn/Ct/R	0.74
Maize/Groundnuts/Soybeans/Sunflower	Mz/Gn/Sb/Sf	0.94
Maize/Cassava/Groundnuts/Sweet potatoes	Mz/Cs/Gn/Sp	1.00
Maize/Groundnuts/Cotton/Soybeans/Sunflower	Mz/Gn/Ct/Sb/Sf	0.61
Maize/Cassava/Groundnuts/Mixed beans/Sweet potatoes	Mz/Cs/Gn/Mb/Sp	0.80
Total	**Total**	**100**

Source: Author's Analysis

4.2 Characteristics of Farmers Using the 33 Enterprise Structures

We examine the general characteristics of farmers who are using the 33 EPs to get an idea of how similar or different they are from each other. The demographic and socio-economic patterns of farmers using the different EPs are presented in Figure 4. 1 , Figure 4.2, Figure 4. 3 and Figure 4.4. Based on Figure 4. 1 , Figure 4.2 and Figure 4. 3, the results show that farmers who were older, the farmers who had lower asset values and those who had smaller farms tended to adopt EPs that were dominated by food crops such as cassava, beans and sweet potato. On the other hand, the farmers who were younger, the farmers who had higher asset values and those that owned larger farms tended to adopt enterprise structures that were dominated by cash crops such as cotton, soybeans and sunflower.

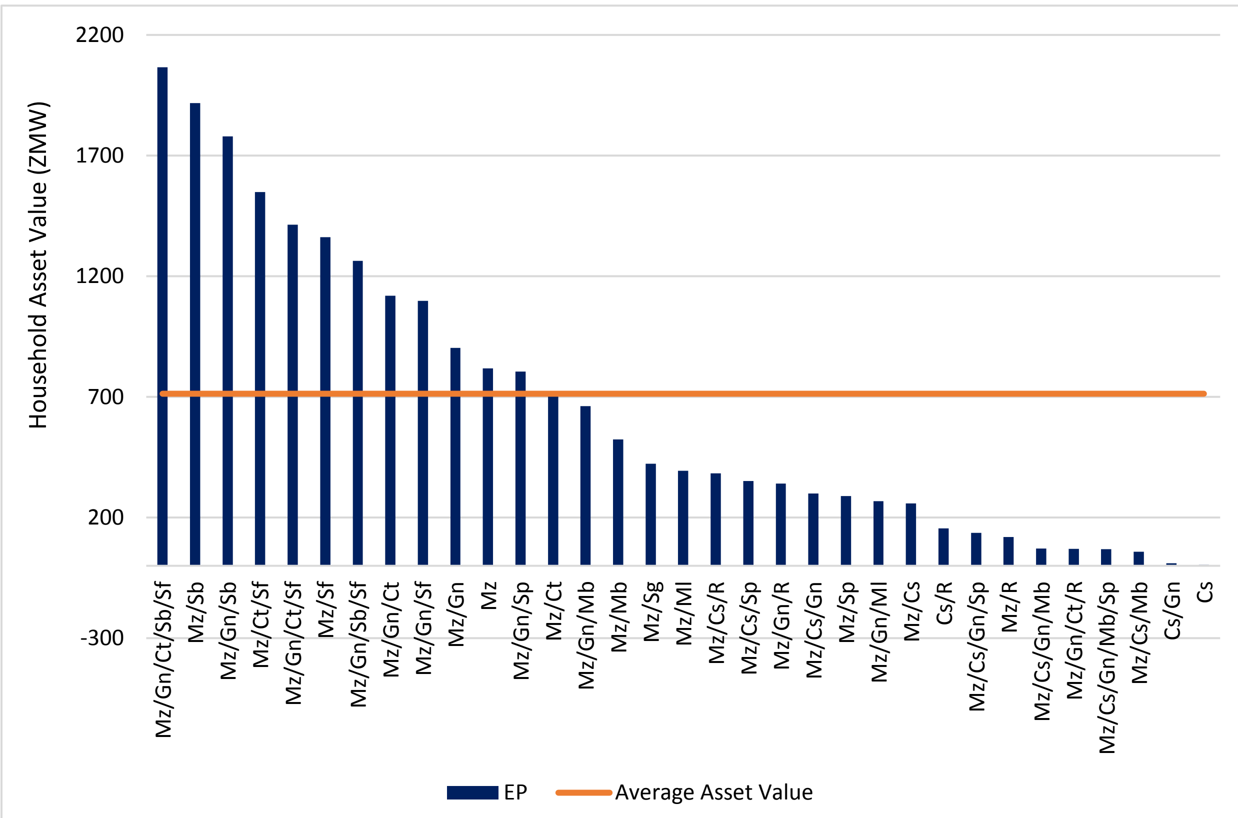
Figure 4. 1: Age of Household Head among the Farmers Using the 33 Enterprise Structures



Source: Author's Analysis

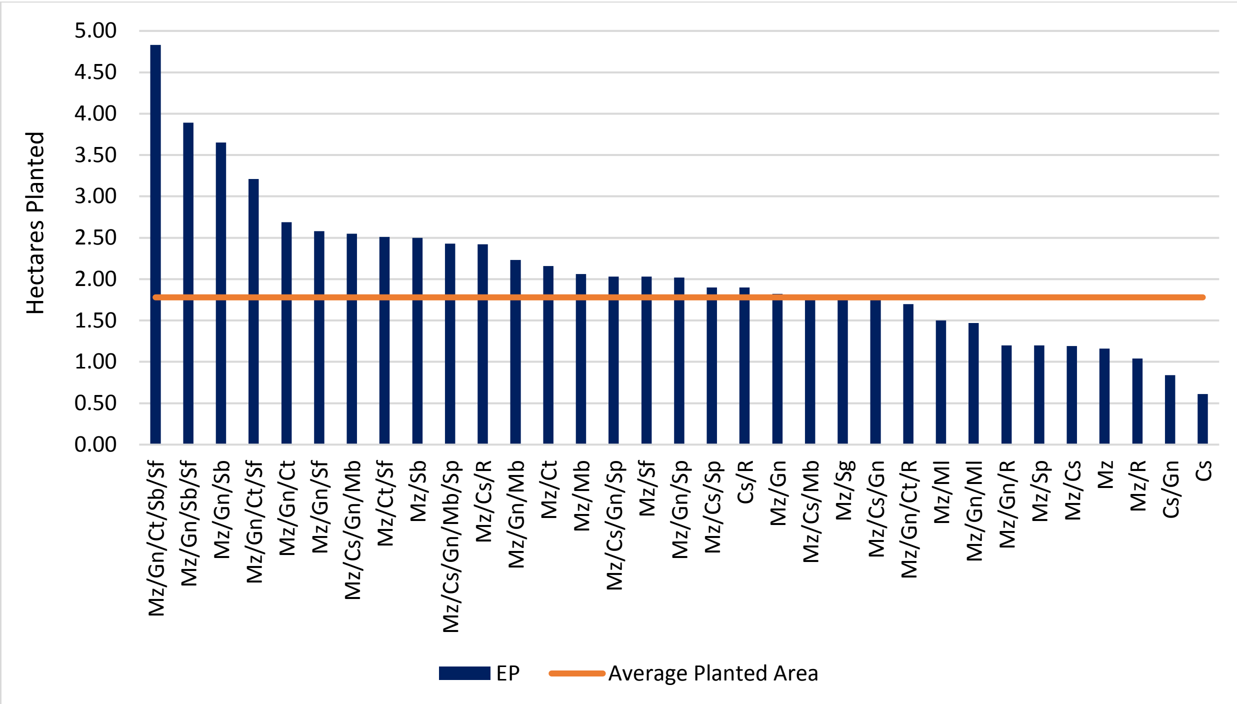
Based on Figure 4.4, the results also suggest that EPs that were dominated by food crops like rice, cassava and groundnuts tended to have a higher proportion of female farmers while those that were dominated by cash crops like cotton, soybeans and sunflower tended to have a higher proportion of male farmers. The results do not show any notable patterns in education, use of subsidies and use of improved seed among farmers. Detailed demographic characteristics of farmers using each of the 33 EPs are presented in Table A.4 in Appendix A.

Figure 4.2: Total Asset Values among Farmers Using the 33 Enterprise Structures



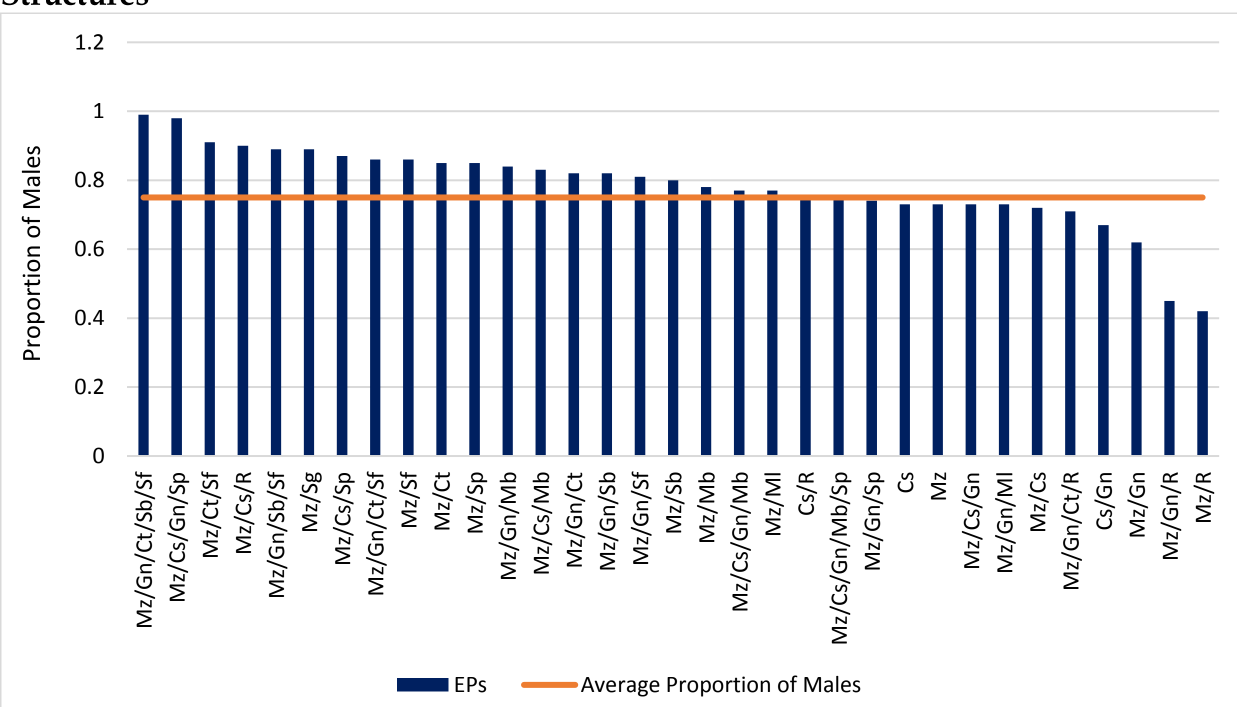
Source: Author's Analysis

Figure 4. 3: Hectares Planted by Farmers Adopting the 33 Enterprise Structures



Source: Author's Analysis

Figure 4.4: Proportion of Male Households among the Farmers Using the 33 Enterprise Structures



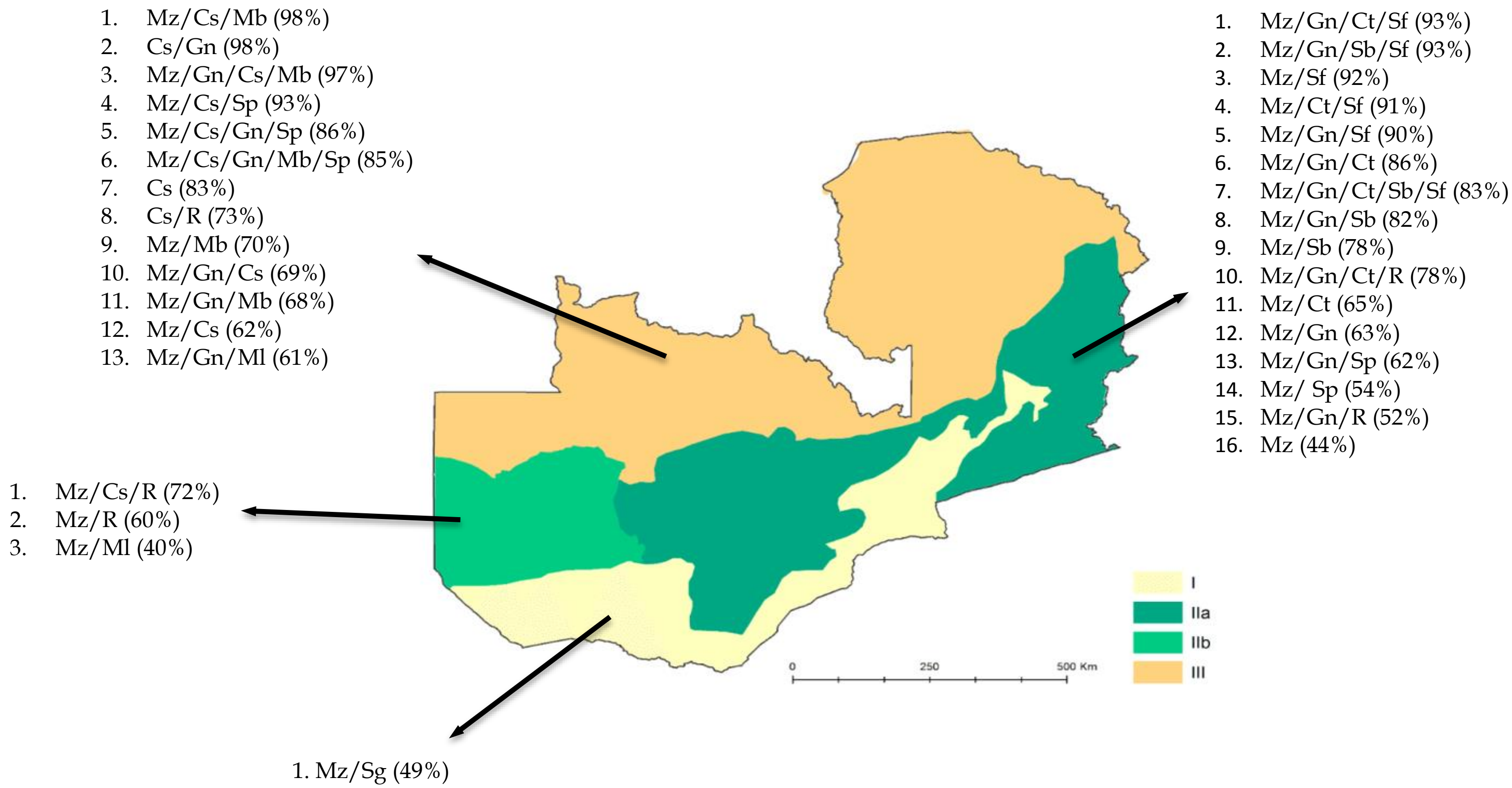
Source: Author's Analysis

4.3 Geographical Distribution of Enterprise Structures

Bearing in mind that geography can influence the type of EPs that farmers adopt as well as their associated profitability, we examined the distribution of EPs across the different agro ecological regions of Zambia. Figure 4.5 shows where the majority of households adopting each of the EPs are located. The results show that, among the farmers who adopted the Mz EP, almost half of them are in AEZ IIa. The results also suggest that the EPs that have cassava and mixed beans are mostly found in AEZ III while the EPs that contain groundnuts, soybean, sunflower and cotton are mostly found in AEZ IIa. The Mz/Sg EP is mostly found in AEZ I, which is the most arid region. Rice-based EPs are mostly found in AEZ IIb, which is the agro-ecological zone with flood plains. A detailed analysis of the distribution of EPs across the different regions is presented in Appendix III.

We further examined the distribution of EPs within each region to determine the relative concentration of EPs in each region. The results in Table 4.3 show that the Mz EP is the most common EP in AEZ I with 32.13% of farmers in the region using it. The Mz/Gn EP (used by 18.67% of households) and the Mz/Ct EP (used by 11.24% of households) are the second and third most popular EPs in AEZ I. The concentration ratio of the top three EPs (CR3) in AEZ I is 62.04%. Unlike AEZ I where the Mz EP is the most common, in AEZ IIa, the most common EP is the Mz/Gn EP which is used by 20.24% of farmers in the region. The Mz EP is the second most popular EP, grown by 17.81% of households. It is followed by the Mz/Gn/Ct EP (used by 12.40% of households) and the Mz/Gn/Sf EP (used by 10.01% of households). The CR3 in AEZ IIb is 50.45%. In AEZ IIb, the most popular EPs are the Mz/Cs (used by 23.95% of households), Mz (used by 16.3% of households) and the Mz/Cs/R EP (used by 13.09% of households) which together account for 53.34% of households. In AEZ III, the top three EPs represent only about 40.97% of households. These EPs include Mz (used by 18.78% of households), Mz/Cs (used by 11.61% of households) and Mz/Gn (used by 10.58% of households).

Figure 4.5: Distribution of Enterprise Structures across Zambia



Source: Author's Analysis

Table 4.3: Percentage of Households Using the Different Enterprise Structures by Agro-Ecological Region

EP	AEZ I	AEZ IIa	AEZ IIb	AEZ III	Total
Mz	32.13	17.81	16.3	18.78	19.47
Cs	0.00	0.04	4.94	6.26	2.53
Mz/Gn	18.67	20.24	3.21	10.58	15.42
Mz/Cs	1.00	0.72	23.95	11.61	6.33
Mz/Ct	11.24	6.26	5.19	0.12	4.62
Mz/Sp	2.01	1.83	0.00	3.83	2.37
Mz/Sf	1.61	4.01	0.00	0.00	2.08
Mz/Mb	1.61	0.89	0.00	4.19	2.00
Mz/Sb	0.2	2.56	0.00	0.97	1.57
Mz/R	2.41	0.21	7.65	0.24	1.06
Cs/Gn	0.00	0.00	0.25	2.49	0.86
Mz/Sg	4.22	0.04	0.99	1.03	0.88
Cs/R	0.00	0.00	1.98	1.34	0.61
Mz/Ml	2.01	0.13	4.44	0.85	0.92
Mz/Gn/Ct	7.23	12.40	3.21	0.00	6.95
Mz/Gn/Sf	3.61	10.01	0.74	0.24	5.31
Mz/Cs/Gn	0.4	1.28	8.15	8.69	4.25
Mz/Gn/Sp	3.21	4.99	0.00	3.40	3.86
Mz/Gn/Mb	1.61	1.53	0.25	5.71	2.84
Mz/Gn/Sb	0.20	2.90	0.49	0.73	1.70
Mz/Cs/R	0.00	0.00	13.09	1.28	1.51
Mz/Cs/Mb	0.00	0.00	0.25	3.47	1.18
Mz/Gn/R	1.81	0.72	0.00	0.43	0.67
Mz/Cs/Sp	0.00	0.13	0.00	2.55	0.92
Mz/Ct/Sf	0.20	1.70	0.74	0.00	0.90
Mz/Gn/Ml	1.20	0.13	1.23	1.34	0.74
Mz/Cs/Gn/Mb	0.00	0.13	0.00	5.23	1.82
Mz/Gn/Ct/Sf	1.20	4.90	0.74	0.00	2.53
Mz/Gn/Ct/R	1.20	1.19	0.49	0.00	0.74
Mz/Gn/Sb/Sf	0.00	1.83	0.49	0.06	0.94
Mz/Cs/Gn/Sp	0.80	0.13	0.00	2.55	1.00
Mz/Gn/Ct/Sb/Sf	0.00	1.07	1.23	0.00	0.61
Mz/Cs/Gn/Mb/Sp	0.20	0.21	0.00	2.01	0.80
Total	**100**	**100**	**100**	**100**	**100**

Source: Author's Analysis

The difference in concentration ratios across the regions is consistent with the differences in the agronomical characteristics of the regions. AEZ III has the lowest CR3 relative to other regions. This low concentration ratio suggests that there is more variety in the EPs that farmers are using in this region. Given that AEZ III has the longest growing period which can accommodate more crops, the high variety of EPs in this region is understandable. AEZ I, on the other hand, has the shortest growing season. As such, the number and type of crops that can be grown in AEZ I is limited. Accordingly, AEZ I has the highest CR3 which shows that most of the farmers are growing similar crops.

4.4 Distribution of Enterprise Structures by Gender

We also looked at the concentration ratios across male and female farmers to find out if there were any gender differences in the variety of EPs within each gender category. Table 4.4 presents the top four EPs in each gender category. The full distribution of all the EPs by gender is presented in Table A.5 in Appendix A. Table 4.4 shows that the most popular EP among female farmers is the Mz/Gn EP while the most popular EP among male farmers is the Mz EP. Although the order is different, the top four EPs among both the male and female farmers are the same i.e., Mz, Mz/Cs, Mz/Gn and Mz/Gn/Ct. In terms of the concentration ratio of the top 4 EPs (CR4), the results show that the CR4 among female farmers is 55.04% while the CR4 among male farmers is 41.66%. The higher concentration ratio among female farmers suggests that there is less variety in EPs among female farmers compared to male farmers.

Table 4.4: Distribution of the Top Four Enterprise Structures, by Gender

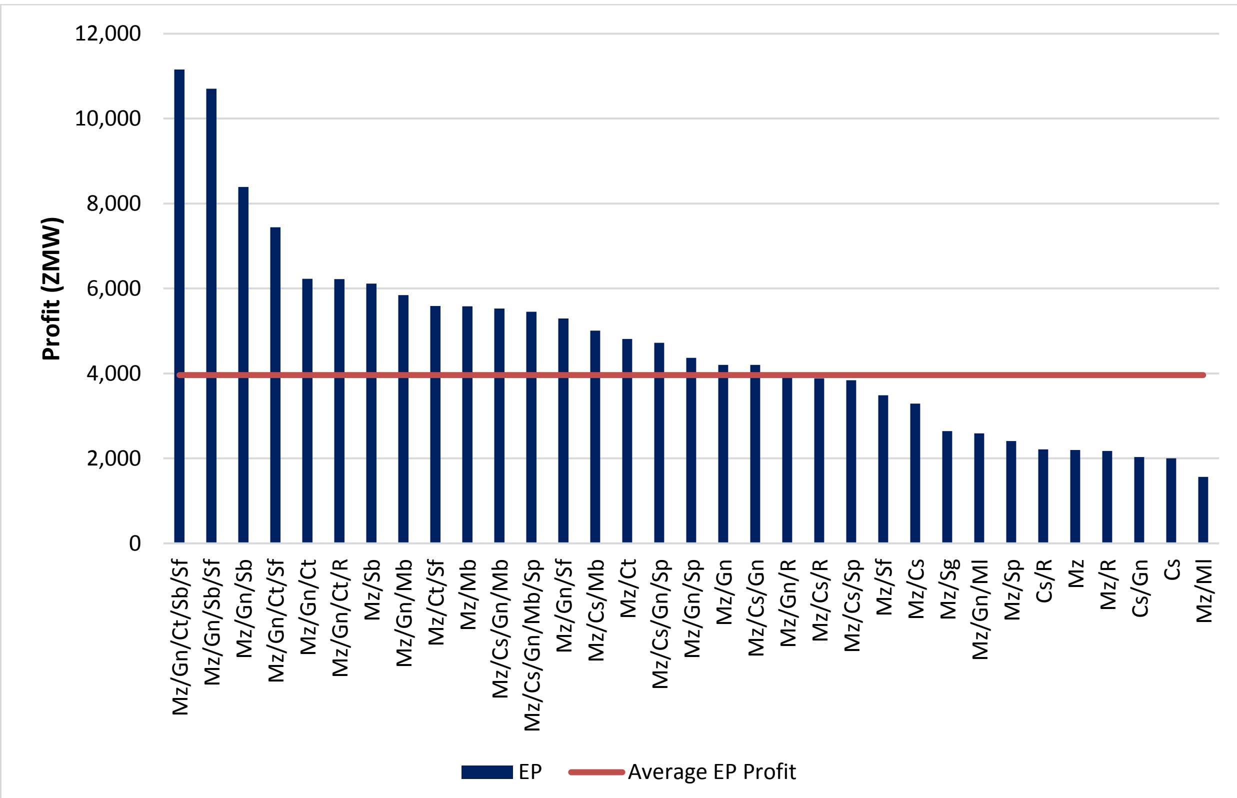
Enterprise Structure	Percent (%) of Female Farmers using the EP	Enterprise Structure	Percent (%) of Male Farmers using the EP
Mz/Gn	21.6	Mz	19.1
Mz	20.99	Mz/Gn	13.9
Mz/Cs	6.69	Mz/Gn/Ct	7.24
Mz/Gn/Ct	5.76	Mz/Cs	6.25
CR4	**55.04**	**CR4**	**46.49**

Source: Author’s Analysis

4.5 Average Profitability of Enterprise Structures

We compared the profit and profitability of the different EPs to find out which EPs were more/less profitable than others. Figure 4.6 shows the average gross margin associated with each EP. Average gross margin is gross revenue less total variable costs. It does not account for the size of production. The results show that the Mz/Gn/Ct/Sb/Sf EP had the highest gross margin followed by the Mz/Gn/Sb/Sf EP. The EPs with the lowest gross margin were the Mz/Ml followed by the Cs EPs.

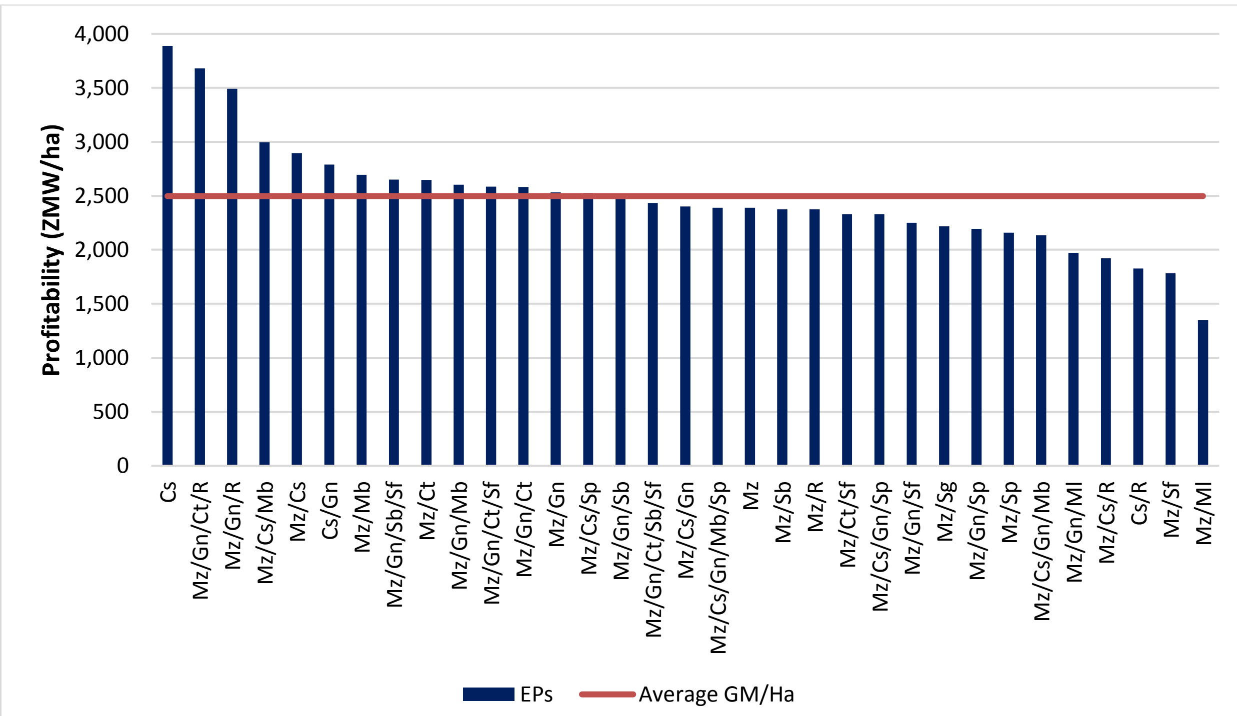
Figure 4.6: Average Gross Margin, by Enterprise Structure



Source: Author's Analysis

When we account for size of production by estimating the average gross margin per hectare for each EP, the results show that the most profitable EP is the Cs EP followed by the Mz/Gn/Ct/R EP as shown in Figure 4.7. The high gross margin per hectare associated with the Cs EP was initially puzzling since cassava is not considered a high-income crop in Zambia. However, the high-volume nature of cassava (as shown in Figure 4.9) as well as the small farm sizes of cassava growers (as shown in Table 4.5) help to explain the high gross margin per hectare associated with the Cs EP. Another factor that partly explains the high gross margin per hectare of the Cs EP is that the cassava output that was recorded in the household questionnaire was the total amount of mature cassava produced, both harvested and unharvested. Households in Zambia tend to harvest cassava as and when need arises. As such, the actual quantity of cassava that the household could have harvested may only be a fraction of what was recorded. The gross margin and revenue for cassava should therefore be interpreted with caution, as being the gross margin and revenue from mature cassava whether harvested or unharvested.

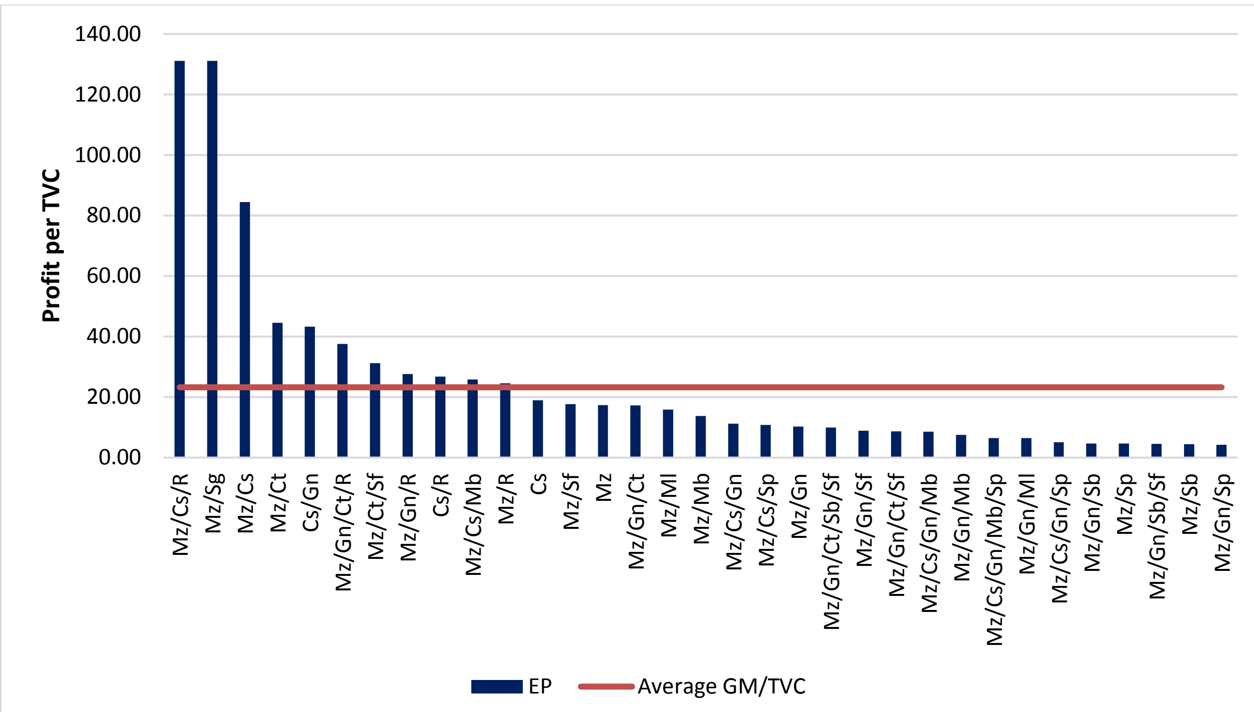
Figure 4.7: Average Gross Margin per Hectare, by Enterprise Structure



Source: Author's Analysis

To get a clearer picture of the profitability of the different EPs, we introduced another measure of profitability, the gross margin per total variable costs. The gross margin per total variable cost is the average gross margin per unit of total variable cost. Based on the gross margin per total variable costs, Figure 4.8 shows that the most profitable EP is the Mz/Cs/R EP followed by the Mz/Sg EP while the least profitable EP is the Mz/Gn/Sp EP. This result contrasts the findings based on gross margin per hectare presented in Figure 4.7, suggesting that the metric used to measure profitability matters when determining what the most profitable EP is for farmers. Therefore, it is important to consider which measure of profitability farmers actually care about when making recommendations on diversification decisions.

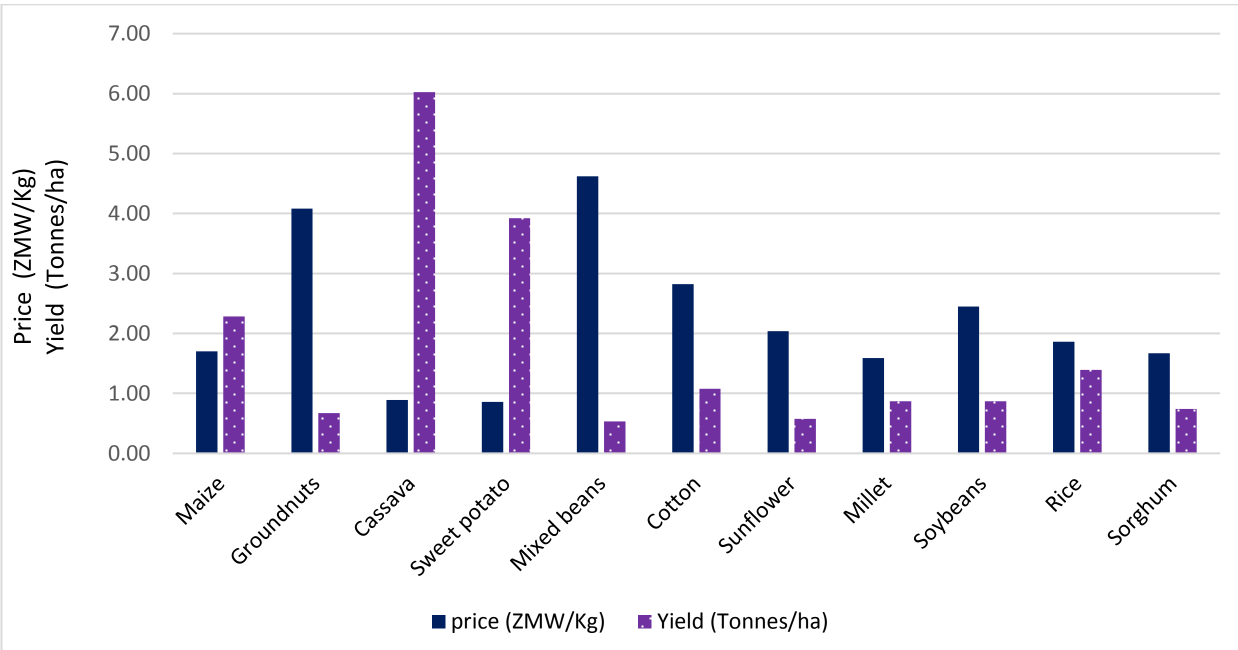
Figure 4.8: Average Gross Margin per Total Variable Costs, by Enterprise Structure



Source: Author's Analysis

Among other things, crop prices, yields and costs may help to explain the differences in gross margin per hectare among EPs. Figure 4.9 shows the average prices received for crops sold as well as the average yields for each of the crops in the sample. The results show that Mb and Gn fetched the highest prices of ZMW4.62/kg and ZMW4.08/kg, respectively in this sample. Although Cs had the highest gross margin per hectare among all EPs, the Cs crop had one of the lowest prices of only ZMW0.89/kg. In terms of yields, however, the Cs crop had the highest yield of 6,022.81kg/ha. The high Cs yields may be one of the reasons behind the high revenues associated with the Cs EP. Sp is another crop that had a low price but high yield. Its price was only ZMW0.86/kg but its yield was 3,924.37kg/ha. Gn and Mb, on the other hand, had high prices of ZMW4.08/kg and ZMW4.62/kg, but low yields of only 670.13kg/ha and 530.96kg/ha, respectively.

Figure 4.9: Average Price and Yields of Crops in the Sample



Source: Author's Analysis

Revenue is calculated based on prices and yields and profitability is measured based on revenue and variable costs. To get more insight on what factors were causing differences in profitability of the EPs, we also examined differences in average revenue and variable costs of the EPs. Table 4.5 shows that Cs had the highest average revenue while Mz/Ml had the lowest average revenue. In terms of cost of hired labor per hectare, Table 4.5 shows that the Mz/R, Mz/Mb, Mz/Sp and Mz/Cs/Gn/Sp EPs involved the highest cost of hired labor at ZMW319.53/ha, ZMW253.07/ha, ZMW235.55/ha and ZMW225.85/ha, respectively. The EPs that involved the lowest cost of hired labor include Mz/Gn/Ct/Sf (ZMW42.80/ha), Cs/R (ZMW46.68) and Mz/Ct (ZMW48.29/ha).

Table 4.5: Revenue, Costs and Gross Margin per Hectare, by Enterprise Structure

EPs	N	Gross Margin Per Hectare	Revenue Per Hectare	Labor Cost Per Hectare	Fertilizer Cost Per Hectare	Hectare
Mz	953	2388.03	3136.62	187.20	561.39	1.16
Cs	124	3887.22	3989.63	97.06	5.35	0.61
Mz/Gn	755	2531.97	3042.08	110.04	400.07	1.82
Mz/Cs	310	2896.63	3189.06	118.57	173.85	1.19
Mz/Ct	226	2647.42	2924.57	48.29	228.86	2.16
Mz/Sp	116	2157.31	3006.93	235.55	614.07	1.20
Mz/Sf	102	1780.73	2142.62	68.91	292.98	2.03
Mz/Mb	98	2693.77	3522.54	253.07	575.70	2.06
Mz/Sb	77	2375.69	3191.83	173.36	642.79	2.50
Mz/R	52	2373.16	2886.58	319.53	193.90	1.04
Cs/Gn	42	2787.87	2842.52	54.65	0.00	0.84
Mz/Sg	43	2217.06	2354.95	57.33	80.55	1.77
Cs/R	30	1827.85	1879.70	46.68	5.17	1.90
Mz/Ml	45	1350.54	1702.99	87.00	265.46	1.50
Mz/Gn/Ct	340	2580.57	2882.73	63.39	238.77	2.69
Mz/Gn/Sf	260	2251.20	2648.29	59.66	337.42	2.58
Mz/Cs/Gn	208	2399.93	2797.58	142.51	255.15	1.75
Mz/Gn/Sp	189	2195.21	2792.27	108.58	488.48	2.02
Mz/Gn/Mb	139	2603.84	3253.61	133.94	515.84	2.23
Mz/Gn/Sb	83	2478.37	3063.65	95.23	490.06	3.65
Mz/Cs/R	74	1921.35	2104.60	124.20	59.04	2.42
Mz/Cs/Mb	58	2997.52	3477.96	186.32	294.12	1.80
Mz/Gn/R	33	3492.32	3777.25	117.15	167.77	1.20
Mz/Cs/Sp	45	2526.78	3003.40	96.56	380.06	1.90
Mz/Ct/Sf	44	2329.93	2627.23	56.39	240.92	2.51
Mz/Gn/Ml	36	1970.86	2304.80	112.75	221.19	1.47
Mz/Cs/Gn/Mb	89	2135.39	2534.96	136.79	262.78	2.55
Mz/Gn/Ct/Sf	124	2586.01	2937.02	42.80	308.20	3.21
Mz/Gn/Ct/R	36	3681.36	3867.99	64.33	122.30	1.70
Mz/Gn/Sb/Sf	46	2649.35	3260.07	98.09	512.63	3.89
Mz/Cs/Gn/Sp	49	2328.93	2875.11	225.85	320.32	2.03
Mz/Gn/Ct/Sb/Sf	30	2433.69	3161.79	98.68	629.42	4.83
Mz/Cs/Gn/Mb/Sp	39	2390.63	2823.31	149.01	283.67	2.43
Total	**4895**	**2497.44**	**2993.73**	**128.73**	**367.56**	**1.78**

All variables are statistically different across the EPs at 1% significance level

Source: Author's Analysis

In terms of fertilizer cost, the Cs/Gn, Cs/R and the Cs EPs had the lowest fertilizer cost per hectare of ZMW0.00/ha, ZMW5.17/ha and ZMW5.35/ha respectively. On the other hand, the Mz/Sb, Mz/Gn/Ct/Sb/Sf and Mz/Sp EPs had the highest fertilizer costs of ZMW642.79/ha, ZMW629.42/ha and ZMW614.07/ha, respectively. Generally, the results suggest that cassava-based EPs involve minimal fertilizer costs while those with cash crops (specifically soybean, cotton, sunflower and sweet potato) have high fertilizer costs.

4.4 Empirical Results

4.4.1 Effect of Enterprise Structures on Profitability in Each Region

Based on the EPs grown in each region, we estimated OLS regressions to determine the average effect of each EP on profitability while controlling for demographic, socio-economic and production characteristics. Because of differences in the distribution of EPs across the regions, the empirical estimation in each region was based on the EPs that had a sample size of at least 30 households in that region. The EPs that were included in the empirical analysis in each region are presented in Table 4.6.

Table 4.7 presents marginal effects from the empirical estimation of the effect of EPs on gross margin per hectare (hereafter GM_ha) and gross margin per total variable costs (hereafter GM_tvc). The four EPs that were included in the analysis in AEZ I were Mz, Mz/Ct, Mz/Gn and Mz/Gn/Ct. From among these, the results for Mz/Ct and Mz/Gn/Ct EPs were statistically significant at 5% and 10% significance levels, respectively. The results show that, relative to the Mz EP, using the Mz/Ct EP significantly increases GM_ha by 63.23% in AEZ I at 5% significance level, holding all else constant. Further, relative to the Mz EP, using the Mz/Gn/Ct EP significantly increases GM_ha by 48.88% in AEZ I at 10% significance level, holding all else constant. The results also show that the effect of using the Mz/Gn EP on GM_ha is not statistically different from that of using the Mz EP at 10% significance level. For AEZ I, therefore, the EP that has the highest positive effect on GM_ha is the Mz/Ct followed by the Mz/Gn/Ct.

Table 4.6: Sample size of Enterprise Structures included in the Empirical Model in Each Region

EP	AEZ I	AEZ IIa	AEZ IIb	AEZ III	Total
Mz	160*	418*	66*	309*	953
Cs	0	1	20	103*	124
Mz/Gn	93*	475*	13	174*	755
Mz/Cs	5	17	97*	191*	310
Mz/Ct	56*	147*	21	2	226
Mz/Sp	10	43*	0	63*	116
Mz/Sf	8	94*	0	0	102
Mz/Mb	8	21	0	69*	98
Mz/Sb	1	60*	0	16	77
Mz/R	12	5	31*	4	52
Cs/Gn	0	0	1	41*	42
Mz/Sg	21	1	4	17	43
Cs/R	0	0	8	22	30
Mz/Ml	10	3	18	14	45
Mz/Gn/Ct	36*	291*	13	0	340
Mz/Gn/Sf	18	235*	3	4	260
Mz/Cs/Gn	2	30*	33*	143*	208
Mz/Gn/Sp	16	117*	0	56*	189
Mz/Gn/Mb	8	36*	1	94*	139
Mz/Gn/Sb	1	68*	2	12	83
Mz/Cs/R	0	0	53*	21	74
Mz/Cs/Mb	0	0	1	57*	58
Mz/Gn/R	9	17	0	7	33
Mz/Cs/Sp	0	3	0	42*	45
Mz/Ct/Sf	1	40*	3	0	44
Mz/Gn/Ml	6	3	5	22	36
Mz/Cs/Gn/Mb	0	3	0	86*	89
Mz/Gn/Ct/Sf	6	115*	3	0	124
Mz/Gn/Ct/R	6	28	2	0	36
Mz/Gn/Sb/Sf	0	43*	2	1	46
Mz/Cs/Gn/Sp	4	3	0	42*	49
Mz/Gn/Ct/Sb/Sf	0	25	5	0	30
Mz/Cs/Gn/Mb/Sp	1	5	0	33*	39
Total	**498**	**2,347**	**405**	**1,645**	**4,895**

*=included in Empirical model

Source: Author's Analysis

When profitability is measured using GM_tvc, the results show that the most profitable EP in AEZ I is still the Mz/Ct EP. Relative to using the Mz EP, using the Mz/Ct EP significantly increases GM_tvc by 156.77% in AEZ I at 5% significance level. The effect of the Mz/Gn and the Mz/Gn/Ct EPs on GM_tvc is not statistically different from that of the Mz EP in AEZ I at 10% significance level, holding all things constant.

In AEZ IIa, 14 EPs were included in the analysis. Among these, the results for seven EPs were statistically significant at 10% significance level. The results in Table 4.7 show that when profitability is measured using GM_ha, the EP with the highest profitability in AEZ IIa is Mz/Gn/Ct/Sf. Relative to the Mz EP, using the Mz/Gn/Ct/Sf EP significantly increases GM_ha by 54.34% in AEZ IIa at 1% significance level, holding all things constant. The EP with the second largest effect on GM_ha is Mz/Cs/Gn which significantly increase GM_ha by 52.04% relative to the Mz EP at 1% significance level. The other EPs that significantly increase GM_ha at 10% significance level relative to the Mz EP in AEZ IIa are Mz/Gn/Ct, Mz/Ct, Mz/Gn/Sb, Mz/Ct/Sf as well as Mz/Gn.

Based on GM_tvc, however, the results show that the EP with the highest profitability in AEZ IIa is the Mz/Ct EP. Relative to the Mz EP, using the Mz/Ct EP significantly increases GM_tvc by 110.01% in AEZ IIa at 1% significance level, holding all else constant. The difference in EPs with the highest effect on GM_ha and on GM_tvc, supports earlier findings that the metric used to measure profitability matters in determining which EP is most profitable for farmers. The results also show that, for AEZ IIa, the effect on GM_ha from using the Mz/Sp, Mz/Sf, Mz/Sb, Mz/Gn/Sf, Mz/Gn/Sp, Mz/Gn/Mb and the Mz/Gn/Sb/Sf EPs is not statistically different from that of the Mz EP, holding all things constant. This supports our *a priori* expectation that more or fewer crops in an EP does not automatically translate to higher profitability. Rather, the unique combination of crops matter in whether a diversified EP produces superior profitability to specialization.

For AEZ IIb, five EPs were included in the analysis. From among these, the effect on GM_ha of using the Mz/R, the Mz/Cs and the Mz/Cs/Gn EP was statistically different from that of using the Mz EP. Table 4.7 shows that relative to the Mz EP, using the Mz/R EP significantly increases GM_ha by 51.35% in AEZ IIb at 5% significance level, holding all things constant. The results in Table 4.7 also show that using the Mz/Cs EP significantly increases GM_ha by 40.07% in AEZ IIb at 10% significance level relative to the Mz EP, holding all things constant. Further, relative to the Mz EP, using the Mz/Cs/Gn EP increases GM_ha by 51.89% in AEZ IIb at 10% confidence level, holding all things constant. Therefore, based on GM_ha, the EP that has the highest effect on profitability in AEZ IIb is Mz/R followed by Mz/Cs and Mz/Cs/Gn.

Based on GM_tvc, however, the most profitable EP in AEZ IIb is the Mz/Cs EP. Relative to the Mz EP, using the Mz/Cs EP increases GM_tvc by 388.42% in AEZ IIb at 1% significance level, holding all things constant. Similar to the results in AEZ IIa, the most profitable EP is different depending on whether profitability is measured using GM_ha or GM_tvc. Again, this implies that diversification recommendations on crop diversification that seek to help farmers select the most profitable EP should consider what farmers care about when they think about their farm profitability. For example, for farmers who care about GM_ha, the most profitable EP in AEZ IIb is Mz/R while for farmers who care more about GM_tvc, the most profitable EP in AEZ IIb is Mz/Cs.

For AEZ III, the results suggest that, after controlling for other exogenous factors, only the Cs and the Mz/Cs EPs have statistically significant effects on GM_ha at 10% significance level. The difference in effects of the EPs on profitability based on the two different measures of profitability is even starker in AEZ III. While the Cs EP has the highest positive effect on GM_ha, it also has the highest negative effect on GM_tvc. Table 4.7 shows that relative to the Mz EP, using the Cs EP significantly increases GM_ha by 77.89% in AEZ III at 1% significance level holding all things constant. On the other hand, using the Cs EP significantly reduces GM_tvc in AEZ III by 106.89% relative to the Mz EP at 1% significance level, holding all things constant. Therefore, the Cs EP is the most profitable EP for farmers who care about GM_ha and it is the least profitable for those who care about GM_tvc.

In summary, the enterprise-structure approach to examining the effect of crop diversification on profitability show that enterprise structures do affect profitability. The effect is different in each agro-ecological region based on the crops included in the enterprise structure and based on what metric is used to measure profitability. The results show that EPs with the same number but different types of crops may have different effects. Further, the results suggest that EPs with more crops may not be necessarily more or less superior to specialization.

Table 4.7: Marginal Effects of Enterprise Structures on Profitability

Variables	AEZ I		AEZ IIa		AEZ IIb		AEZ III	
	GM_ha	GM_tvc	GM_ha	GM_tvc	GM_ha	GM_tvc	GM_ha	GM_tvc
Mz/Gn	-17.94 (0.153)	-38.68 (0.27)	23.99 (0.073)***	-25.99 (0.097)**			-1.61 (0.111)	
Mz/Ct	63.23 (0.209)**	156.77 (0.274)**	38.54 (0.096)***	110.01 (0.169)***				
Mz/Gn/Ct	48.88 (0.208)*	48.88 (0.286)	47.55 (0.077)***	23.74 (0.103)**				
Mz/Sp			-19.96 (0.173)	-82.76 (0.231)***			-0.50 (0.113)	-98.38 (0.183)***
Mz/Sf			-18.89 (0.117)	-44.92 (0.173)**				
Mz/Sb			18.06 (0.110)	-57.15 (0.118)***				
Mz/Gn/Sf			12.98 (0.083)	-50.23 (0.110)***				
Mz/Cs/Gn			52.04 (0.105)***	50.98 (0.143)***	42.33 (0.247)*	55.89 (0.301)	0.30 (0.093)	-63.07 (0.151)***
Mz/Gn/Sp			5.87 (0.103)	-69.89 (0.133)***			2.22 (0.109)	-95.42 (0.151)***
Mz/Gn/Mb			14.11 (0.156)	-42.19 (0.192)*			7.68 (0.094)	-57.15 (0.150)***
Mz/Gn/Sb			33.38 (0.088)***	-30.60 (0.121)**				
Mz/Ct/Sf			32.31 (0.124)**	66.03 (0.291)*				
Mz/Gn/Ct/Sf			54.34 (0.088)***	-0.90 (0.110)				
Mz/Gn/Sb/Sf			17.35 (0.176)	-49.03 (0.210)*				
Mz/Cs					40.07 (0.221)*	388.42 (0.301)***	16.42 (0.092)*	38.13 (0.164)**

Variables	AEZ I		AEZ IIa		AEZ IIb		AEZ III	
	GM_ha	GM_tvc	GM_ha	GM_tvc	GM_ha	GM_tvc	GM_ha	GM_tvc
Mz/R					51.13	31.26		
					(0.259)**	(0.338)		
Mz/Cs/R					-15.72	73.33		
					(0.265)	(0.401)		
Cs							77.89	-106.89
							(0.120)***	(0.263)***
Mz/Mb							2.12	-23.74
							(0.138)	(0.191)
Cs/Gn							20.44	15.95
							(0.147)	(0.251)
Mz/Cs/Mb							6.93	-31.65
							(0.151)	(0.278)
Mz/Cs/Sp							-8.22	-7.04
							(0.156)	(0.206)
Mz/Cs/Gn/Mb							-18.18	-84.04
							(0.137)	(0.195)***
Mz/Cs/Gn/Sp							-10.41	-86.26
							(0.149)	(0.200)***
Mz/Cs/Gn/Mb/Sp							-4.39	-73.33
							(0.156)	(0.217)**
_cons	102,047.20	2908.42	167,137.49	2358.16	96,484.17	557.32	141,133.55	2292.68
	(0.349)***	(0.525)***	(0.106)***	(0.156)***	(0.374)***	(0.575)***	(0.135)***	(0.220)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.14	0.38	0.07	0.50	0.13	0.39	0.07	0.46
N	334	334	2,186	2,186	273	273	1,479	1,404

* p<0.1; ** p<0.05; *** p<0.01
Standard error in parenthesis

Source: Author's Analysis

4.4.2 Differences in Profitability among Farmers Using the Same Enterprise Structure but with Different Proportions of the Individual Crops

Recognizing that although farmers can be using the same EP, they can have different proportions of individual crops, we checked for statistical differences in profitability across farmers with different proportions of crops in the same EP. Because of the small number of farmers who have the exact same proportions of crops in the EP, we categorize farmers into four groups based the proportion of a given crop in the EP. These four groups are: (1) farmers with less than 25% of a given crop in the EP; (2) farmers with more than 25% but less than 50% of a given crop in the EP; (3) farmers with more than 50% but less than 75% of a given crop in the EP; and (4) farmers with more than 75% of a given crop in the EP. The proportions are calculated based on the contribution of individual crops to the revenue of the EP. For example, for farmers using the Mz/Ct EP in AEZ I, we compare the profitability of farmers with less than 25% of maize in the portfolio to those with more than 25% but less than 50% of maize, to those with more than 50% but less than 75% of maize and to those with more than 75% of maize revenue in their portfolio. In this chapter, we present the results for EPs that had a statistically significant effect on profitability at 10% significance level as shown in Table 4.7. The results for EPs that did not have a statistically significant effect on profitability are presented in Appendix A.

Let, 1 = a proportion of less than or equal to 0.25;

2 = a proportion of more than 0.25 but less than or equal to 0.5;

3 = a proportion of more than 0.5 but less than or equal to 0.75; and

4 = a proportion of more than 0.75.

The results in Table 4. 8 show that profitability (in terms of both GM_ha and GM_tvc) does not statistically differ as the proportion of Mz in the Mz/Gn and Mz/Ct EPs changes in AEZ I at 10% significance level. Profitability only differs as proportions of Mz change in the Mz/Gn/Ct at 1 % significance level. That is, of the farmers using the Mz/Gn/Ct EP in AEZ I, those who had less than 25% of Mz, less than 25% of Gn and more than 75% of Ct in the portfolio had the highest GM_tvc, followed by those who had more than 75% of maize, more than 75% of Ct and less than 25% of Gn. The results also indicate that all the farmers who used the Mz/Gn/Ct EP in AEZ I had less than 25% of groundnuts and more than 75% of cotton. These results imply that for AEZ I, the proportion of individual crops in the Mz/Gn/Ct EP matter for profitability of the EP. Higher proportions of Ct, lower proportions of Mz and lower proportions of Gn are associated with the highest GM_tvc.

Table 4. 8: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ I

		Proportion of Crop			
EP	**Profitability**	**1**	**2**	**3**	**4**
Mz/Ct		*Proportion of Maize*			
	GM_ha	3331.8	3992.366	4984.75	5811.575
	GM_tvc	59.66894	44.78781	37.67992	9.298621
Mz/Gn/Ct		*Proportion of Maize*			
	GM_ha	12128.72	4430.954	4387.207	7742.523
	GM_tvc***	264.1389	10.70362	12.76588	28.41205
		Proportion of Groundnuts			
	GM_ha	5254.134	-	-	-
	GM_tvc	16.63852	-	-	-
		Proportion of Cotton			
	GM_ha	-	-	-	5254.134
	GM_tvc	-	-	-	16.63852

Statistical difference in means: * $p<0.1$; ** $p<0.05$; *** $p<0.01$
If no observations, entry is -

Source: Author's Analysis

The results in Table 4. 9 show that profitability in AEZ IIa also differs as the proportion of crops changes in some EPs. Generally, for all EPs in AEZ IIa, farmers who have a higher proportion of Mz in their EP have a higher GM_ha. For example, among the farmers who are using the Mz/Gn and Mz/Ct EP, the ones who have the highest GM_ha are those with a Mz proportion of more than 0.75. In the case of the Mz/Gn/Ct EP, the results show that higher proportions of Mz and Ct are associated with higher GM_ha in AEZ IIa. Similarly, in the Mz/Gn/Cs EP, higher proportions of Mz are associated with higher GM_ha in AEZ IIa. Differences in GM_ha for farmers with different proportions of Gn and Cs in the Mz/Gn/Cs are not statistically significant at 10% significance level in AEZ IIa. For the Mz/Gn/Sf EP, the results show that higher proportions of Mz and lower proportions of Sf are associated with the highest GM_ha in AEZ IIa at 5% significance level. In the case of the Mz/Gn/Ct/Sf EP, proportions of Ct of between 0.25 and 0.5 have the lowest GM_ha at 10% significance level. Generally, the results suggest that higher proportions of Mz and Ct and lower proportions of Sf are associated with higher GM_ha in AEZ IIa.

Table 4. 9: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ II a

AEZ IIa		**Proportion of Crops**			
EP	Profitability	**1**	**2**	**3**	**4**
			Proportion of Maize		
Mz/Gn	GM_ha**	1059.52	3928.07	2638.73	5349.76
	GM_tvc**	5.04	6.58	10.34	11.18
Mz/Ct			***Proportion of Maize***		
	GM_ha***	1894.26	3138.28	3660.88	8471.86
	GM_tvc***	39.18	53.93	58.97	27.88
Mz/Gn/Ct			***Proportion of Maize***		
	GM_ha***	3932.16	5564.39	6581.99	6873.47
	GM_tvc***	27.12	19.68	17.69	12.25
			Proportion of Groundnuts		
	GM_ha	6373.49	4824.88	7626.63	-
	GM_tvc	17.74	15.26	5.47	-
			Proportion of Cotton		
	GM_ha***	6760.28	5551.05	7058.16	13218.48
	GM_tvc	15.23	18.52	23.53	4.24
Mz/Gn/Cs			***Proportion of Maize***		
	GM_ha*	3382.42	3465.74	6438.18	15790.22
	GM_tvc*	43.03	8.45	13.85	4.00
			Proportion of Groundnuts		
	GM_ha	7050.80	2724.52	-	-
	GM_tvc	13.11	5.09	-	-
			Proportion of Cassava		
	GM_ha	9521.94	4446.76	3096.26	-
	GM_tvc	9.52	9.95	25.00	-

Mz/Gn/Sf			***Proportion of Maize***		
	GM_ha***	3286.63	3031.16	4690.92	5963.57
	GM_tvc	4.66	5.44	9.59	9.84
			Proportion of Groundnuts		
	GM_ha	5587.02	3740.08	8185.30	7328.17
	GM_tvc	9.01	12.39	7.79	10.39
			Proportion of Sunflower		
	GM_ha*	5521.03	1959.29	-1.91	-
	GM_tvc	9.77	4.56	-0.01	-
Mz/Ct/Sf			***Proportion of Maize***		
	GM_ha**	-	4602.25	5139.43	10228.32
	GM_tvc	-	56.74	15.18	9.78
			Proportion of Cotton		
	GM_ha	7128.55	4763.68	3233.57	-
	GM_tvc	10.98	51.75	29.14	-
			Proportion of Sunflower		
	GM_ha**	5790.45	3247.57	-	-
	GM_tvc	34.43	5.47	-	-
Mz/Gn/Ct/Sf			***Proportion of Maize***		
	GM_ha	4908.76	5866.74	7720.49	9215.09
	GM_tvc	8.65	11.24	8.91	5.71
			Proportion of Groundnuts		
	GM_ha	7634.81	6214.24	-	-
	GM_tvc	8.45	15.10	-	-
			Proportion of Cotton		
	GM_ha*	8230.03	6022.47	8100.31	-
	GM_tvc	9.58	7.89	6.31	-
			Proportion of Sunflower		
	GM_ha	7521.72	-	-	-
	GM_tvc	8.98	-	-	-

Statistical difference in means: * $p<0.1$; ** $p<0.05$; *** $p<0.01$

If no observations, entry is -

Source: Author's Analysis

The results of statistical differences in profitability across farmers with different proportions of the same EP in AEZ IIb are presented in Table 4. 10. Table 4. 10 shows that, in the Mz/Cs and in the Mz/Gn/Cs EP, differences in proportions of crops were associated with statistical differences in profitability. Higher proportions of Cs (lower proportions of Mz) in the Mz/Cs EP were associated with higher profitability. Similarly, higher proportions of Cs and lower proportions of Mz in the Mz/Gn/Cs EP were associated with higher GM_ha at 1% significance level. In the Mz/R EP, however, differences in profitability among farmers with different proportions of Mz and R were not statistically significant at 10% significance level.

Table 4. 10: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ II b

EP	Profitability	Proportion of Crop			
		1	2	3	4
Mz/R		*Proportion of Maize*			
	GM_ha	1046.74	2208.44	2153.84	435.70
	GM_tvc	34.61	16.35	8.33	6.09
Mz/Cs		*Proportion of Maize*			
	GM_ha***	5887.25	3162.50	2024.81	932.64
	GM_tvc*	137.40	133.88	89.83	51.43
Mz/Gn/Cs		*Proportion of Maize*			
	GM_ha***	12188.57	2757.13	4069.89	1096.46
	GM_tvc***	35.23	12.64	8.02	22.13
		Proportion of Groundnuts			
	GM_ha	3840.80	3936.51	871.46	-
	GM_tvc	18.69	9.60	3.26	-
		Proportion of Cassava			
	GM_ha***	2521.08	2714.88	3774.71	25550.61
	GM_tvc	15.53	12.16	16.47	59.35

Statistical difference in means: * $p<0.1$; ** $p<0.05$; *** $p<0.01$

If no observations, entry is -

Source: Author's Analysis

Table 4. 11: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ III

		Proportion of Crops			
EP	Profitability	1	2	3	4
Mz/Cs		*Proportion of Maize*			
	GM_ha***	5218.51	4121.48	3042.45	1619.02
	GM_tvc***	234.37	57.42	46.42	18.43

Statistical difference in means: * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Source: Author's Analysis

For AEZ III, the results of statistical differences across farmers with different crop proportions of the same EP are presented in Table 4. 11. The results show that lower proportions of Mz (higher proportions of Cs) in the Mz/Cs EP are associated with higher profitability (both in terms of GM_ha and GM_tvc) at 1% significance level in AEZ III.

In summary, the results show that differences in proportions of crops in the same EP may be associated with differences in profitability. Statistical tests across groups of farmers with difference crop proportions in the various agro-ecological zones generally show that higher proportions of Ct in the Mz/Ct EP are associated in higher profitability in AEZ I, higher proportions of Mz in the Mz/Gn, Mz/Ct, Mz/Gn/Ct, Mz/Gn/Cs and Mz/Ct/Sf EPs in AEZ IIa are associated with higher profitability. Further, higher proportions of Cs in the Mz/Cs EP in AEZ IIb and AEZ III are associated with higher profitability.

4.4.3 Effect of the Simpson Index of Diversification on Profitability in Each Region

The enterprise structure approach clearly accounts for heterogeneity in crops, whereby two enterprise structures with the same number of crops may have different effects on profitability. To compare the results of the enterprise structure approach with those of the index approach, we also examined the effect of crop diversification on profitability based on the Simpson index measure of crop diversification. The Simpson index is one of the most popular measures of crop diversification used in the literature. The estimation employed the same semi-log specification as the enterprise structure-approach. In place of the enterprise structure variable, we used the Simpson index.

Table 4. 12 shows that based on the Simpson index, crop diversification has no significant effect on profitability (in terms of both GM_ha and GM_tvc) in AEZ I and AEZ IIb. However, for AEZ IIa, Table 4. 12 shows that crop diversification significantly increases GM_ha. A one unit increase in the crop diversification index significantly increases GM_ha in AEZ IIa by 43.62% at 1% confidence level, holding all things constant. Therefore, based on the Simpson index, the results suggest that adding crops to a farmer’s portfolio increases GM_ha in AEZ IIa, regardless of which crop is added.

This result would imply that both the Mz/Ct and Mz/Sp EP should be significantly more profitable that the Mz only EP in AEZ IIa. However, the results of the enterprise structure approach for AEZ IIa earlier presented in Table 4.7 tell a different story. Table 4.7 showed that Mz/Ct has a statistically significant positive effect on GM_ha relative to Mz at 1% significance level in AEZ IIa, while Mz/Sp has no significant effect on GM_ha at 10% significance level in this region. Similarly, Table 4.7 showed that, although the Mz/Gn/Sp EP involves more crops that the Mz EP, its effect on gross margin per hectare is not statistically different from that of the Mz EP at 10% significance level holding all things constant.

Based on the Simpson index, the results in Table 4. 12 also show that crop diversification has a negative significant effect on GM_tvc in AEZ III. This suggests that growing fewer crops should be more profitable in terms of GM_tvc in AEZ III. However, the results of the enterprise structure approach in Table 4.7 showed that, the Mz/Cs has more crops than the Mz EP yet it has significantly higher GM_tvc than Mz. That is, using the Mz/Cs EP significantly increases GM_tvc by 38.13% at 5% significance level relative to the Mz EP. Diversification recommendations based on the index approach would therefore result in a 38.13% loss in GM_tvc for farmers who would switch from Mz/Cs to Mz.

The index approach also fails to distinguish the effects on GM_tvc cost of specializing in maize versus specializing in cassava in AEZ III. Based on the index, the effect on profitability of specializing in Mz and specializing in Cs are the same. However, based on the enterprise structure approach, the results in Table 4.7 show that using the Cs EP reduces GM_tvc by 106.89% at 1% significance level compared to using the Mz EP. Again, recommendations based on the index approach would result in a 106.89% loss in GM_tvc for farmers who would choose to specialize in Cs instead of Mz. Using the Cs EP increases GM_ha by 77.89% relative to Mz in AEZ III. The index-approach would therefore result in a 77.87% loss in GM_ha for farmers who would switch from growing Cs to growing Mz.

Clearly, the ease of using the index to measure crop diversification comes at a cost of useful insights from the detailed analysis of crop portfolios. Generalized recommendations from the index measure of crop diversification result in ambiguous conclusions which are unable to effectively help farmers make diversification decisions. The results from the index-approach lack the depth of insight needed for farmers to identify superior diversification choices and may result in losses (in terms of opportunity cost) for farms who select sub-optimal portfolios. The enterprise structure approach improves upon the shortfalls of the index by providing a better understanding of the effects of crop diversification. Results of the enterprise structure approach allow farmers to effectively select portfolios that best suit their objectives.

Table 4. 12: Marginal Effects of the Effect of the Simpson Diversification Index on Profitability

Variables	AEZ1		AEZ2a		AEZ2b		AEZ3	
	GM_ha	GM_tvc	GM_ha	GM_tvc	GM_ha	GM_tvc	GM_ha	GM_tvc
SID	27.00	14.91	43.62	-11.74	-2.43	82.94	-14.57	-36.34
	(0.305)	(0.418)	(0.103)***	(0.146)	(0.326)	(0.538)	(0.105)	(0.176)*
Constant	94,856.12	27.74	159,938.58	2,466.17	116,461.02	1,245.03	172,575.64	2,295.08
	(0.364)***	(0.534)***	(0.103)***	(0.161)***	(0.375)***	(0.571)***	(0.132)***	(0.225)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.08	0.32	0.04	0.45	0.08	0.25	0.03	0.41
N	334	334	2,186	2,186	273	273	1,479	1,404

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Standard error in parenthesis

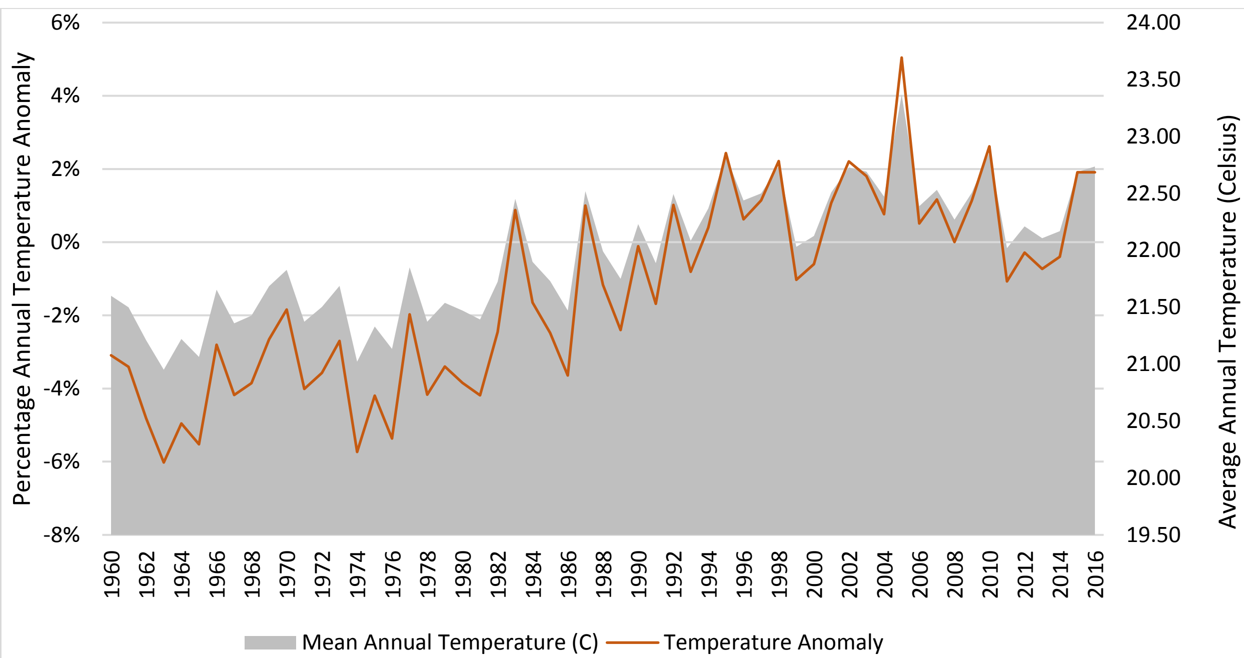
Source: Author's Analysis

4.7 Characteristics of the Study Period

This study is based on a cross sectional snapshot from the 2013/2014 agricultural season in Zambia. The results of the study should, therefore, be interpreted within the context of the production and market conditions that prevailed in the 2013/2014 agricultural season.

Data from the World Bank's climate change knowledge portal shows that the 2013/2014 agricultural season (2014 calendar year) was not a climatic anomaly in Zambia. The average annual temperatures and rainfall did not deviate much from that of the baseline period of 1980 to 2010. The average annual temperature between 1980 and 2010 was 23.5°C. Figure 4.10 shows that the average annual temperature in 2014 was only 0.4% cooler than the average temperature in the baseline period.

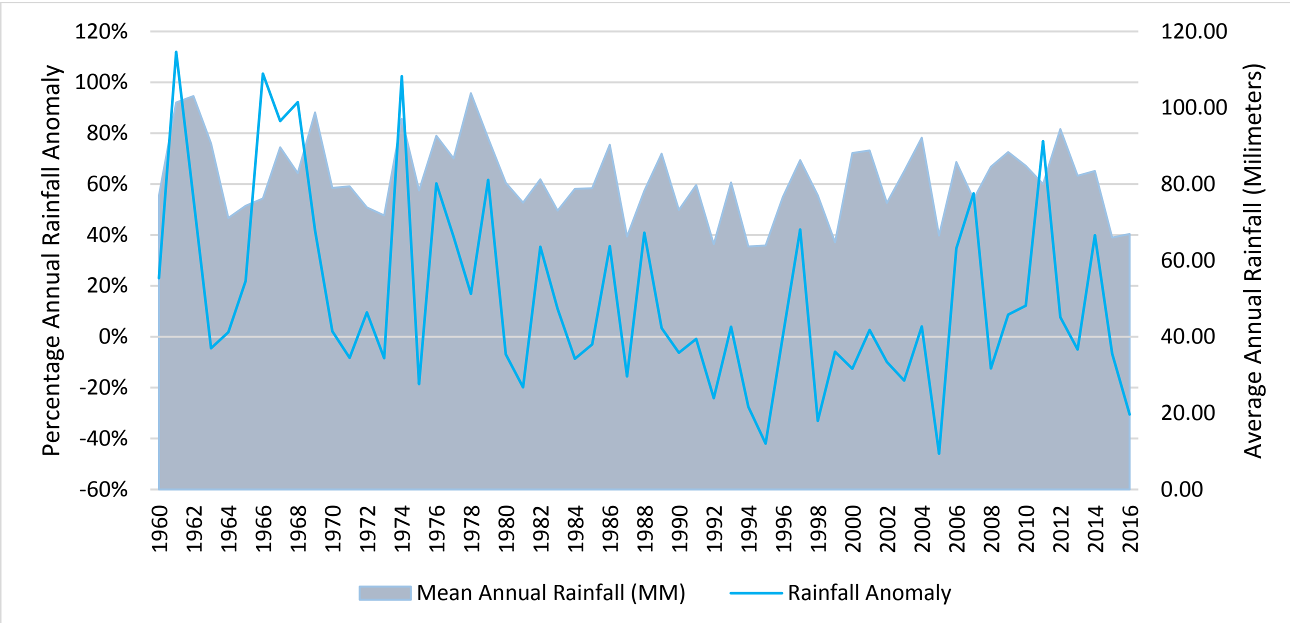
Figure 4.10: Average Annual Temperatures and Temperature Anomalies between 1960 and 2016 in Zambia



Source: World Bank 2020

In terms of precipitation, Figure 4.11 shows that Zambia received about 40% more rainfall in 2014 compared to the average annual rainfall of 222.5mm in the baseline period. However, the rainfall distribution was similar to the baseline (Chapoto et al. 2015).

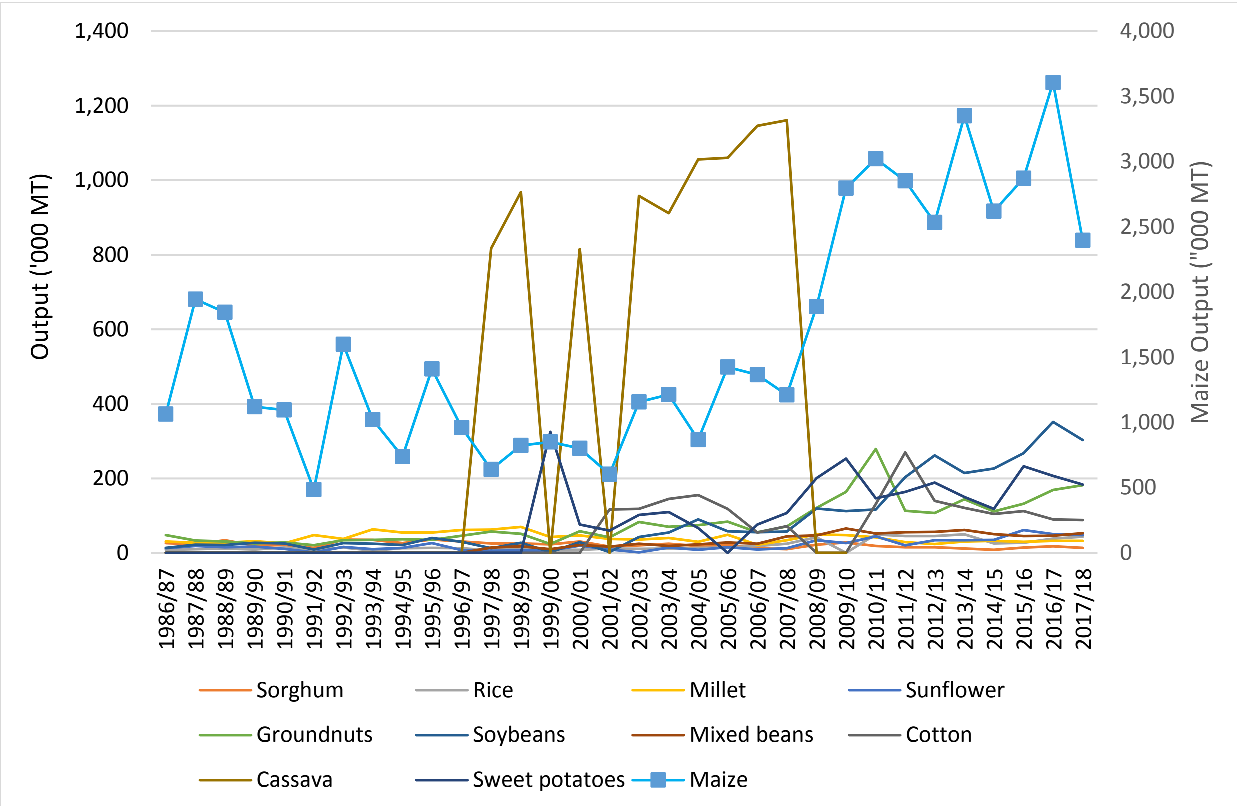
Figure 4.11: Average Annual Rainfall and Rainfall Anomalies between 1960 and 2016 in Zambia



Source: World Bank 2020

The adequate and well distributed rainfall in the 2013/2014 agricultural season resulted in a bumper harvest for maize. The national maize output for the season was 3,350,671 metric tons (CSO 2014) as depicted in Figure 4.12. This output had been the highest ever recorded in the country since the high of 3,020,380 metric tons in 2011 (CSO 2014; Chapoto et al. 2015). Besides good weather, the expansion in the area planted to maize in the 2013/2014 agricultural season (as shown in Figure 4.13) also contributed to the high maize production. The expansion of maize area planted in the 2013/2014 season was largely in response to high maize prices in the 2012/2013 marketing season (ReNAPRI 2014).

Figure 4.12: Output of Key Crops in Metric Tons between 1987 and 2018 in Zambia

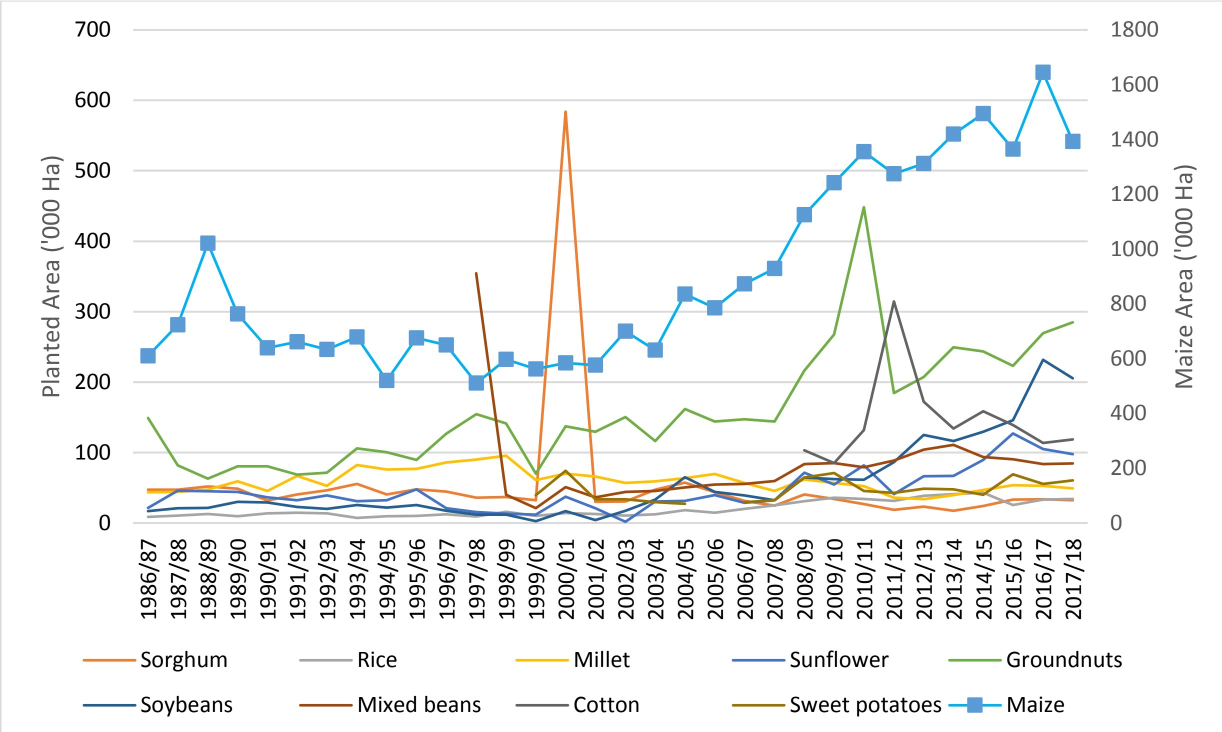


Source: CSO 2020

Other crops that saw an increase in area planted and output in the 2013/2014 agricultural season included groundnuts, mixed beans, millet and rice as shown in Figure 4.13 and Figure 4.12. On the other hand, sorghum, soybeans, cotton and sweet potatoes saw a decrease in area planted and output. Fluctuations in soybean output and yields have been due to changes in weather patterns while the decline in area planted and output of cotton has mostly been due to low prices (Chapoto and Chisanga 2016).

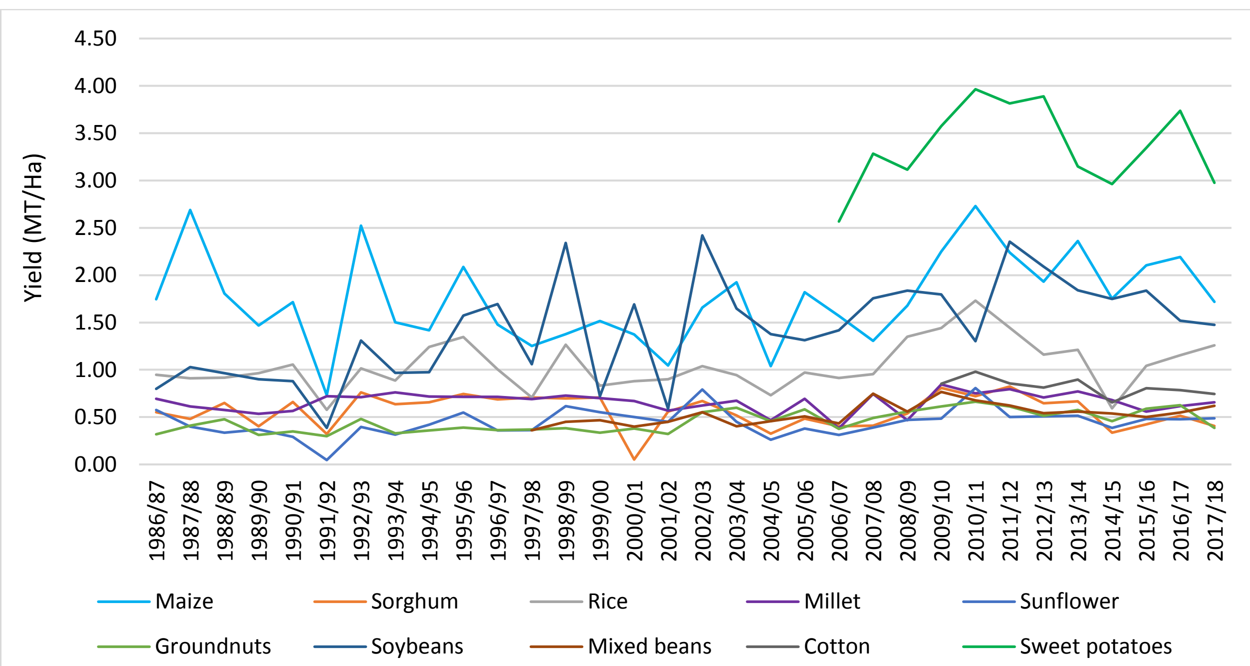
In general, the conducive climatic conditions in the 2013/2014 agricultural season resulted in an increase in yields for maize, rice, millet, groundnuts and mixed beans despite an increase in area allocated to these crops. The yields of key crops are presented in Figure 4.14.

Figure 4.13: Area Planted to Key Crops between 1987 and 2018 in Zambia



Source: CSO 2020

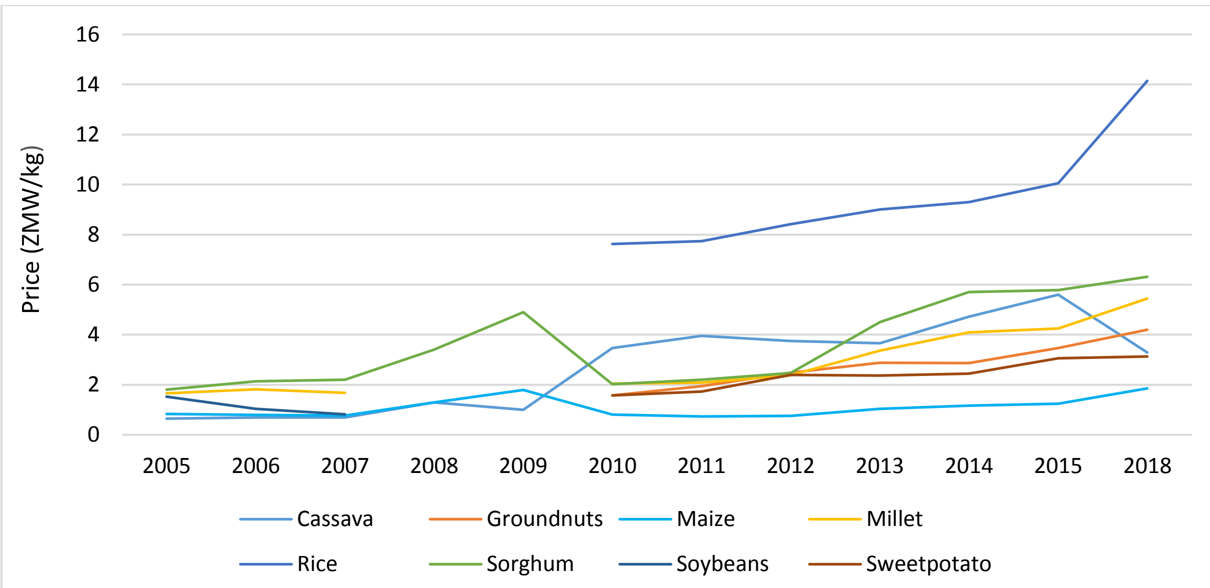
Figure 4.14: Yields for Key Crops between 1987 and 2018 in Zambia



Source: CSO 2020

The high crop production and yields recorded in the 2013/2014 agricultural season are expected to bias the revenue estimates in this study upwards. The average annual prices of major crops for the period between 2005 and 2018 are presented in Figure 4. 15. Figure 4. 15 shows a general upward trend in prices between 2013 and 2015. For this 2013 to 2015 period, there are no drastic changes or anomalies in prices. The general upward trend in prices in 2014 to 2015 marketing season is also expected to result in higher than normal revenue estimates for farmers in this study.

Figure 4. 15: Prices of Major Crops between 2005 and 2018 in ZMW per KG in Zambia



Source: (FAOSTAT 2019)

Chapter 5: Conclusion and Recommendations

Crop diversification has been used to mean growing different crops or using different cropping systems. Our review of the literature showed that the use of indices to measure crop diversification has constrained the depth of insight that research on crop diversification can offer to policy makers and practitioners. This is because indices ignores the heterogeneity in crops that could be important for understanding strategic choices decision-makers make about how they construct their choices and solutions.

This study sought to address this gap in literature. The study recognizes diversification not in number of crops, but the types of crops in a farmer's production 'portfolio'. We called these portfolios farm enterprise structures. In seeking to identify existing enterprise structures and their related profitability, we first evaluated the distribution of enterprise structures in the study area and the characteristics of farmers adopting them. Using secondary data from the 2015 rural agricultural livelihood survey in Zambia, we identified 33 enterprise structures that had been used by at least 30 households.

Our results showed that female farmers, farmers who were older, the farmers who had lower asset values and those who had smaller farms tended to adopt EPs that were dominated by food crops. On the other hand, male farmers, farmers who were younger, farmers who had higher asset values and those that owned larger farms tended to adopt enterprise structures that were dominated by cash crops. The results also showed that when profitability was measured as gross margin per hectare, the enterprise structure that was most profitable was cassava. However, when profitability was measured using gross margin per total variable costs, the most profitable enterprise structure was maize/cassava/rice. This suggested that the metric used to measure profitability matters when identifying the most profitable enterprise structures for farmers.

Secondly, the study examined the effect of enterprise structures on crop production while controlling for farmer characteristics. We utilized the ordinary least square regression to estimate the effect of enterprise structures on profitability in each agro-ecological zone. We found that, enterprise structures significantly affected profitability. The direction and magnitude of the effect was different for different enterprise structures in the respective agro-ecological zones. Based on both gross margin per hectare and gross margin per total variable costs, the enterprise structure that had the highest positive effect on profitability in AEZ I was maize/cotton. In AEZ IIa, the most profitable enterprise structure, in terms of gross margin per hectare was the maize/groundnut/cotton/sunflower enterprise structure while based on gross margin per total variable costs, it was the maize/cotton enterprise structure. In AEZ IIb, the enterprise structure with the highest gross margin per hectare was maize/rice while the enterprise structure with the highest gross margin per total variable costs was maize/cassava. In AEZ III, the cassava enterprise structure had the highest gross margin per hectare while the maize/cassava enterprise structure had the highest gross margin per total variable costs. The list of the most profitable enterprise structures in each region are presented in Table 5. 1 and Table 5. 2.

Table 5. 1: Enterprise Structures with the Highest Gross Margin per Hectare, Relative to Maize in Each Agro-Ecological Zone

AEZ I	AEZ II a	AEZ II b	AEZ III
1. Maize and cotton 2. Maize, groundnuts and cotton	1. Maize, groundnuts, cotton and sunflower 2. Maize, cassava and groundnuts 3. Maize, groundnuts and cotton 4. Maize and cotton 5. Maize, groundnuts and soybeans 6. Maize, cotton and sunflower 7. Maize and groundnuts	1. Maize and rice 2. Maize and cassava 3. Maize, cassava and groundnuts	1. Cassava

Source: Author’s Analysis

Table 5. 2: Enterprise Structures with the Highest Gross Margin per Total Variable Costs, Relative to Maize in Each Agro-Ecological Zone

AEZ I	AEZ II a	AEZ II b	AEZ III
1. Maize and cotton	1. Maize and cotton 2. Maize, cotton and sunflower 3. Maize, groundnuts and cotton	1. Maize and cassava	2. Maize and cassava

Source: Author's Analysis

Other enterprise structures had no significance effect on profitability relative to the maize enterprise structure at 10% significance level. These included maize/groundnut enterprise structure in AEZ I, the maize/sweet potato, maize/sunflower, maize/soybeans, maize/groundnuts/sunflower, maize/groundnuts/sweet potato, maize/groundnuts/mixed beans and maize/groundnuts/soybeans/sunflower enterprise structure in AEZ IIa which had no significant effect on gross margin per hectare. Further, the maize/cassava/rice had no significant effect on gross margin per hectare in AEZ IIb. In AEZ III, the enterprise structures that had no significant effect on gross margin per hectare at 10% significance level included the maize/sweet potato, maize/groundnuts/sweet potato, maize/cassava/groundnuts, and cassava/groundnuts among others. Other enterprise structures significantly reduced profitability relative to the maize enterprise structure. For example, the maize/sweet potato, and the maize/groundnuts/sweet potato enterprise structures were the enterprise structures with the highest negative effect on gross margin per total variable costs in AEZ IIa and AEZ III at 10% significance level.

The results also clearly showed that the metric used to measure profitability mattered when making diversification decisions. For example, in AEZ III, when profitability was measured using gross margin per hectare, the cassava enterprise structure has the highest positive effect on profitability relative to the maize enterprise structure holding all things constant. However, based on gross margin per total variable costs, the cassava enterprise structure had the highest negative effect on profitability. This suggests that the cassava enterprise structure was the most profitable enterprise structure for farmers who cared about gross margin per hectare, but it was the least profitable for those who cared about gross margin per total variable costs. To suit the farmer's objectives, recommendations on diversification for increased profitability should be specific to what farmers care about when they think about their farm profitability.

Recognizing that farmers could have different proportions of crops for the same enterprise structure, we examined the statistical difference in profitability of farmers who had the same enterprise structure but different crop proportions. We found that, profitability was statistically different for farmers with different proportions of crops in some enterprise structures. Generally, higher proportions of cotton in the maize/cotton enterprise structure in AEZ I were associated with higher profitability, higher proportions of maize in the maize/groundnuts, maize/cotton, maize/groundnuts/cotton, maize/groundnuts/cassava and maize/cotton/sunflower enterprise structures in AEZ IIa were associated with higher profitability. Further, higher proportions of cassava in the maize/cassava enterprise structure in AEZ IIb and AEZ III were associated with higher profitability. The results imply that proportions of individual crops matter for the profitability of each enterprise structure.

Comparing the results of the enterprise structure approach and that of the index approach to measuring crop diversification, the results of the study confirmed our *a priori* expectation that recommendations based on the index would not effectively help practitioners to identify superior diversifications strategies. Conclusions from the index approach were merely that planting more or fewer crops was more beneficial for profitability. However, the enterprise structure approach clearly showed which portfolios would significantly result in higher or lower profitability. We were also able to identify potential losses in profitability from the index approach that could be avoided when the enterprise structure approach was used.

For policy makers and practitioners who are interested in increasing farm profitability, these results imply that the careful selection of crop portfolios can enhance farm profitability. The most popular enterprise structure in the sample was the maize enterprise structure (i.e., farmers specializing in maize production) which accounted for almost 20% of households. These maize farmers would be likely to increase their gross margin per hectare the most if they switched to producing maize and cotton if they are in AEZ I, maize, groundnuts, cotton and sunflower if they are in AEZ IIa, maize and rice if they are in AEZ IIb and cassava if they are in AEZ III. Other crop portfolios that would significantly increase their gross margin per hectare are presented in Table 5. 1. The maize farmers would also likely increase their gross margin per total variable costs the most if they switched to producing maize and cotton if they are in AEZ I or AEZ IIa and to producing maize and cassava if they are in AEZ IIb or AEZ III. Farmers who are using any of the 33 enterprise structures, besides maize, can also increase or maintain a high profitability by switching to or continuing to use a more profitable enterprise structure.

While choosing a more profitable enterprise structure can increase profitability, another necessary step in enhancing profitability is the careful selection of proportions of the individual crops. The results showed that higher proportions of maize in maize-based portfolios in AEZ I and AEZ IIa were associated with higher profitability and that higher proportions of cassava in the cassava-based portfolios in AEZ IIb and AEZ III were associated with higher profitability.

5.1 Study Limitations and Further Research

One major limitation of this study is that it did not account for the effect of diversification on risk management. Crop diversification has been shown to be an important risk management strategy. Farmers may, therefore, select enterprise structures on the basis of lower variability in profitability other than on profitability alone. Because this study was based on cross sectional data, variability in profitability could not be practically accounted for. Further research can examine the effect of enterprise structures on variability of returns to shed more light on how effective different enterprise structures are in managing risk.

Another limitation of the study is that the only costs that were accounted for in our measurement of gross margin were fertilizer costs, cost of transporting fertilizer and cost of hired labor. We did not account for seed cost, cost of agro chemicals and their related transport costs. Accounting for these costs may improve the accuracy of the profitability measure. Future research can explore the use of a more-encompassing measure of profitability to see if the results obtained in this study would be robust.

Further, although the results show that the enterprise structure affects profitability, the agronomic or economic sources of synergy among crops in different enterprise structures could not be isolated or explained within the context of this study. The goal of this study was to identify existing enterprise structures and their related profitability. Therefore, exploring the agronomic and economic sources of synergy among crops was beyond the scope of the study. Future research can examine the agronomic and economic relationships among crops in each enterprise structure to identify the sources and mechanisms through which synergies among crops are realized.

Finally, future research can also explore profitability of enterprise structures by gender. In this study, we showed that the distribution and composition of enterprise structures is different across male and female farmers. However, in examining the effect of enterprise structure on profitability, we controlled for gender but did not compare the effects of enterprise structures on profitability across male and female farmers. This was partly because, in most cases, the sample size for female farmers was not large enough to allow us to compare the effects statistically. Future research can examine the effect of enterprise structures on profitability by gender to determine whether the most profitable enterprise structures for female farmers are similar or different from those of male farmers.

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Appendix A – Additional Descriptive Statistics Tables

Table A. 1: Distribution of Enterprises

S/N	Enterprise	Number of Households with the Enterprise	Percent of Households with the Enterprise
1	Maize	1,222,356	87.35%
2	Groundnuts	703,546	50.28%
3	Cassava	352,814	25.21%
4	Cotton	221,455	15.83%
5	Mixed beans	195,145	13.95%
6	Sweet potato	185,492	13.26%
7	Sunflower	173,568	12.40%
8	Soybean	112,620	8.05%
9	Millet	88,393	6.32%
10	Rice	80,443	5.75%
11	Sorghum	48,644	3.48%
12	Bambara nuts	39,181	2.80%
13	Groundnuts*Cassava	30,852	2.20%
14	Maize*Mixed beans	23,281	1.66%
15	Maize*Cassava	23,092	1.65%
16	Maize*Groundnuts	21,388	1.53%
17	Cassava*Millet	18,549	1.33%
18	Cowpeas	17,603	1.26%
19	Cassava*Sweet potato	15,710	1.12%
20	Burley tobacco	15,331	1.10%
21	Maize*Pumpkin leaves	12,303	0.88%
22	Cassava*Mixed beans	11,546	0.83%
23	Virginia tobacco	10,221	0.73%
24	Popcorn	10,221	0.73%
25	Groundnuts*Sunflower	5,300	0.38%
26	Maize*Sweet potato	5,110	0.37%
27	Irish potato	3,786	0.27%
28	Maize*Cassava*Groundnuts	3,596	0.26%
29	Maize*Cowpeas	3,407	0.24%
30	Soybean*Sunflower	3,028	0.22%
31	Maize*Cassava*Mixed beans	3,028	0.22%
32	Mixed beans*Sweet potato	2,271	0.16%
33	Maize*Groundnuts*Mixed beans	2,082	0.15%
34	Maize*Sorghum	2,082	0.15%
35	Maize*Sunflower	1,893	0.14%
36	Cassava*Groundnuts*Sweet potato	1,704	0.12%
37	Groundnuts*Cowpeas	1,514	0.11%

S/N	Enterprise	Number of Households with the Enterprise	Percent of Households with the Enterprise
38	Maize*Cassava*Millet	1,514	0.11%
39	Maize*Soybeans	1,325	0.09%
40	Millet*Cowpeas	1,325	0.09%
41	Cassava*Bambara nuts	1,136	0.08%
42	Maize*Bambara nuts	1,136	0.08%
43	Maize*Cassava*Sweet potato	1,136	0.08%
44	Maize*Groundnuts*Sweet potato	1,136	0.08%
45	Groundnuts*Bambara nuts	946	0.07%
46	Groundnuts*Sweet potato	946	0.07%
47	Maize*Cassava*Mixed beans*Sweet potato	946	0.07%
48	Cassava*Cowpeas	757	0.05%
49	Groundnuts*Mixed beans	757	0.05%
50	Maize*Cassava*Groundnuts*Cowpeas	757	0.05%
51	Maize*Millet	757	0.05%
52	Sorghum*Bambara nuts	757	0.05%
53	Soybean*Sweet potato	568	0.04%
54	Cassava*Soybeans	568	0.04%
55	Maize*Cowpeas*Pumpkin leaves	568	0.04%
56	Maize*Groundnuts*Cowpeas	568	0.04%
57	Maize*Groundnuts*Pumpkin leaves	568	0.04%
58	Sugarcane	568	0.04%
59	Sweet potato*Bambara nuts	568	0.04%
60	Cassava*Millet*Groundnuts	379	0.03%
61	Cassava*Sorghum	379	0.03%
62	Cassava*Sunflower	379	0.03%
63	Cotton*Soybean*Groundnuts	379	0.03%
64	Maize*Cassava*Bambara nuts	379	0.03%
65	Maize*Cassava*Mixed beans*Bambara nuts*Sweet potato	379	0.03%
66	Maize*Cassava*Mixed beans*Groundnuts	379	0.03%
67	Maize*Cassava*Groundnuts*Pumpkin leaves	379	0.03%
68	Maize*Cassava*Rice	379	0.03%
69	Maize*Millet*Groundnuts*Cowpeas*Bambara nuts	379	0.03%
70	Maize*Millet*Groundnuts*Cowpeas	379	0.03%
71	Maize*Sorghum*Groundnuts*Cowpeas	379	0.03%
72	Mixed beans*Sorghum	379	0.03%
73	Paprika	379	0.03%
74	Sorghum*Millet	379	0.03%
75	Sunflower*Sweet potato	379	0.03%
76	Velvet beans	379	0.03%
77	Cassava*Mixed beans*Bambara nuts*Sweet potato	189	0.01%
78	Cassava*Groundnuts*Mixed beans	189	0.01%

S/N	Enterprise	Number of Households with the Enterprise	Percent of Households with the Enterprise
79	Cassava*Millet*Pumpkin leaves	189	0.01%
80	Cassava*Sweet potato*Groundnuts*Mixed beans	189	0.01%
81	Maize*Mixed beans*Soybeans	189	0.01%
82	Maize*Cassava*Groundnuts*Sweet potato	189	0.01%
83	Maize*Cassava*Rice*Millet*Sweet potato	189	0.01%
84	Maize*Cotton	189	0.01%
85	Maize*Cowpeas*Millet	189	0.01%
86	Maize*Cowpeas*Millet*Pigeon peas	189	0.01%
87	Maize*Groundnuts*Bambara nuts	189	0.01%
88	Maize*Groundnuts*Cowpeas*Mixed beans*Bambara nuts	189	0.01%
89	Maize*Groundnuts*Millet*Cowpeas	189	0.01%
90	Maize*Groundnuts*Soybeans	189	0.01%
91	Maize*Rice	189	0.01%
92	Maize*Sunflower*Cowpeas	189	0.01%
93	Mixed beans*Cowpeas	189	0.01%
94	Mixed beans* Soybeans	189	0.01%
95	Sesame	189	0.01%

Source: Author's Analysis

Table A. 2: Summary Statistics on Farmers Adopting the 33 Enterprise Structures (N = 4895, Weighted N = 921, 273)

Variable	Mean	Std. Dev.	Min	Max
Independent variable				
Gross Margin per hectare	2497.44	1872.23	-15062.26	21300.29
Demographic variables				
Male	0.75	0.43	0	1
Age	48.26	15.56	16	105
Household size	6.54	2.81	1	29
Years of Education	5.74	3.99	0	19
Socio-economic variables				
Value of assets	713.05	4310.84	0	160100
Amount of subsidy	282.15	793.17	0	19470
Small farm (0-1 hectares)	0.72	0.45	0	1
Medium farm (2 - 4.99 hectares)	0.21	0.41	0	1
Large farm (5 - 19.99 hectares)	0.07	0.25	0	1
Production variables				
Kgs of fertilizer per hectare	119.84	136.06	0	1275
Improved seed	0.58	0.37	0	1
Crop rotation	0.46	0.50	0	1
Geographical location				
AEZ I	0.08	0.28	0	1
AEZ II a	0.46	0.50	0	1
AEZ II b	0.10	0.29	0	1
AEZ III	0.36	0.48	0	1

Source: Author’s Analysis

Table A. 3: Summary Statistics on Farmers Who Did Not Adopt the 33 Enterprise Structures (N = 2498, Weighted N = 478, 078)

Variable	Mean	Std. Dev.	Min	Max
Independent variable				
Gross Margin per hectare	2461.28	2071.46	-6683.39	36286.78
Demographic variables				
Male	0.78	0.42	0	1
Age	47.60	14.69	17	95
Household size	6.81	2.77	1	30
Years of Education	5.91	3.54	0	19
Socio-economic variables				
Value of assets	609.50	3481.30	0	121300
Amount of subsidy	262.60	437.29	0	7044.738
Small farm (0-1 hectares)	0.70	0.46	0	1
Medium farm (2 - 4.99 hectares)	0.23	0.42	0	1
Large farm (5 - 19.99 hectares)	0.07	0.26	0	1
Production variables				
Kgs of fertilizer per hectare	96.34	116.42	0	1200
Improved seed	0.52	0.29	0	1
Crop rotation	0.52	0.50	0	1
Geographical location				
AEZ I	0.09	0.28	0	1
AEZ II a	0.29	0.45	0	1
AEZ II b	0.05	0.22	0	1
AEZ III	0.57	0.49	0	1

Source: Author's Analysis

Table A. 4: Demographic Characteristics of Farmers Adopting the 33 EPs

EP	Males	Age	Education	Household size	Asset value	Improved seed
Mz	0.73	47.86	6.01	6.16	817.76	0.6
Cs	0.73	51.95	4.24	6.54	3.67	0.62
Mz/Gn	0.62	51.97	5.6	6.45	903.55	0.52
Mz/Cs	0.72	49.58	5.36	6.51	258.48	0.62
Mz/Ct	0.85	45.4	4.95	6.31	717.79	0.76
Mz/Sp	0.85	42.45	7.12	6.46	288.45	0.84
Mz/Sf	0.86	43.49	4.83	6.13	1361.5	0.4
Mz/Mb	0.78	49.6	6.97	6.8	524.35	0.65
Mz/Sb	0.8	47.41	6.26	6.8	1917	0.67
Mz/R	0.42	48.21	7.1	6.44	119.35	0.43
Cs/Gn	0.67	51.4	4.55	6.35	10.11	0.51
Mz/Sg	0.89	50.32	5.18	6.2	422.92	0.14
Cs/R	0.75	48.97	3.18	6.3	154.44	0.37
Mz/Ml	0.77	44.65	5.42	6.37	394.39	0.21
Mz/Gn/Ct	0.82	45.64	5.24	6.98	1119.77	0.65
Mz/Gn/Sf	0.81	46.93	4.99	6.47	1098.12	0.48
Mz/Cs/Gn	0.73	49.76	6.02	6.83	299.12	0.6
Mz/Gn/Sp	0.74	49.18	6.9	7.26	804.52	0.72
Mz/Gn/Mb	0.84	48.75	6.92	6.77	661.79	0.53
Mz/Gn/Sb	0.82	48.9	6.03	7.1	1779.5	0.63
Mz/Cs/R	0.9	47.18	6.26	7.62	382.78	0.43
Mz/Cs/Mb	0.83	42.18	5.63	6.79	58.66	0.57
Mz/Gn/R	0.45	43.83	6.24	5.09	341.34	0.15
Mz/Cs/Sp	0.87	45.01	6.11	6.06	350.66	0.78
Mz/Ct/Sf	0.91	43.6	3.99	6.82	1549.14	0.55
Mz/Gn/Ml	0.73	49.28	6.2	7.63	267.31	0.37
Mz/Cs/Gn/Mb	0.77	47.39	5.12	6.21	71.07	0.48
Mz/Gn/Ct/Sf	0.86	44.5	5.58	7.19	1414.1	0.66
Mz/Gn/Ct/R	0.71	41.45	7.4	5.54	70.47	0.53
Mz/Gn/Sb/Sf	0.89	49.4	6.79	7.54	1264.33	0.58
Mz/Cs/Gn/Sp	0.98	51.14	7.56	6.81	136.71	0.71
Mz/Gn/Ct/Sb/Sf	0.99	41.12	6.4	6.78	2065.81	0.66
Mz/Cs/Gn/Mb/Sp	0.75	46.07	5.68	7	68.64	0.56
Total	**0.75**	**48.26**	**5.74**	**6.54**	**713.05**	**0.58**

Source: Author's Analysis

Table A. 5: Distribution of EPs across Agro ecological zones

EP	AEZ I	AEZ IIa	AEZ IIb	AEZ III	Total
Mz	16.79	43.86	6.93	32.42	100
Cs	0	0.81	16.13	83.06	100
Mz/Gn	12.32	62.91	1.72	23.05	100
Mz/Cs	1.61	5.48	31.29	61.61	100
Mz/Ct	24.78	65.04	9.29	0.88	100
Mz/Sp	8.62	37.07	0	54.31	100
Mz/Sf	7.84	92.16	0	0	100
Mz/Mb	8.16	21.43	0	70.41	100
Mz/Sb	1.3	77.92	0	20.78	100
Mz/R	23.08	9.62	59.62	7.69	100
Cs/Gn	0	0	2.38	97.62	100
Mz/Sg	48.84	2.33	9.3	39.53	100
Cs/R	0	0	26.67	73.33	100
Mz/Ml	22.22	6.67	40	31.11	100
Mz/Gn/Ct	10.59	85.59	3.82	0	100
Mz/Gn/Sf	6.92	90.38	1.15	1.54	100
Mz/Cs/Gn	0.96	14.42	15.87	68.75	100
Mz/Gn/Sp	8.47	61.9	0	29.63	100
Mz/Gn/Mb	5.76	25.9	0.72	67.63	100
Mz/Gn/Sb	1.2	81.93	2.41	14.46	100
Mz/Cs/R	0	0	71.62	28.38	100
Mz/Cs/Mb	0	0	1.72	98.28	100
Mz/Gn/R	27.27	51.52	0	21.21	100
Mz/Cs/Sp	0	6.67	0	93.33	100
Mz/Ct/Sf	2.27	90.91	6.82	0	100
Mz/Gn/Ml	16.67	8.33	13.89	61.11	100
Mz/Cs/Gn/Mb	0	3.37	0	96.63	100
Mz/Gn/Ct/Sf	4.84	92.74	2.42	0	100
Mz/Gn/Ct/R	16.67	77.78	5.56	0	100
Mz/Gn/Sb/Sf	0	93.48	4.35	2.17	100
Mz/Cs/Gn/Sp	8.16	6.12	0	85.71	100
Mz/Gn/Ct/Sb/Sf	0	83.33	16.67	0	100
Mz/Cs/Gn/Mb/Sp	2.56	12.82	0	84.62	100
Total	**10.17**	**47.95**	**8.27**	**33.61**	**100**

Source: Author’s Analysis

Table A. 6: Distribution of Enterprise Structures, by Gender

Enterprise Structure	Percent (%) of Female Farmers using the EP	Enterprise Structure	Percent (%) of Male Farmers using the EP
Mz/Gn	21.6	Mz	19.1
Mz	20.99	Mz/Gn	13.9
Mz/Cs	6.69	Mz/Gn/Ct	7.24
Mz/Gn/Ct	5.76	Mz/Cs	6.25
Mz/Gn/Sf	4.73	Mz/Gn/Sf	5.46
Mz/Cs/Gn	4.01	Mz/Ct	4.77
Mz/Ct	3.91	Mz/Cs/Gn	4.31
Mz/Gn/Sp	3.7	Mz/Gn/Sp	3.9
Cs	2.98	Mz/Gn/Mb	3.01
Mz/R	2.37	Mz/Gn/Ct/Sf	2.8
Mz/Gn/Mb	2.16	Mz/Sp	2.58
Mz/Mb	1.75	Cs	2.42
Mz/Sb	1.65	Mz/Sf	2.24
Mz/Sp	1.54	Mz/Mb	2.07
Mz/Sf	1.44	Mz/Cs/Gn/Mb	1.94
Mz/Gn/Ct/Sf	1.44	Mz/Gn/Sb	1.78
Mz/Gn/Sb	1.34	Mz/Cs/R	1.63
Mz/Cs/Gn/Mb	1.34	Mz/Sb	1.56
Mz/Ml	1.23	Mz/Cs/Mb	1.25
Mz/Gn/R	1.23	Mz/Cs/Gn/Sp	1.22
Cs/Gn	1.13	Mz/Gn/Sb/Sf	1.12
Mz/Gn/Ct/R	1.13	Mz/Ct/Sf	1.05
Mz/Cs/R	1.03	Mz/Cs/Sp	1.02
Mz/Cs/Mb	0.93	Mz/Sg	0.94
Mz/Gn/Ml	0.82	Mz/Ml	0.84
Mz/Sg	0.62	Mz/Cs/Gn/Mb/Sp	0.84
Cs/R	0.62	Cs/Gn	0.79
Mz/Cs/Gn/Mb/Sp	0.62	Mz/R	0.74
Mz/Cs/Sp	0.51	Mz/Gn/Ct/Sb/Sf	0.74
Mz/Ct/Sf	0.31	Mz/Gn/Ml	0.71
Mz/Gn/Sb/Sf	0.21	Mz/Gn/Ct/R	0.64
Mz/Cs/Gn/Sp	0.1	Cs/R	0.61
Mz/Gn/Ct/Sb/Sf	0.1	Mz/Gn/R	0.54
CR33	100	CR33	100

Source: Author's Analysis

Table A. 7: Semi-Log Regression Results of the Effect of EPs on Gross Margin per Hectare

Variables	AEZ I	AEZ IIa	AEZ IIb	AEZ III
Age	0.005	-0.001	0.007	0.003
	(0.005)	(0.001)	(0.005)	(0.002)
Female	-0.037	0.012	0.083	-0.039
	(0.162)	(0.056)	(0.159)	(0.069)
Education	0.019	0.004	-0.006	0.014
	(0.019)	(0.006)	(0.030)	(0.009)
Household size	0.021	0.001	-0.035	0.016
	(0.024)	(0.007)	(0.024)	(0.010)
Asset value (000)	-0.008	0.392	0.006	0.001
	(0.171)	(0.018)	(0.002)***	(0.023)
Subsidy (000)	-0.265	-0.253	-0.028	0.143
	(0.514)	(0.128)	(0.062)	(0.058)**
Fertilizer use	0.002	0.001	0.000	0.000
	(0.001)**	(0.000)***	(0.001)	(0.000)
Use of improved seed	-0.184	-0.01	0.207	-0.026
	(0.224)	(0.05)**	(0.224)	(0.099)
Crop rotation	0.138	-0.021	-0.561	0.065
	(0.178)	(0.044)	(0.358)	(0.053)
Medium farm	-0.218	0.001	0.071	-0.161
	(0.198)	(0.042)	(0.153)	(0.055)***
Large farm	-0.196	-0.026	0.164	-0.145
	(0.155)	(0.049)	(0.268)	(0.071)**
Mz/Gn	-0.165	0.215		-0.016
	(0.153)	(0.073)***		(0.111)
Mz/Ct	0.490	0.326		
	(0.209)**	(0.096)***		
Mz/Gn/Ct	0.398	0.389		
	(0.208)*	(0.077)***		
Mz/Sp		-0.182		-0.005
		(0.173)		(0.113)
Mz/Sf		-0.173		
		(0.117)		
Mz/Sb		0.166		
		(0.110)		
Mz/Gn/Sf		0.122		
		(0.083)		
Mz/Cs/Gn		0.419	0.353	0.003
		(0.105)***	(0.247)	(0.093)

Variables	AEZ I	AEZ IIa	AEZ IIb	AEZ III
Mz/Gn/Sp		0.057	0.28***	0.022
		(0.103)		(0.109)
Mz/Gn/Mb		0.132		0.074
		(0.156)		(0.094)
Mz/Gn/Sb		0.288		
		(0.088)***		
Mz/Ct/Sf		0.280		
		(0.124)**		
Mz/Gn/Ct/Sf		0.434		
		(0.088)***		
Mz/Gn/Sb/Sf		0.160		
		(0.176)		
Mz/Cs			0.337	0.152
			(0.221)	(0.092)*
Mz/R			0.413	
			(0.259)	
Mz/Cs/R			-0.146	
			(0.265)	
Cs				0.576
				(0.120)***
Mz/Mb				0.021
				(0.138)
Cs/Gn				0.186
				(0.147)
Mz/Cs/Mb				0.067
				(0.151)
Mz/Cs/Sp				-0.079
				(0.156)
Mz/Cs/Gn/Mb				-0.167
				(0.137)
Mz/Cs/Gn/Sp				-0.099
				(0.149)
Mz/Cs/Gn/Mb/Sp				-0.043
				(0.156)
_cons	6.929	7.422	6.873	7.253
	(0.349)***	(0.106)***	(0.374)***	(0.135)***
R^2	0.14	0.07	0.13	0.07
N	334	2,186	273	1,479

* $p<0.1$; ** $p<0.05$; *** $p<0.01$
Standard error in parenthesis

Source: Author's Analysis

Table A. 8: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ I

		Proportion of Crop			
EP	**Profitability**	**Less than or equal to 0.25**	**Greater than 0.25 and less than or equal to 0.5**	**Greater than 0.5 and less than or equal to 0.75**	**Greater than 0.75**
		Proportion of Maize			
Mz/Gn	Gross margin per hectare	4525.417	996.2885	2138.656	3155.799
	Gross margin per total variable costs	3.636361	3.11389	11.83148	10.95124

* *p*<0.1; ** *p*<0.05; *** *p*<0.01
Standard error in parenthesis
If no entry, then -

Source: Author's Analysis

Table A. 9: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ IIa

AEZ IIa		Proportion of Crops			
EP	Profitability	**1**	**2**	**3**	**4**
		Proportion of Maize			
Mz/Sp	Gross margin per hectare	-	772.96	884.83	3085.75
	Gross margin per total variable costs**	-	2.50	1.10	6.30
Mz/Sf		***Proportion of Maize***			
	Gross margin per hectare	-	-	1660.91	3150.97
	Gross margin per total variable costs	-	-	18.76	19.20
Mz/Sb		***Proportion of Maize***			
	Gross margin per hectare**	-	7920.65	2759.78	8660.62
	Gross margin per total variable costs	-	17.68	2.78	5.03
Mz/Gn/Sf		***Proportion of Maize***			
	Gross margin per hectare***	3286.63	3031.16	4690.92	5963.57
	Gross margin per total variable costs	4.66	5.44	9.59	9.84
		Proportion of Groundnuts			
	Gross margin per hectare	5587.02	3740.08	8185.30	7328.17
	Gross margin per total variable costs	9.01	12.39	7.79	10.39
		Proportion of Sunflower			
	Gross margin per hectare*	5521.03	1959.29	-1.91	-
	Gross margin per total variable costs	9.77	4.56	-0.01	-
Mz/Gn/Sp		***Proportion of Maize***			
	Gross margin per hectare**	5750.66	3254.30	3365.69	5023.54
	Gross margin per total variable costs	7.51	4.93	3.57	4.12
		Proportion of Groundnuts			
	Gross margin per hectare	4389.14	2913.93	3635.658	9093.416
	Gross margin per total variable costs	3.71	3.91	11.23	6.35
		Proportion of Cassava			
	Gross margin per hectare	4178.90	-	-	-

Mz/Gn/Mb		***Proportion of Maize***			
	Gross margin per hectare	423.88	2733.50	3835.84	8470.86
	Gross margin per total variable costs	2.97	3.35	2.72	3.39
		Proportion of Groundnuts			
	Gross margin per hectare	7156.85	-	423.88	-
	Gross margin per total variable costs	3.27	-	2.97	-
		Proportion of Mixed beans			
	Gross margin per hectare	7248.93	2721.93	-	-
	Gross margin per total variable costs	3.26	3.25	-	-
Mz/Gn/Sb/Sf		***Proportion of Maize***			
	Gross margin per hectare**	-	5754.54	5272.09	14549.98
	Gross margin per total variable costs	-	7.19	3.28	4.60
		Proportion of Groundnuts			
	Gross margin per hectare	11505.28	4102.98	11267.61	-
	Gross margin per total variable costs	4.17	6.66	8.63	-
		Proportion of Soybeans			
	Gross margin per hectare**	10510.86	7015.11	-	-
	Gross margin per total variable costs	4.79	3.34	-	-
		Proportion of Sunflower			
	Gross margin per hectare**	10284.83	-	-	-
	Gross margin per total variable costs	4.70	-	-	-

* *p*<0.1; ** *p*<0.05; *** *p*<0.01
Standard error in parenthesis
If no observations, then -

Source: Author's Analysis

Table A. 10: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ IIb

EP	Profitability	Proportion of Crop			
		1	**2**	**3**	**4**
Mz/Cs/R					
		Proportion of Maize			
	Gross margin per hectare	3397.78	2427.943	2232.449	13.13191
	Gross margin per total variable costs	47.56465	24.48885	22.28251	-0.12351
		Proportion of Cassava			
	Gross margin per hectare	3767.94	2247.816	1979.801	9800.63
	Gross margin per total variable costs	43.21035	37.14802	29.08135	31.27195
		Proportion of Rice			
	Gross margin per hectare	2265.543	2101.199	3799.621	4555.627
	Gross margin per total variable costs	38.22868	18.07076	25.0513	110.0461

* $p<0.1$; ** $p<0.05$; *** $p<0.01$
Standard error in parenthesis
If no observations, then -

Source: Author's Analysis

Table A. 11: Statistical Differences in Profitability across Farmers with Different Crop Proportions of the Same Enterprise Structure in AEZ III

EP	Profitability	Proportion of Crops			
	Profitability	Less than or equal to 0.25	Greater than 0.25 and less than or equal to 0.5	Greater than 0.5 and less than or equal to 0.75	Greater than 0.75
Mz/Gn		***Proportion of Maize***			
	Gross margin per hectare*	9747.64	2538.15	2024.67	4029.28
	Gross margin per total variable costs	4.21	9.77	4.92	9.80
Mz/Sp		***Proportion of Maize***			
	Gross margin per hectare	-	6004.1	2462.96 2	2219.61 1
	Gross margin per total variable costs	-	4.52648 9	6.04499 1	3.37663 6
Mz/Mb		***Proportion of Maize***			
	Gross margin per hectare	-	4715.16 7	2211.44 9	5708.34 6
	Gross margin per total variable costs	-	21.2732 1	28.0418 9	10.1287
Cs/Gn		***Proportion of Cassava***			
	Gross margin per hectare	880.15	1011.69	2572.06	2357.96
	Gross margin per total variable costs	7.48	37.70	49.10	54.19
Mz/Cs/Gn		***Proportion of Maize***			
	Gross margin per hectare	4494.22	4208.76	3540.26	3442.54
	Gross margin per total variable costs	13.83	14.15	5.25	5.99
		Proportion of Cassava			
	Gross margin per hectare***	3676.13	3763.20	4186.23	7661.17
	Gross margin per total variable costs	8.76	5.23	16.74	14.99
		Proportion of Groundnuts			
	Gross margin per hectare	4189.04	2967.50	5467.11	1546.84
	Gross margin per total variable costs	9.13	8.56	19.36	0.90
Mz/Gn/Sp		***Proportion of Maize***			
	Gross margin per hectare**	-	3814.77	2415.16	6555.64
	Gross margin per total variable costs	-	5.78	1.96	6.44

		Proportion of Groundnuts			
	Gross margin per hectare***	4265.01	3677.13	7105.09	-
	Gross margin per total variable costs	4.29	4.89	4.91	-
		Proportion of Sweet potato			
	Gross margin per hectare	4568.42	3033.42	-	-
	Gross margin per total variable costs	4.56	3.93	-	-
Mz/Gn/Mb		*Proportion of Maize*			
	Gross margin per hectare*	2165.75	4413.84	3284.52	9510.30
	Gross margin per total variable costs**	4.73	16.13	6.65	6.26
		Proportion of Groundnuts			
	Gross margin per hectare	6136.17	4075.16	557.20	-
	Gross margin per total variable costs	7.64	5.40	13.60	-
		Proportion of Mixed beans			
	Gross margin per hectare	5923.36	4431.64	4956.49	-
	Gross margin per total variable costs	7.34	8.61	7.05	-
Mz/Cs/Mb		*Proportion of Maize*			
	Gross margin per hectare	6126.60	6099.98	5176.32	3783.16
	Gross margin per total variable costs	130.38	30.38	5.52	4.18
		Proportion of Cassava			
	Gross margin per hectare***	3215.86	7435.22	7786.48	11533.1 0
	Gross margin per total variable costs***	11.59	19.35	28.04	360.41
		Proportion of Mixed beans			
	Gross margin per hectare	5949.48	3038.94	2286.10	-
	Gross margin per total variable costs	23.15	22.85	52.10	-
Mz/Cs/Sp		*Proportion of Maize*			
	Gross margin per hectare	4431.90	3389.90	3359.79	3629.58
	Gross margin per total variable costs	26.07	5.74	10.43	7.48
		Proportion of Cassava			
	Gross margin per hectare**	3117.48	5290.88	3467.73	5074.94
	Gross margin per total variable costs	9.41	4.84	9.10	31.78
		Proportion of Sweet potato			
	Gross margin per hectare	4291.88	2044.52	-	-

	Gross margin per total variable costs	13.65	8.29	-	-
Mz/Cs/Gn/Mb		***Proportion of Maize***			
	Gross margin per hectare	9119.31	5377.90	4783.71	4677.56
	Gross margin per total variable costs***	21.13	9.29	7.01	6.66
		Proportion of Cassava			
	Gross margin per hectare*	4258.35	5578.27	10749.99	14167.68
	Gross margin per total variable costs***	7.33	8.11	13.83	38.29
		Proportion of Groundnuts			
	Gross margin per hectare	5563.35	2212.89	9341.22	-
	Gross margin per total variable costs	9.24	5.26	6.05	-
		Proportion of Mixed beans			
	Gross margin per hectare	5638.50	4580.89	5034.62	-
	Gross margin per total variable costs	9.44	7.43	8.81	-
Mz/Cs/Gn/Sp		***Proportion of Maize***			
	Gross margin per hectare	7029.88	2723.89	3008.23	7401.05
	Gross margin per total variable costs***	8.39	6.79	3.30	1.83
		Proportion of Cassava			
	Gross margin per hectare*	4109.37	4035.36	6452.44	11505.30
	Gross margin per total variable costs***	3.52	6.74	8.19	15.76
		Proportion of Groundnuts			
	Gross margin per hectare	4713.51	3319.60	9817.93	-
	Gross margin per total variable costs	4.11	6.57	4.31	-
		Proportion of Sweet potato			
	Gross margin per hectare	4630.85	2498.90	2388.28	-
	Gross margin per total variable costs	4.80	1.56	1.10	-
Mz/Cs/Gn/Mb/Sp		***Proportion of Maize***			
	Gross margin per hectare	11755.76	6193.13	4291.53	4291.53
	Gross margin per total variable costs	13.79	5.78	5.99	0.37
		Proportion of Cassava			
	Gross margin per hectare***	4249.86	5102.55	15162.87	18535.90

Gross margin per total variable costs***	6.54	3.65	6.69	23.40
	Proportion of Groundnuts			
Gross margin per hectare	6039.74	10295.97	-	-
Gross margin per total variable costs	6.89	5.27	-	-
	Proportion of Mixed beans			
Gross margin per hectare	6537.03	2959.71	-	-
Gross margin per total variable costs	7.19	5.86	-	-
	Proportion of Sweet potato			
Gross margin per hectare	6854.20	3805.09	-	-
Gross margin per total variable costs	7.19	5.86	-	-

* *p*<0.1; ** *p*<0.05; *** *p*<0.01
Standard error in parenthesis
If no observations, then -

Source: Author's Analysis