PRODUCTION RISK UNDER IMPROVED MAIZE PRODUCTION SYSTEMS IN THE UNITED REPUBLIC OF TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Production risk is very important in developing countries, including Tanzania, which result in variance in production that may have severe consequences for a smallholder farmer and his family. The main aim of this study was to assess the determinants of production risk associated with adoption of improved maize seed varieties in order to inform sustainable food security. The specific objectives were to; (i) evaluate factors affecting the adoption and diffusion of improved maize seed varieties in Tanzania (ii) assess the intensity of adopting improved maize seed varieties; and (iii) determine the factors that increase production risk in farming system which use improved maize seed varieties. The Just and Pope framework and Heckman two step procedure were used to estimate adoption, adoption intensity and production risk function respectively with selection bias taken into account. The study used cross section data collected by national panel of survey in 2012/13 from different agro-ecological zones growing maize in the United Republic of Tanzania. The results from the analysis of adoption show that the factors that influenced adoption and diffusion of improved maize seed varieties significantly were farm size (P<0.05), proportion of land allocated to maize production (P<0.01), organic fertilizer (P<0.01), distance from the farm to homestead (P<0.05), distance from the farm to market (P<0.05) and agro-ecological zones specifically for the Eastern zone (P<0.01) and Southern highlands zone (P<0.10). The adoption intensity was influenced significantly by farm size (P<0.01), proportion of land allocated to improved maize seed varieties (P<0.01), organic fertilizer (P<0.05), quantity of herbicides (P<0.05), adult equivalent (P<0.10) and agro-ecological zone specifically Western zone (P<0.05). Lastly, the results of the analysis of production risk show that age, quantity of herbicides and adult equivalent were the only factors that influenced production risk positively at (P<0.10), (P<0.01) and (P<0.01) respectively. The study recommends improvement in the provision of extension services both in terms of number of visits and quality of extension services provided to farmers to encourage the adoption of improved maize seed varieties, the use of organic fertilizers and other improved technologies so as to increase maize yield. In addition, the study recommends further research to generate information that will allow planners to predict future trends of maize production to inform future food security decisions. In this regard the use of time series and panel data is recommended over the use of cross-sectional data.

DECLARATION

I, Annajoyce Raphael, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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The above declaration is confirmed by;

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Prof. R. M. J. Kadigi Date

(Supervisor)

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DEDICATION

I dedicate this work specifically to the family the late Raphael C. Mdima family for their support during my studies.

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ACRONYMS AND ABBREVIATION

ASDP	Agriculture Sector Development Program
CIAWFB	Central Intelligence Agency World Factbook
CIMMYT	Centro International de Mejoramiento de Maize Trigo (International Maize and Wheat Centre)
DTMA	Drought Tolerance Maize for Africa
FAO	Food and Agriculture Organization of United Nations
FAOSTAT	Food and Agriculture Organization Statistics
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
IMR	Inverse Mill's Ratio
MAFAP	Monitoring African Food and Agricultural Policies
MNLD	Maize Necrosis Lethal Disease
MSV	Maize Streak Virus
NAIVS	National Agricultural Input Voucher Scheme
NBS	National Bureau of Statistics
OLS	Ordinary Least Square
URT	United Republic of Tanzania
WFP	World Food Programme
WPR	World Population Review

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Agriculture sector is one of the most risky economic activities compared to other sectors because of its dependency on the highly variable weather. The sector is underdeveloped on many fronts, including technology, markets and support services (Tumbo *et al*., 2010). Despite its underdevelopment, it is the dominant sector in the Tanzanian economy, contributing 25% of the Gross Domestic Product (GDP), 24% of the exports and supports the livelihood of about 75-80%, the majority of whom being poor people (URT, 2014).

The risky characteristic of agriculture sector in the United Republic of Tanzania is a result of the farming system being highly influenced by the natural environment and weather conditions as well as geographical and other attributes that are beyond the control of farmers (Akyoo *et al.,* 2013). According to Kaliba *et al.* (2000), geographical characteristics influence the general performance of many agricultural innovations. Just as important, weather conditions such as rainfall and temperature are the major factors affecting agricultural production in smallholder farming systems in Tanzania and other low-income countries. Their effects are experienced differently in different agro ecological zones and influence farmers' decision to adopt improved maize technology packages making them more vulnerable economically.

Poor farmers in developing countries are vulnerable to a range of risks and constraints that impede their socio-economic development. One example of these risks and constraints is the weather risk which is persistent in smallholder agriculture. Its shock does not only trap farmers and households in poverty, but also limits the willingness of farmers to invest in agronomic practices that might increase productivity and improve their economic status (IFAD and WFP, 2011). Among all the agricultural risks that affect smallholder farmers in developing countries, production risk is very important, since any variance in production may result into severe consequences for the farmer and his family (Roll *et al.*, 2006) and severe impact on agricultural GDP and the national economy at large (Fuchs and Wolff, 2010).

Climate change causes adverse effects on agricultural production which vary from one place to another depending on the differences in geographical conditions, altitude and relief. For example, in Tanzania climate change is reported to have caused a decrease in average yield of 33% countrywide, 84% in the Central region, 22% in the North-Eastern highland, 17% in the Lake Victoria region and 10-15% in the Southern highlands region (URT, 2007).

Moreover, biotic stresses due to insects, pests, bacteria, pathogens, viruses, and fungi are severely constraining agricultural production in developing countries; often aggravating crop losses (James, 2003; and Suleiman and Rosentrater, 2015). Similarly, abiotic stresses due to drought, salinity, acid soils and deficiency or toxicity of micronutrients also constrain crop productivity (James, 2003; and Kassie *et al.*, 2012). Overcoming these biotic and abiotic constraints, through conventional and biotechnology applications, would allow the potential of the current maize germplasm to be realized, resulting in significant yield increases (James, 2003). The pest problem is more pronounced in the country and farmers are yet to fully integrate synthetic pesticides into their insect pest management systems due to the subsistence nature of production and high poverty levels that make them rely on indigenous knowledge systems to meet their needs (Mihale *et al.*, 2009).

In Tanzania maize is the main food crop, produced on 45% of the total cultivated area in the country (Lyimo *et al*., 2014). The crop is produced for both food as well as a cash purposes. The overall trend of maize production in Tanzania is highly volatile when compared to other East African countries which experienced steady growth yields or at least slow growth over time. For instance, with exception to Kenya and Tanzania other East African Countries such as Rwanda, Uganda, Malawi and Ethiopia have risen maize production since 2003 in terms of both production quantity and area harvested (Aylward *et al*., 2015).

The Government of Tanzania has been introducing several initiatives to support the agriculture sector including the reintroduction of agricultural input subsidies in 2003/04 to support technology adoption by smallholder farmers in the country and introduction of the National Agricultural Input Voucher Scheme (NAIVS) in 2008/09. NAIVS was introduced as a part of implementing Agriculture Sector Development Program (ASDP) to subsidize agricultural inputs so as to increase crop production/productivity and achieve food security (Hepelwa *et al*., 2013). The Government intends to achieve its goal of increasing production and productivity of maize and other crops through the use of irrigation, improved and appropriate technology and provision of agricultural inputs so as to support smallholder farmers (URT, 2012). The available evidence shows that NAIVS has generally succeeded to improve crop yields and the average cultivated area per household has more than doubled in 2012 (Hepelwa *et al*., 2013).

Despite this increase in the Government efforts crop productivity is still far below the potential yields mainly due to over reliance on unpredictable natural precipitation, use of manual labour to work on the land, limited use of improved seed and fertilizer (MAFAP, 2013). The NAIVS has generally failed to reach the majority of the poor smallholder farmers and the use of agro-inputs have remained low for the poor farmers due to high market prices of the inputs (Hepelwa *et al*., 2013).

According to Nyangena and Juma (2014) proper use of inorganic fertilizers and improved maize varieties for instance, would have significantly increased maize yields, especially when adopted as a package, rather than individual elements. This calls for the need to design policies that would promote complementary agricultural technologies (packaged), and target households and areas experiencing with low yields.

According to Jaleta *et al*. (2013) smallholder farmers' decision on whether to use or not to use a certain improved agricultural technology such as improved maize seed varieties is complex because it is affected by both internal and external factors. On the other hand, production risk in term of yield variability is also affected by internal factors such as labour, manure, mulch and fertilizer (Wanda, 2009) and external factors such as rainfall, frost, pests and diseases (Fufa and Hassan, 2003). Important is to understand the factors which influence the adoption of such technologies significantly and how these factors interact together with production risk to determine the adoption intensity and determinants of production risk of agricultural technologies. In particular the study focused on improved maize seed variety as the technology.

1.2 Problem Statement and Justification

Despite its importance as food as well as cash crop, maize yields in Tanzania are reported to be low (1.43 tons/ha) when compared to other East African countries eg: 1.84 tons/ha in Kenya, 3.03 tons/ha in Uganda, 22.85 tons/ha in Rwanda and 13.22 tons/ha in Burundi (FAOSTAT, 2013). This is attributed to many factors including changing climatic condition, diseases and pests and the use of inferior production technologies.

The available projections by Rowhani *et al.* (2011) and URT (2014) suggest that an increase in seasonal temperature by 2°C by 2050 will result into further decrease in average maize, sorghum and rice production by about 13%, 8.8% and 7.6% respectively. According to Van Ittersum *et al*. (2016) projections using national population growth and food consumption patterns, area under production of five potential cereal crops such as maize, rice, sorghum, millet and wheat in Tanzania and other nine Sub-Saharan Countries such as Ethiopia, Kenya, Uganda, Zambia, Burkina Faso, Ghana, Mali, Niger and Nigeria will need to increase by at least 80% to meet the domestic demand for the crops by 2050.

In the face of increasing human population and declining land resources, crop productivity increase is vital for meeting food requirements to achieve food security in the country. Agricultural input packages with high yielding varieties combined with fertilizers and best agronomic management practices are key to the achievement of this goal (Kassie *et al*., 2013). This also requires that consideration of the risk aspect by promoting adoption of improved maize seed varieties which are resistant to production risk.

To attain sustainable food security, there must be strategies in place that promote the use and adoption of improved maize seed varieties as the main cereal crop grown in the country. This in turn requires a thorough understanding of the factors which influence the adoption and diffusion of these varieties as well as the factors which increase production risk. Currently this understanding is scanty and largely based on isolated case studies lacking the national perspective.

In addition, most of the previous studies have analyzed adoption using land allocated to improved seeds as an outcome/observable equation (Kaliba *et al*., 2000 and Jaleta *et al*., 2013). In this study, the observed final outcome is a function of yield per plot (kg/acre) based on the understanding that farmers make decisions about the type of seeds, acreage and level of input to use based on their perception about yield.

1.3 Significance of the Study

The findings of this study will be useful in assisting policy makers to establish policies, programs and strategies to promote the adoption of improved maize seed varieties which are resistant to weather and biological related risks so as to reduce production risk and improve yield and food security for smallholder farmers in Tanzania.

1.4 Objectives of the Study

1.4.1 Overall objective

The overall objective of this study was to assess determinants of production risk associated with smallholder farmers who adopted improved maize seed varieties in the United Republic of Tanzania so as to inform policies and strategies for sustainable food security.

1.4.2 Specific objectives

i) To evaluate factors affecting adoption and diffusion of improved maize seed varieties in Tanzania,

ii) To assess intensity of adopting improved maize seed varieties, and

iii) To determine factors that increase production risk in farming systems which use improved maize seed varieties.

1.5 Research Hypotheses

i) Socio-economic characteristics do not influence the adoption and diffusion of improved maize seed varieties.

ii) Household and farm specific characteristics do not affect the intensity of adopting improved maize seed varieties among smallholder farmers.

iii) Household and farm specific characteristics do not affect production risk for smallholder farmers who adopted improved maize production system.

1.6 Organization of the Dissertation

This dissertation is organized in five chapters. Chapter one presents the background information, the significance of the study, problem statement and justification, study objectives and research hypotheses. Chapter two reviews literature for the study. Chapter three presents the methodology used for the study. Chapter four presents results and a discussion of the study. Chapter five presents the summary of the research findings, conclusion and recommendations emanating from the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concept of Production Risks and Agricultural Risks

Production risk refers to the potential deviation between expected and real outcome which are caused by all factors affecting production which are not under the farmer’s control, oscillating randomly from year to year and not related to other types of agricultural risks apart from production risk (Deutshe Bank Research, 2010).

Agricultural risks refer to all risks associated with negative outcomes stemming or originating from deficiently predictable biological, climatic, and price variables. These variables include biological factors such as pests and diseases, extreme climatic factors which are not within the control of agricultural producers such as flood, drought and adverse changes in both input and output prices (World Bank, 2005). According to Deutshe Bank Research (2010) agricultural risks are classified as production risks, market/price risks, financial risks, institutional/regulatory risks and personal/human resource risks (Table 1).

Table 1: Types of agricultural risks and their sources

S/N	Types of agricultural risks	Source
1.	Production risks	✓ Variation in crops yield and livestock production caused by: ✓ Weather related risks such as drought, floods and other extreme weather ✓ Biological risks such as diseases and pests ✓ Technological risks
2.	Market /Price risks	✓ Inputs and output price volatility ✓ Integration in the food supply value chain with respect to quality, safety and environmental regulation
3.	Financial risks	✓ Changes in the interest rates charged on the debt on the farmer ✓ Credit availability ✓ Interest rate and exchange rate
4.	Institutional/ regulatory risks	✓ Changes in agricultural policies such as subsidies ✓ Food safety and environmental regulations ✓ Trade policies
5.	Personal/ Human resource risks	✓ These are risks associated with the unavailability of personnel such as death, divorce, health issues and accidents

Source: Deutshe Band Research (2010)

2.2 Concept of Adoption and its Application to Improved Maize Seed Varieties

Adoption can be defined as the decision to apply an innovation and to continue to use it in the long term (Van den Ban and Hawkins, 1988). Maize can be adopted as a non-package, partial package or complete package depending on the farmers' decision. Non package adoption occurs when a farmer decided to adopt only one of the improved agricultural technologies such as improved maize only, agricultural chemical only or inorganic fertilizer only. According to Nyangena and Juma (2014) complete package refers to joint adoption of improved maize seed varieties, planting fertilizer and top dressing fertilizer. Partial adoption includes other combinations such as planting fertilizer with certified seed, planting fertilizer with top dressing fertilizer, planting fertilizer only, certified seed only and top dressing fertilizer only.

Most studies on the use of new agricultural technology have used the concept of adoption differently. For example Kaliba *et al*. (2000) and Ghimire *et al*. (2015) used to examine factors affecting adoption of improved maize seeds and rice respectively. They both used binary dependent variable to indicate farmers' decision to use improved varieties 1 for adoption of improved varieties and 0 for non-adoption. Kaliba *et al*. (2000) did not only examine the decision to use, but also the intensity of adoption was analyzed using a continuous dependent variable in terms of hectares under improved maize varieties.

Similarly, other studies such as Tura *et al*. (2010) and Kim (2017) also used binary dependent variable to study the use of improved technology. Different from Kaliba *et al*. (2000) studies by Tura *et al*. (2010) and Kim (2017) in the second step they analyzed continued use of improved technology.

Similar to Kaliba *et al.* (2000), Koundari and Nauges (2005) used the concept of adoption using a binary dependent variable to indicate a farmers' decision to use improved varieties 1 for adoption of improved varieties and 0 for non-adoption and the intensity of adoption. The study differs from other studies on that intensity of adoption was in terms of mean yield. Moreover, the study analyzed production risk in terms of yield variability for adopters in order to identify determinants of production risk for adopters of improved maize seeds.

2.3 Theoretical Framework

The study was based on the Just and Pope (1979) production function expressed as the summation of the mean and variance functions. The framework, made it possible for the econometrician to study the determinants of mean production and variance (production risk) separately. It addresses the question of how a smallholder farmer makes decisions on which input to use in maize production under risk condition. This understanding helps to analyze how the farmers' decisions are affected by production risk. Mathematically, the theoretical framework is presented as follows:

$$Y_i = f(X, \beta) + h(X, \alpha)\mu \quad (1)$$

Where: Y_i = Total production, f(X, β) = Mean production function and h(X, α) = Variance of output and μ = An error term.

In addition, the Heckman (1979) two step model was employed to reduce sample selection bias. In particular, (Eq.1) was adjusted to include the Inverse Mill's Ratio (IMR) calculated in the Heckman two step model as follows;

$$Y_i = f(X, \beta) + h(X, \alpha)\mu + \sigma\lambda \quad (2)$$

Where: Y_i = Stochastic production function, $f(X, \beta)$= Mean production function and $h(X, \alpha)$= Variance of output, μ = An error term and σ = Coefficient for Inverse Mill's Ratio and λ = Inverse mill's ratio.

According to Wanda (2009) stochastic production function in (Eq.1) can be represented as $y = f(X, \alpha) + \mu$ where $\mu = h^{1/2}(X, \delta)\varepsilon$. The second step involved the use of Ordinary Least Square (OLS) to obtain the estimates of $\hat{\alpha}$ and μ from the regression of y on $f(X, \alpha)$or in logarithmic form as lny on $\ln f(X, \alpha)$. In the third step residuals are then calculated as the difference between actual output (y) and mean output ($f(X, \alpha)$) which can be in linear form (Eq. 3) or logarithmic form (Eq. 4).

$$\hat{\mu} = y - f(X, \alpha) = h(X, \delta) \quad (3)$$

Where: y = Actual output, $f(X,\alpha)$= Mean output and $h(X,\delta)$ = Variance of output, X = explanatory variables, α and δ = Coefficients for mean output and variance of output respectively.

Residuals in logarithmic form

$$\hat{\mu} = \ln y - \ln f(X,\alpha) = \ln h(X,\delta) \qquad (4)$$

Where: ln = Natural logarithm, y = Actual output , $f(X,\alpha)$= Mean output and $h(X,\delta)$ = Variance of output, X = Explanatory variables, α and δ = Coefficients for mean output and variance of output respectively.

2.3.1 Maize sub-sector

2.3.1.1 Importance of maize

Maize is one of the two most important food crops worldwide (Hellin *et al.*, 2012). It is grown throughout the world, with a large difference in yields. In Sub-Saharan Countries, specifically in Angola, Malawi, Mozambique, Zambia and Zimbabwe, maize is the primary crop both in terms of acreage and absolute yield levels (Lobell *et al.*, 2008). Maize, wheat and rice provide 30% of the food calories to 4.5 billion people in almost 100 developing countries, most of which are from Sub-Saharan Africa and South Asia (Hellin *et al.*, 2012).

Apart from being a staple food for many people, especially in Africa, maize is used in feeding livestock and as a raw material for many industries. Human consumption of the grains has remained fixed when compared to the use of maize for animal feed. The amount of maize used to feed depends on the crop's supply and price, amount of additional ingredients used in feed rations and supplies and prices of competing ingredients. In industries maize can be processed into a range of food and industrial products, such as starch, sweeteners, oil, beverages, glue, industrial alcohol, and fuel ethanol. In the previous decade, the United States has increased significantly the use of maize as a raw material in industrial activities specifically fuel production for about 40% (Ranum *et al.*, 2014).

In Tanzania, Maize is a distinct and important staple food used by a good number of people, both in rural and urban areas. Just like in other developing countries, maize in the country is mainly used for human consumption (Oladejo and Adetunji, 2012). It is also a major source of income for the majority of smallholder farmers. The crop is produced for both human consumption and the market, where about 40 percent is sold, mostly locally (DTMA, 2014).

2.3.1.2 Maize consumption in Tanzania

Maize is the main staple food consumed by many people in Tanzania. Most consumers prefer white flint maize compared to other types of maize and hence the amount of yellow maize grown in Tanzania is therefore minor (DTMA, 2014). Maize accounts for 31% of the total food production and constitutes more than 75% of the cereal consumption in the country. According to DTMA (2014) maize provides 60% of dietary calories and more than 35% of the utilizable protein to the Tanzanian population. Annual per capita consumption is 73kg/person/year.

2.3.1.3 Maize production trend in Tanzania

Despite its importance as a food and export crop maize production in Tanzania is still low when compared to the rising demand of maize in food provision as well as in animal feeding. Its growth rate is very variable with minimum growth rate of about -14.07% in

2003 and the maximum growth rate of about 42.30% in 2010 and hence it becomes difficult to make future predictions of maize production (Table 2).

Table 2: Maize production in the United Republic of Tanzania by year from 2000 to 2016

Year	Production (tons)	Growth rate (%)
2000	2 000 000	
2001	2 500 000	25.00
2002	2 700 000	8.00
2003	2 320 000	-14.07
2004	3 230 000	39.22
2005	3 300 000	2.17
2006	3 423 000	3.73
2007	3 302 000	-3.53
2008	3 556 000	7.69
2009	3 326 000	-6.47
2010	4 733 000	42.30
2011	4 341 000	-8.28
2012	5 104 000	17.58
2013	5 356 000	4.94
2014	6 737 000	25.78
2015	6 000 000	-10.94
2016	5 500 000	-8.33

Source: URT (2016)

2.4 Production Risks Affecting Maize Production in Tanzania

Insects and pests have been a major threat in maize production in Tanzania for many years (Ak'habuhaya and Lodenius, 1998; Mihale *et al*., 2009; and Suleiman and Rosentrater, 2015). According to Shiferaw *et al*. (2011) maize is attacked by many insects and pests during all stages of growth from seedling to storage. The diseases, pests, and common weeds affecting maize production in Tanzania are discussed in the following sub-sections.

2.4.1 Diseases affecting maize production in Tanzania

Maize diseases are natural factors beyond farmers control that have a powerful explanation of maize variability (Fufa and Hassan, 2003). The effect of diseases to maize production range from the early stage when they start to grow to harvest stage and thus, may lead to increase in yield variability. Some of the diseases which affect maize production in Tanzania are as summarized in (Table 3).

Table 3: Common maize diseases in Tanzania

Common Name	Scientific Name	Agricultural zone
Maize Streak Virus (*MS*V)		Southern Highlands, Lake
Leaf rust	*Puccinia sorghi* and *P. polysora*	Northern,
Leaf blights	*Helminthosporium turcicum and maydis*	Lake, Northern
Common smut	*Ustilago maydis*	Lake
Maize Necrosis Lethal Disease (*MNLD)*		Lake, Central and Northern

Source: ASSP (2004), cited by Suleiman and Rosentrater (2015) and Kitenge *et al.* (2015).

2.4.2 Major pests affecting maize production in Tanzania

Pests has been a major threat in maize crop production for a long time due to lack of knowledge. This might be due to the fact that most of the farmers are rural based and conservative. Failure of pest management technologies application when coupled with the low number of extension staff contributes highly to low maize production. Some of pests affecting maize production in different agricultural zones of Tanzania are as summarized in (Table 4).

Table 4: Common field pests of maize in Tanzania

Insects	Scientific Name	Agricultural zone
Maize Stalk Borer	*Busseola Fusca*	Southern highlands, Lake, Northern, Western, Eastern, Central
African Armyworm	*Spodoptera exempta*	Northern, Western, Eastern, Central
Leaf hoppers	*Cicadulina mbila*	Southern highlands
Mole crickets	*Gryllotalpidae*	Southern highlands
African Ballworm	*Helicoverpa armigera*	Southern highlands
Cutworms	*Agrotis Ipsilon*	Southern highlands
Maize Sterm Borer	*Chilo Partellus*	Northern

Source: ASSP (2004), cited by Suleiman and Rosentrater (2015)

2.4.3 Common weeds affecting maize in Tanzania

Weeds are among factors which reduce maize yield in Tanzania. The decrease in yield might be attributed due to the competition of sunlight and nutrients available in the soil between weeds and maize crop. Therefore, weed control at appropriate time leads to the increase in maize yield. Some of weeds affecting maize production in Tanzania are as shown in (Table 5).

Table 5: Common weeds of maize in Tanzania

Weeds	Scientific Name	Agricultural zone	Picture
Wild lettuce	*Lactuca virosa*	Southern highlands, Lake, Northern, Western, Eastern, Central	
Wandering Jew	*Tradescantia pallid*	Southern highlands, Lake, Northern, Western, Eastern, Central	
Witch weed	*Striga spp*	Lake	
Simama (Mbigili/Nyamwezi)	*Oxygonum Sinuatum*	Lake	
Bristly Starbur Weeds	*Acanthospermum hispidum*	Lake	
Star grass	*Heteranthera zosterifolia*	Eastern	
Crabgrass	Digitaria spp.	Southern highlands	
Mexican poppy	Argemone Mexicana	Southern highlands	

Source: ASSP (2004), cited by Suleiman and Rosentrater (2015)

2.5 Factors Affecting Adoption and Diffusion of Agricultural Technology Specifically Improved Maize Seed Varieties

Determinants of adoption of agricultural technology have been grouped differently by many researchers due to lack of distinguishing factors between one variable and another. According to Bonabana-Wabbi (2002) categorization is done to suit the current technology being investigated, the location, and the researcher's preference, or even to suit client needs. For instance the level of education of a farmer has been classified as a human capital by some researchers while others classify it as a household specific factor. Mwangi and Kariuki (2015) categorized the factors determining adoption of agricultural technology into technological factors, economic factors, institutional factors, environmental and household specific factors.

2.5.1 Economic factors

Economic factors are factors that indicate smallholder farmers resource endowment such as farm size, proportion of land allocated to maize production and off-farm income. These factors affect smallholder farmer decision to adopt and diffuse new agricultural technology such as improved maize seed varieties. Some of economic factors affecting adoption of improved maize seed varieties are discussed in the sub-sections as follows:

2.5.1.1 Farm size

Farm size is one of the factors affecting adoption and diffusion of improved agricultural technology. Some studies have shown that farm size influences adoption of new agricultural technology negatively. For example, studies by Katinila *et al.* (1998) and Bruce *et al.* (2014) showed that farm size was negatively related to adoption of improved maize seeds and improved rice varieties respectively. This means that farmers with small farms had a higher probability of adoption compared to the one with larger farms. Thus, farm size can influence adoption of improved agricultural technology negatively.

2.5.1.2 Off-farm income

Off-farm income or off-farm earnings can be defined as the income generated by households from any non-agricultural income generating enterprises such as metal work, transportation or any other informal businesses, as well as transfers and remittances (Diiro, 2013). It is another driver of adoption that has been shown by Diiro *et al.* (2015) who reported non-farm income increases the likelihood of adopting fertilizer. Similarly, Barrett *et al*. (2001) found that income from non-farm activities assists in overcoming liquidity and credit constraints, which means that farmers can have savings that might be used in the adoption of new technology.

2.5.2 Technological factors

Characteristics of a technology

Characteristics of a technology are one of the important factors that a smallholder farmer consider before taking a decision to adopt or not to adopt a certain technology (Mignouna *et al*., 2011). Moreover, Loevinsohn *et al*. (2013) reported that farmers' decisions about whether and how to adopt new technology are accustomed by the dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances. According Mwangi and Kariuki (2015) farmers who perceive a technology being reliable with their requirements and well-suited to their environment are to be expected to adopt since they discover it as a positive investment to them. Farmers' perception about the performance of the technologies significantly influences their decision to adopt them. Diffusion itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison of the uncertain benefits of the new invention with uncertain costs of adopting it (Hall and Khan, 2002).

2.5.3 Social factors

2.5.3.1 Age of the head of the household

Age of the head of the household is another factor that influences adoption of a technology. It is assumed to have a positive influence on the farmers' decision to adopt a certain technology because older farmers have more experience and knowledge. For example, according to Mignouna *et al.* (2011) there is positive relationship between age and imazapyr-resistant maize technologies adoption, which indicates that the older the household head, the greater the chances of adopting the improved technology. In contrast, Akinbode and Bamire (2015) study on adoption of improved maize varieties in Osun State, Nigeria reported that age was negatively related to adoption of improved maize varieties.

2.5.3.2 Gender of the head of the household

Gender refers to the sex of the head of the household either male in male headed households or female in female headed households. Hailu *et al.* (2014) found that gender had positive and statistically significant relationship with fertilizer adoption. Other things remaining constant, male headed households had higher probability of adopting fertilizer than female headed households who are mostly widowed or divorced.

2.5.3.3 Level of Education of the head of the household

Education is one factor among many factors affecting adoption that is most frequently used in empirical models due to its theoretical uncontroversial nature. It is measured in terms of the number of years of schooling. Most studies show that education and technology adoption are positively correlated. This is due to the fact that educated farmers have better access to information and knowledge that are of use in farming operation compared to uneducated farmers. Apart from that, they have higher potential of analyzing information and knowledge which is crucial for new technology implementation and realization of expected results (Uematsu and Mishra, 2010).

2.5.3.4 Household size

Household size refers to the total number of people in a household. It is a proxy for household labour and thus larger households are expected to have more labour compared to smaller households. Household size had a positive effect on the adoption of improved maize varieties. Its significance can be due to the fact that large household size can be served as a source of labour (Bruce *et al.,* 2014; and Akinbode and Bamire, 2015).

2.5.4 Institutional factors

2.5.4.1 Involvement in social groups

Belonging to a certain social group enhances social capital, allowing trust, idea and information exchange. According to Simtowe *et al.* (2010) probability of farmers' awareness of the improved groundnut variety is higher among the farmers who are members of a faith based organization when compared to those who are not members. The membership in a producer marketing group returned a positive and significant coefficient indicating that farmers who are members of such groupings have a higher propensity to adopt improved varieties.

2.5.4.2 Acquisition of information about a new technology

Acquisition of information about a new technology is another determinant of adoption of technology that enables farmers to gain knowledge of its existence, effective use of technology and also it eases its adoption (Mwangi and Kariuki, 2015). On the other hand, katinila *et al.* (1998) reported that in Southern Tanzania many respondents are unaware of improved maize technologies such as the use of fertilizers, use of ox-drawn implements, herbicides and disease control measures which resulted to low use of improved maize technologies due to lack of contact between farmers and extension services and agricultural research organizations.

2.5.4.3 Access to extension services

Access to extension services is also a determinant of technology adoption, as it is used by many studies. Extension services are measured in terms of the number of extension visits. Diiro *et al.* (2015) reported that there is a positive relationship between the number of extension visits and adoption in male headed households. The study showed that extension visit increases the likelihood of adoption.

2.5.4.4 Access to credit

Access to credit is another factor affecting adoption and diffusion of improved maize seed varieties. It is the best option for helping smallholder farmers to diversify their economic base. According to Hailu *et al.* (2014) access to credit was statistically significant and positively related to adoption of fertilizer and high yielding varieties.

2.5.5 Environmental factors

2.5.5.1 Location

Location is also a factor that determines adoption of a technology. According to Smale *et al.* (2011) maize is an extra photosensitive food crop, which is grown over a wider range of altitudes and latitudes than any other food crop. It is grown under temperatures ranging from cool to very hot, on wet to semi-arid lands, and in many different types of soil. Maize is a major staple food crop grown in diverse agro-ecological zones and farming systems. It is consumed by people with varying food preferences and socio-economic backgrounds in the Sub-Saharan Africa (SSA).

2.5.5.2 Soil fertility

Soil fertility is another important factor that affects smallholder farmers in their decision on whether to use improved agricultural technology such as mechanized instruments, improved seeds and other input or not. According to Hepelwa *et al.* (2013) crop cultivation is characterized by low mechanization where the majority of farmers use poor farm inputs such as hand hoe and traditional seeds. The use of tools of low quality and poor agronomic practices results to degraded soils with significant loss of nutrients and thus contributing to low productivity problem.

2.5.5.3 Weather related risks

In Southern Tanzania maize production is highly affected by weather related risks such as unpredictable rainfall and drought. In this region maize production is risky due to its reliance on unpredictable rainfall and also maize is highly affected by drought. Apart from that performance of drought-tolerant seeds such as Staha and Katumani is still poor (Katinila *et al.,* 1998). Moreover, Scandizzo and Savastano (2010) on their study of adoption and diffusion of genetically modified crops in the United States found that the coefficient of uncertainty proxies (variance and beta parameters) reflects the negative relationship between adoption and objective risk.

2.6 Empirical Studies on the Adoption of Improved Maize Seed Varieties

There are many studies on adoption of improved maize and other complementary inputs such as fertilizer and herbicides who used Heckman two step procedure model and other binary models such as logistic regression models. For example, Lyimo *et al.* (2014) used

Heckman two step procedure model to conduct a study on the use of improved seed in Tanzania. The study observed that drought, low prices of the products, pests, diseases and high input prices were mentioned by extension officers as the most important constraints in maize production. The study reported that high costs of improved seed, poor availability and lack of knowledge were some of the reasons why farmers did not use improved seed.

Hailu *et al*. (2014) used probit and Ordinary Least Square (OLS) regression models to identify the determinants of agricultural technology adoption decision and examine the impact of adoption on farm income. The study used cross sectional data collected through semi-structured questionnaire administered on 270 randomly selected smallholder farmers. The results showed that agricultural technology adoption decision of farm households has been determined by irrigation use, land ownership right security, credit access, distance to the nearest market, plot distance from the homestead, off-farm participation and tropical livestock unit. The regression result also revealed that agricultural technology adoption has a positive and significant effect on farm income by which adopters are better-offs than non-adopters.

Chuma (2009) used a logistic regression model in the investigation of the factors affecting the adoption of selected agricultural technologies on maize production in Mvomero District. In the study area, 74% of the farmers applied improved maize seed. The results showed that the estimate for fertilizer application was significantly explained by education, credit and extension.

Moreover, Kaliba *et al*. (2000) used the Heckman two-step procedure model with the selection equation (probit model) and regression equation (OLS) to conduct adoption studies in the intermediate and lowland zones of Tanzania. The results indicated that availability of extension services, on-farm field trials, variety characteristics and rainfall were the most important factors that influenced the extent of adopting improved maize seeds and the use of inorganic fertilizer for maize production. Farmers preferred varieties which minimized field loss rather than maximizing yields.

Nkonya *et al.* (1998) conducted a study on the adoption of maize production technologies in Northern Tanzania. A study employed the Heckman two-step procedure to simultaneously analyze factors affecting adoption of improved maize seed and inorganic fertilizer and their adoption intensity. The study found that the demand for composite seed was less than that for hybrids, despite the release of recyclable composite seed by the National Maize Research Program. Farming experience was the only factor that significantly influenced the probability of adopting improved maize in the intermediate zone. None of the factors significantly influenced the intensity of adopting improved maize seed varieties.

2.7 Empirical Studies on Production Risks

There are numerous empirical studies on production risk such as Fufa and Hassan (2003), they used Just and Pope (1979) production function to analyze the impact of inputs on mean levels and variability of maize yield in Dadar district, Ethiopia. The study is based on cross sectional production data collected during the 2001/02 agricultural production year in the district. Results from the estimation of the mean maize yield function for adopters showed that land allocated to maize production, fertilizer, larger maize plot size and use of oxen were statistically significant and positively related to mean maize yield. Results from the estimation of the second moment for adopters of improved maize technology showed that the size of the maize plot, fertilizer and planting labour were found to be risk-increasing in maize production whereas cultivation labour and oxen reduce production risk. However, the effects of all factors were statistically insignificant. On the other hand, the mean yield estimation results for non-adopters suggest that larger maize plots and planting labour were significant and positively related to mean maize yield. Results from the estimation of the second moment for non-adopters of improved maize technology showed that the use of higher seeding rates and cultivation labour were found to increase the variability in maize yield while larger size plots and planting labour reduce production risk for non-adopters.

Also, Koundouri and Nauges (2005) used the Just and Pope (1979) production function with Heckman two step model to examine how risk analysis was affected by selectivity bias in the estimation of the production function. The study used a cross-section of 239 farms located in the agricultural region of Kiti in Cyprus surveyed in 1998. Overall, the results showed that there were differences between estimates with and without selectivity correction for both vegetable growers and cereal growers, despite of the insignificance of mill's ratio in the production model for cereal producers. At a higher level of significance labor and water were found to be risk-decreasing inputs in both models, but the extent of their effects varied depending on the model used.

Roll *et al*. (2006) also used the Just and Pope production function and treated production risks as heteroskedasticity to investigate how production risk may influence the way a risk-averse producer, like a subsistence farmer chooses optimal input levels in Kilimanjaro region in Tanzania. They found evidence of output risk in inputs with the mean and variance function re-estimated using a maximum likelihood estimator to correct the standard errors and provide valid inference. The result showed that risk-averse producers took into account both the mean and the variance of output, and therefore their input level choice differed from that of the optimal input level of risk-neutral producers.

Czekaj and Henningsen (2013) used non parametric panel data kernel regression in their study on production risk, output price uncertainty and risk attitudes of Polish dairy farmers based on a firm-level unbalanced panel data set for the period 2004-10. The study used expected utility derived from the expected normalized restricted profit, which was an expansion of the expression of Just and Pope (1978) to give an explanation for both production risk and price uncertainty. The study used a model for production risks only, output price risks/output price uncertainties only or both production risks and output price risks to show farmers' risks. Expected utility function was derived from expected normalized restricted profit. The risk preference function of production risk only, price risk only and for both production and price risk only were obtained after calculating the first order condition of the expected utility function derived from expected normalized restricted profit.

Hasanthika *et al.* (2013) study on climate variability, risk and paddy production used data of a panel of 6 major paddy growing districts for the period, 1980-10 for the two major paddy growing seasons. The study aimed at identifying how increased variability in paddy yields was related to increased risk and investigates the impact of climatic and production factors on risk. The study used Just and Pope production function with related risk properties to see how variation in climatic variables and production factors affects the probability distribution of paddy yields. The results showed that only rainfall, minimum temperature, labor and machinery, minimum temperature influenced mean equation. The results of the main function showed that, climatic factors as rainfall, minimum temperature and fertilizer cost had a negative effect on the mean yield. Whereas, the maximum temperature and other production factors as labour, machinery cost, time trend, extent of paddy cultivation had a positive relationship with the mean yield distribution. On the other hand, variance equation results showed that only rainfall, fertilizer and, time were statistically significant.

Guttormsen and Roll (2013) used Just and Pope (1978) framework for modeling risk in subsistence agriculture. The analysis is based on data obtained from a 2002 survey of subsistence farmers in the Kilimanjaro region of Tanzania. The results showed that access to credit was the only socio-economic factor that was significant and positively related to mean production. On the other hand, the results of the analysis of production risk showed that seed, extension services and learning were negatively associated with production risk, whereas land usage, fertilizer, pesticide, traditional irrigation, access to credit and sex dummy were positively related to production risk.

1.6 Conceptual Framework

Adoption is conventionally conceptualized to be the mental process through which an individual passes from first stage learning about an agricultural innovation to the final stage of adoption (Mutundwa *et al*., 2007). New technology adoption is often modeled by the way of a choice between two alternatives the local (traditional) variety and the new improved (modern) variety (Mmbando and Baiyegunhi, 2016).

In most adoption studies the decision making process of farmers with respect to the adoption of new technologies focus on one time dichotomous adoption decision and intensity of technology adoption/continued use (kaliba *et al*., 2000 and kim, 2017). In this study the decision making process of the farmer is assumed to involve three stages: (1) the decision on whether to use improved seed or not (2) decision on the level of intensity of adopting (3) how does the adoption decision made in the first stage affect the determinants of yield variability (production risk) with selection bias taken into account.

Smallholder farmer just like most of the decision makers tend to invest in a new technology that could help them to reduce the sources of uncertainty that he/she had to face and when the expected marginal benefits were larger than the costs he/she had to sustain (Scandizzo and Savastano, 2010).

The study was conducted under the assumption that smallholder farmers make decisions on input use such as type of seed, fertilizers, acreage to allocate to maize production and the level of input to use, which were the determinants of the observable outcome/yield. Apart from that, production risk and adoption were assumed to have forward and backward relationship. This implies that production risk might affect smallholder farmers' adoption decision and also the adoption of improved maize seed varieties might affect the determinants of production risk. Moreover, adoption of improved maize seed varieties which are tolerant to the production might result in a reduction in the production risk.

The effect of production risk to smallholder farmers differs from one farmer to another due to differences in socio-economic and other factors, but under improved maize production system yield per plot is assumed to be increasing due to reduction in risks and hence it is presumed to result to improved smallholder farmers socio-economic factors.

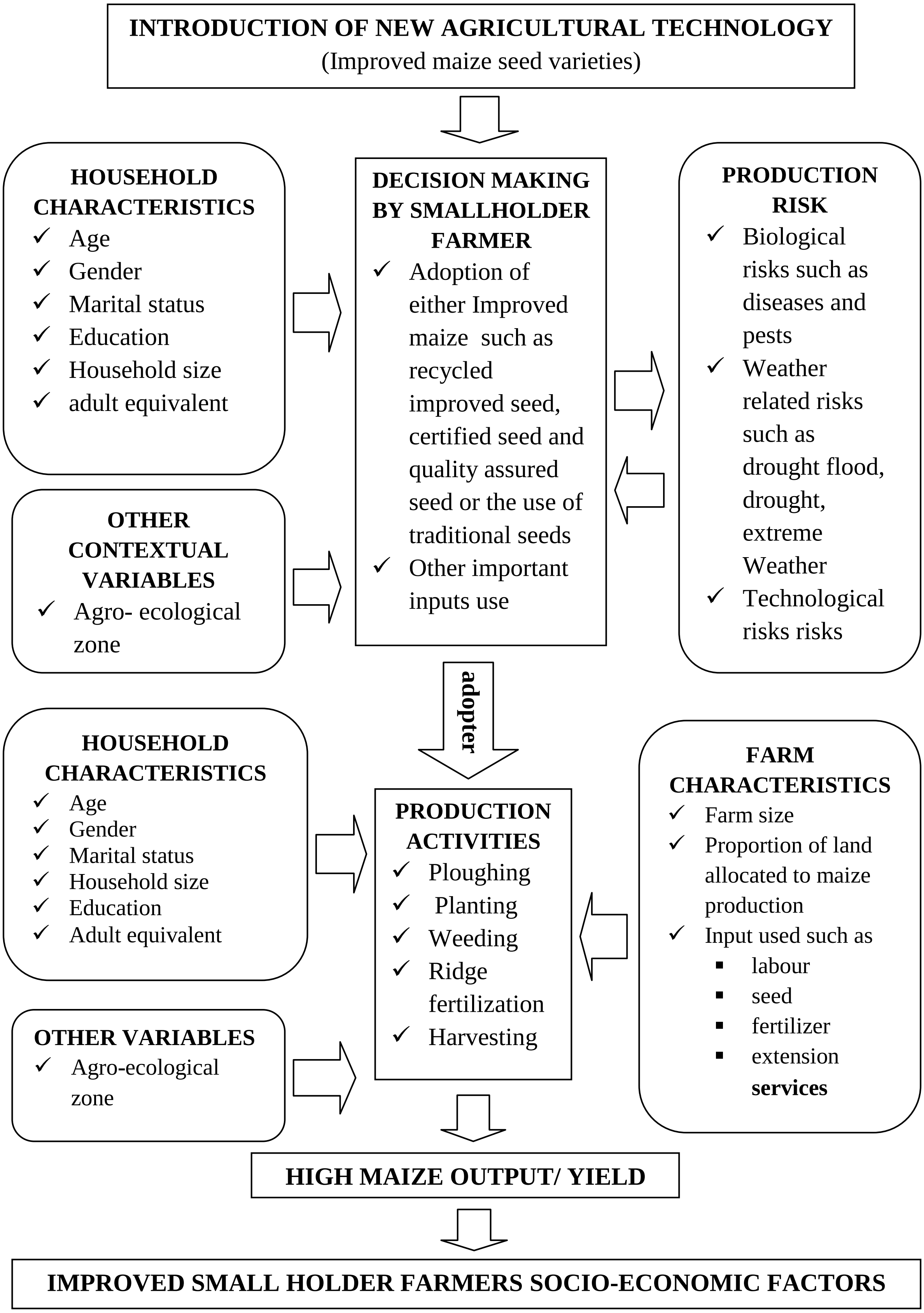

Figure 1: Conceptual framework of impact of production risk on Improved Maize Production system

Source: Own conceptualization

CHAPTER THREE

3.0 METHODOLOGY

3.1 Research Design

The study used cross sectional data collected in the 2012/13 cropping season. The data were collected by the Tanzania national panel survey in a one year cycle starting from October 2012 to November 2013.

3.2 Area of the Study Area

Tanzania is the largest amongst East African Countries which consists of Tanzania mainland initially called Tanganyika and offshore islands of Zanzibar (Unguja and Pemba) and Mafia in the Indian Ocean (URT, 2007). It is the thirty first country worldwide in area coverage, a total area of 947 300km^2 where the land is 885 800km^2 and water covers 61 500km^2 (CIAWFB, 2016). According to last United Nations estimate in 1 July 2017 the population was 57.31 million with an average growth rate of about 3.13% per annum (WPR, 2017).

3.3 Location

The United Republic of Tanzania is one among the countries found on the East coast of Africa. The country lies between longitudes 30º and 40º east and latitude 1º and 12º South of the equator (URT, 2007). Tanzania Mainland has frontiers with the following countries: in the Northern part: Kenya and Uganda; West: Rwanda, Burundi and Democratic Republic of Congo; South West: Zambia and Malawi; South: Mozambique; East: Indian Ocean. On the other hand, Zanzibar which comprises of Unguja and Pemba Islands situated 30km from Tanzania Mainland in the Indian Ocean (NBS, 2013).

3.4 Climatic Condition

According to Rowhani *et al*. (2011) climatic condition varies considerably from tropical at the cost to temperate in the highlands. Average annual precipitation over the entire nation is 1 042mm. Average temperatures range between 17°C and 27°C, depending on the geographical location. Natural hazards which are prone in Tanzania include both flooding and drought. Within the country, altitude plays a large role in determining the rainfall pattern, with higher elevations receiving more precipitation (Agrawala *et al.*, 2003).

Tanzania experiences two major rainfall regimes namely the Unimodal in the Southern parts and Bimodal in Northern parts. Unimodal is experienced from November to May while Bimodal is normally long rains which start from March to May and short rains October to December (Timiza and Mwabumba, 2015). According to Baregu *et al*. (2015) a Unimodal zone covers the South, Central and West of Tanzania and experiences one long rainy season from December to April. The Bimodal zone covers the East, North, North coast and North West of the country, and experiences two shorter rain periods, one from October to December and one from March to May. This causes the harvesting periods to be different across the country and take place one to three months after the end of the respective rainy season. Bimodal zones are generally more prone to conditions of drought. The North and Central North of Tanzania are usually affected most by erratic rains or extreme drought.

3.5 Sampling Procedure and Sample Size

3.5.1 Sampling procedures

The study was conducted in 21 regions in Tanzania mainland and 3 regions in Zanzibar which were selected randomly. Whereas, purposive sampling procedure was employed to select 2 124 households who either planted recycled improved seeds, certified seed, quality assured seeds or traditional seeds located in different agro-ecological zones.

3.5.2 Sample size

The sample size is 2 124 households which represent smallholder farmers who grow maize in Tanzania mainland and Zanzibar. The figure includes smallholder farmers who grow improved maize seeds such as improved recycled seeds, certified seed, quality assured seeds or traditional seeds in 24 regions growing maize in the United Republic of Tanzania. Among 2 124 respondents selected 930 were adopters of improved maize seed varieties and 1 194 were non adopters.

3.6 Data Collection

The study used secondary data collected by the national panel survey in the third round of data collection. The main data collection began in October 2012 and finished in October 2013, with tracking fieldwork continuing until the end of November 2013. Four survey instruments were used in data collection which are: a) Household questionnaire, b) Agriculture questionnaire, c) Livestock/fishery questionnaire, and d) Community questionnaire. In this study only data collected by agriculture and household questionnaires were used because they have important factors affecting adoption, doption intensity and production risk.

3.7 Analytical Technique

In the analytical technique the study employed quantitative analysis namely: probit model, OLS and multiple linear regression based on objectives and hypotheses tested as discussed and summarized in (Table 6).

The first objective was to evaluate factors affecting adoption and diffusion of improved maize seed varieties in Tanzania. In this objective, adoption equation using a probit model was used to estimate socio-economic characteristics influencing adoption and diffusion of improved maize seed varieties. The data for both adopters and non adopters of improved maize seed varieties was used and thus, the total number of observations in the model was 2 124.

The second objective of the study was to assess factors affecting intensity of adopting improved maize seed varieties. In this objective, OLS equation in the linearized Cobb-Douglas function form was used in the estimation of household characteristics and farm specific characteristics which affect adoption intensity of improved maize seed varieties among smallholder farmers. Total number of observations is 930 which was the total number of smallholder farmers who adopted improved maize seed varieties only.

The third objective was to determine factors that increase production risk under the improved maize production system. In this objective, the production risk equation using multiple linear regression taking the form of the linearized Cobb-Douglas function was used in the estimation of household and farm specific characteristics that affect production risk for smallholder farmers who adopted improved maize seed varieties. The total number of observations used was 930 which was the total number of smallholder farmers who adopted improved maize seed varieties only.

Table 6: Analytical Framework

No	Objectives	Hypothesis	Model	Hypotheses Testing	Test Statistics
1.	To evaluate factors affecting the adoption and diffusion of improved maize seed varieties	Socio-economic characteristics do not affect the adoption and diffusion of improved maize seed Varieties	Probit model	χ^2 -test	z-test
2.	To assess factors affecting the intensity of adopting improved maize seed varieties	Household characteristics, farm characteristics and other factors do not affect the intensity of adoption of improved maize seed varieties	OLS analysis (log-log function)	F-test	t-test
3.	To determine variables that increase production risks in farming systems which use improved maize seed varieties	Household characteristics, farm characteristics and other factors do not increase production risks under improved maize production system	Multiple Linear regression analysis (log-log function)	F-test	t-test

3.8 Model Specification and Variable Description

3.8.1 Model specification

3.8.1.1 Heckman model

Most adoption studies such as (Lyimo *et al.*, 2014; Kaliba *et al.*, 2000; and Nkonya *et al.*, 1998) used Heckman two step procedure model that allows the estimation of both use and intensity of adopting agricultural technology. They used the probit model in the first step and OLS equation in the second step made it possible for the studies to estimate whether or not smallholder farmers were using improved maize technologies and the intensity of using improved maize technologies respectively.

Similarly, in this study Heckman two step procedure was used to investigate factors which influence adoption and intensity of use of improved maize in smallholder farms in Tanzania and reduce selectivity bias caused by lack of randomness in the smallholder farmers' decision on whether to adopt an improved maize seed varieties or not. In the analysis, a probit model (selection equation) was used for estimating whether or not smallholder farmers are using improved maize seed varieties and calculate the IMR to account for selectivity bias. The equation was estimated under the assumption that the error term is normally distributed.

The first step entailed the estimation of the probit model on a set of independent variables that explain the adoption and diffusion of improved maize seed varieties and calculation of IMR to account for selectivity bias as follows:

a) Estimation of selection equation

Selection equation

$$Y_i^* = \theta_i x_i + \varepsilon_i ; \varepsilon_i = (0, \sigma^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:

Y_i^* = Latent variable representing unobservable net benefits of the smallholder farmer arising from adoption of improved maize seed varieties where Y_i^* = 1 represents smallholder farmers who adopt improved maize seed varieties and Y_i^* = 0 represents smallholder farmers who did not adopt improved maize seed varieties

X_i = Column vector of independent variables as shown in (Table 7)

θ_i = Coefficients to be estimated from i=1 up to i=21

ε_i = Disturbance term or an error term with mean 0 and variance σ^2

$$Y = \begin{bmatrix} 1 & if & Y_i^* > 0 \\ 0 & if & Y_i^* \leq 0 \end{bmatrix} \quad \text{..........} (6)$$

Conditional probability, showing that the smallholder farmers adopt the improved maize seed production system can be expressed as follows;

$$\Pr[Y_i = 1|] = \Pr[Y_i^* > 0|x_i] = \Pr[\theta_i x_i + \varepsilon_i | x_i]$$

$$\Pr[Y_i = 1|x_i] = \int_{-\infty}^{\theta x_i} \phi(\theta_i x_i) \partial x_i$$

Probit Equation

$$\Pr[Y_i = 1|x_i] = \Phi(\theta_i x_i) + \varepsilon_i \quad \text{..........} (7)$$

Where:

$y_i =$ Adoption where y_i =1 represents smallholder farmer who adopted improved maize seed varieties and y_i =0 represents non-adopters

$x_i =$ Independent variables

$\theta_i =$ Coefficients of independent variables

$\Phi =$ Standard normal cumulative distribution/ cumulative frequency

$\varepsilon_i =$ Error terms with mean 0 and variance 1

Probit Model specified

$$\begin{aligned} \Pr[A = 1|X_i] = \Phi(&\theta_0 + \theta_1 X_1 + \theta_2 X_2 + \theta_3 X_3 + \theta_4 X_4 + \theta_5 X_5 + \theta_6 X_6 + \\ &\theta_7 X_7 + \theta_8 X_8 + \theta_9 X_9 + \theta_{10} X_{10} + \theta_{11} X_{11} + \theta_{12} X_{12} + \theta_{13} X_{13} + \theta_{14} X_{14} + \\ &\theta_{15} northern\_zone + \theta_{16} southern\_zone + \theta_{17} shighland\_zone + \\ &\theta_{18} eastern\_zone + \theta_{19} western\_zone + \theta_{20} Lake\_zone1 + \\ &\theta_{21} lake\_zone2 + \varepsilon \quad \text{..........} (8) \end{aligned}$$

Where:

A= Adoption (dummy) 1 for adopters of improved maize seed varieties and 0 otherwise

Φ = Standard normal cumulative distribution/ cumulative frequency

θ_i = Estimated coefficients of the independent variables

ε_i = Error terms with mean 0 and variance 1

X_i = Explanatory variables

X_1 = Age of the household head

X_2 = Gender of the household head (dummy) 1 if male and 0 otherwise

X_3= Marital status of the household head (dummy) 1 if monogamous married, polygamous married or living together and 0 if never married, separated, divorced or widow(er)

X_4 = Household size

X_5 = Education (number of years of schooling)

X_6 = Farm size (acre)

X_7 = Proportion of land allocated to improved maize seed varieties

X_8 = The use of organic fertilizer (dummy) 1 if smallholder farmers use organic fertilizer and 0 otherwise

X_9 = The use of inorganic fertilizer (dummy) 1 if smallholder farmers use inorganic fertilizer and 0 otherwise

X_{10} = Distance from homestead to the farm (km)

X_{11} = Distance from the farm to the road (km)

X_{12} = Distance from the farm to the market (km)

X_{13} = Extension services (number of visits)

X_{14} = Adult equivalent

AGRO-ECOLOGICAL ZONES (dummy variables)

northern_zone = 1 if Northern zone and 0 otherwise

eastern_zone = 1 if Eastern zone and 0 otherwise

western_zone = 1 if Western zone and 0 otherwise

southern zone = 1 If Southern zone and 0 otherwise

shighlands_zone = 1 if Southern highlands zone and 0 otherwise

lake_zone1 = 1 if lake zone 1 and 0 otherwise

lake_zone2 = 1 if lake zone 2 and 0 otherwise

central_zone = 1 if central zone and 0 otherwise

b) Calculation of Inverse Mills Ratio

Inverse Mills Ratio (IMR) is the ratio of probability density function to the cumulative distribution function of a distribution (Mills, 1926). IMR sometimes named as "selection hazard" arises in regression analysis to take account of the selection bias. The problem of sample selection bias mostly occurs when the dependent variable is censored which causes a concentration of observations at zero values. The problem causes the OLS estimation to produce biased parameter estimates when selectivity bias is not taken into account (Tobin, 1958). The latent variable model of the study can be presented as follows:

$$D_i^* = W_i\alpha + \eta_i \quad if \quad D_i = \begin{cases} 1 \ for \ D_i^* > 0, \\ 0 \ otherwise \end{cases} \quad ....(9)$$

Where:

D_i = Binary variable for the adoption of the new agricultural technology where $D_i = 1$ if the technology is adopted and $D_i = 0$ otherwise

α_i = A vector of parameters estimated

W_i = A vector that represents household and farm-level characteristics

η_i = the random error term.

Let Y_i represent yield per acre of the maize enterprise. Due to sample selection or self-selection problem the adopter group may not be representative of the population as a whole (Heckman and MaCurdy, 1986). To avoid biased estimates the mean function cannot be estimated before solving the selection bias problem. The proposed analytical technique uses the endogenous switching regression model of Winship and Mare (1992) that accounts for unobservable factors that affect the adoption process and also allows estimating different coefficients for adopters and non-adopter (Khonje *et al.*, 2015).

$$E(\varepsilon_i | D = 1) = \frac{\Phi(W_i\alpha)}{\Theta(W_i\alpha)} = \sigma_{\varepsilon 1i}\lambda_{1i} \quad ....(10)$$

Where:

D = The binary variable for the adoption of the new agricultural technology where D = 1 if the technology is adopted

Φ = The standard normal probability density function

Θ = The standard normal cumulative density function

α = A vector of parameters to be estimated

W_i = A vector that represents household- and farm-level characteristics

σ_{1i} = Coefficient of IMR

λ_{1i} = The IMR calculated from the selection equations to account for selection bias.

3.8.2.2 Just and pope production function

In the second step and the third step the study used a modified form of Just and Pope production function to explain the adoption intensity (mean function) and production risk (Variance function) where an IMR calculated in the first step was included as an explanatory variable in both adoption intensity and production risk equations and hence it resulted in the unbiased results (Koundari and Nauges, 2005).

Despite its well-known restrictions on production parameters Cobb-Douglas functional form is frequently used in most of partial productivity studies (Smale *et al.*, 1998; Smale *et al*., 2008 and Wanda, 2009). For example, Smale *et al.* (1998) used a Cobb-Douglas function with a Just and Pope (1979) specification to test the effects of wheat diversity on mean and variance of yields in the irrigated and rain-fed districts of the Punjab of Pakistan from 1979 to 1985.

Similarly, in this study linearized Cobb-Douglas function form with Just and Pope (1979) specification were used to examine adoption intensity of improved maize seed varieties in

μ_i

terms of mean yield and production risk in terms of yield variability respectively. Therefore, the results for the last two equations were obtained after doing post-estimation command to find elasticity and semi elasticity for both equations and hence their results are interpreted as a unit change or percentage change in an independent variable can result in a certain percentage change in the dependent variable while keeping other independent variables constant.

In the second step adoption intensity of improved maize seed varieties in terms of mean yield (kg/acre) was regressed on a set of explanatory variables, including the IMR by using OLS model (Eq.13). The term mean yield per plot (kg/acre) was calculated by taking a quantity harvested (kg) divided by the area under improved maize seed varieties (acre). In this part, the data of smallholder farmers who used improved maize seed varieties were used.

Adoption intensity (outcome equation) in Cobb-Douglas function form

$$Y_i = A\prod_{i=1}^{23} X_i^{\alpha_i}\,\mu_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

Where:

Y_i = Maize mean yield (kg/acre) for the ith farmer

X_i =A vector of explanatory variables

α_i = A vector of coefficients

A = Technology parameter

μ_i = An error term

Adoption intensity (Output equation) in Linearized Cobb-Douglas Function form

$$\ln y_i = \ln \alpha_i x_i + \mu_i \quad if \quad Y_i^* > 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Where:

y_i = Yield per farm in kg/acre

ln = Natural logarithm (logarithm to base e)

x_i = Vector of independent variables and IMR

α_i = Coefficients for explanatory variables and IMR respectively

μ_i = An error term with mean 0 and variance σ^2

$Y_i^* > 0$ = Latent variable representing unobservable net benefits of the smallholder farmer arising from adoption of improved maize seed is greater than zero.

Adoption intensity function specified

$$\begin{aligned}
&\ln(y) = \alpha_0 + \alpha_1 \ln(X_1) + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 \ln(X_4) + \alpha_5 \ln(X_5) + \alpha_6 \ln(X_6) + \\
&\alpha_7 \ln(X_7) + \alpha_8 X_8 + \alpha_9 X_9 + \alpha_{10} X_{10} + \alpha_{11} X_{11} + \alpha_{12} X_{12} + \alpha_{13} X_{13} + \alpha_{14} X_{14} + \\
&\alpha_{15} northern_zone + \alpha_{16} eastern_zone + \alpha_{17} western_zone + \alpha_{18} southern_zone \\
&+ \alpha_{19} shighlans_zone + \alpha_{20} lake_zone1 + \alpha_{21} lake_zone2 + \alpha_{22} central_zone + \\
&\alpha_{23} \ln(IMR +) \varepsilon_i \quad if \quad Y_i^* > 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)
\end{aligned}$$

Where:

y = Adoption intensity in terms of mean yield (kg/acre)

ln = Natural logarithm (logarithm to base e)

α_i = Estimated coefficients for all explanatory variables, including Inverse Mills Ratio from i= 1, 2, 3, ….. , 23

ε = An error term

$Y_i^* > 0$ = Latent variable representing unobservable net benefits of the smallholder farmer arising from adoption of improved maize seed is greater than zero.

$\ln(X_1)$ = Natural logarithm of age (years)

X_2 = Gender of the head of the household (dummy) 1 if male and 0 if female

X_3 = Marital status of the household head (dummy) 1 if monogamous, polygamous or living together and 0 if never married, separated, divorced or widow(er)

$\ln(X_4)$ = Natural logarithm of household size

$\ln(X_5)$ = Natural logarithm of education (number of years of schooling)

$\ln(X_6)$ = Natural logarithm of farm size (acre)

$\ln(X_7)$ = Natural logarithm of proportion of allocated to improved maize seed varieties

X_8 = The use of organic fertilizer (dummy) 1 if smallholder farmers use organic fertilizer and 0 otherwise

X_9 = The use of inorganic fertilizer (dummy) 1 if smallholder farmers use inorganic fertilizer and 0 otherwise

X_{10} = Quantity of herbicides (ml)

X_{11} = Extension services (visits)

X_{12} = Distance from farm to homestead (km)

X_{13} = Distance from the farm to the road (km)

X_{14} = Distance from the farm to the market (km)

$\ln(X_{15})$ = Natural logarithm of adult equivalent

AGRO-ECOLOGICAL ZONES (dummy variables)

northern_zone = 1 if Northern zone and 0 otherwise

eastern_zone = 1 if Eastern zone and 0 otherwise

western_zone = 1 if Western zone and 0 otherwise

southern_zone = 1 if Southern zone and 0 otherwise

shighlands_zone = 1 if Southern highlands zone and 0 otherwise

lake_zone1 = 1 if Lake zone1 and 0 otherwise

lake_zone2 = 1 if Lake zone2 and 0 otherwise central_zone = 1 if Central zone and 0 otherwise

ln(IMR) = Natural logarithm of IMR

In the third step production risk equation in terms of yield variability (kg/acre) was regressed on a set of explanatory variables, including the IMR. Similar to the adoption intensity equation, the data of smallholder farmers who used improved maize seed varieties only was used. The regression of production risk equation to a set of explanatory variables including the IMR is as follows:

Production risk function In Cobb-Douglas function form

$$\mu_i = A\prod_{i=1}^{21} X_i^{\delta_i}\varepsilon_i \qquad (14)$$

Where:

Yi = Maize mean yield (kg/acre) for the i^th farmer

Xi =A vector of explanatory variables

δ_i = A vector for coefficients

A = technology parameter

ε_i = An error term

Production risk function in linearized Cobb-Douglas function form

$$\ln\hat{\mu} = \ln\delta_i X_i + \varepsilon \quad if \quad Y_i^* > 0 \qquad (15)$$

Where;

$\hat{\mu}$ =Production risk

X_i= All independent variables from i=1to n=21

Coefficients estimated a measure of risk from i=0 to 21

ε = An error term

Y_i^* > 0 = Latent variable representing unobservable net benefits of the smallholder farmer arising from adoption of improved maize seed varieties are greater than zero.

Production risk model specified

$$\ln(\Pr oduction\_risk1) = \delta_0 + \delta_1 \ln(X_1) + \delta_2 X_2 + \delta_3 X_3 + \delta_4 \ln(X_4) + \delta_5 \ln(X_5) + \delta_6 \ln(X_6) + \delta_7 X_7 + \delta_8 X_8 + \delta_9 X_9 + \delta_{10} X_{10} + \delta_{11} X_{11} + \delta_{12} \ln(X_{12}) + \delta_{13} northern\_zone + \delta_{14} eastern\_zone + \delta_{15} western\_zone + \delta_{16} southern\_zone + \delta_{17} shighlands\_zone + \delta_{18} central\_zone + \delta_{19} lake\_zone1 + \delta_{20} lake\_zone2 + \delta_{21} \ln(IMR) + \varepsilon_i \quad if \quad Y_i^* > 0 \; \ldots\ldots (16)$$

Where:

Production_risk1 = Production risk (kg/acre)

δ_0 = A constant

δ_i = Estimated coefficients of explanatory variables in a risk function (measure risk) including IMR for i = 1, 2, 3, …, 21.

ln = Natural logarithm (logarithm to base e)

ε = An error term

Y_i^* > 0 = Latent variable representing unobservable net benefits of the smallholder farmer arising from adoption of improved maize seed are greater than zero.

$\ln(X_1)$ = Natural logarithm of age (years)

X_2 = Gender Gender of the household head (dummy) 1 for male and 0 otherwise

X_3 = Marital status of the household head (dummy) 1 if monogamous married, polygamous married or living together and 0 if never married, separated, divorced and widow (er)

$\ln(X_4)$ = Natural logarithm of household size

$\ln(X_5)$ = Natural logarithm of education (number of years of schooling)

$\ln(X_6)$ = Natural logarithm of farm size (acre)

X_7 = Quantity of herbicides (ml)

X_8 = Extension services (number of visits)

X_9 = Distance from the farm to the homestead (km)

X_{10} = Distance from the farm to the road (km)

X_{11} = Distance From the farm to the market (km)

$\ln(X_{12})$ = Natural logarithm of adult equivalent

AGRO-ECOLOGICAL ZONES (dummy variables)

northern_zone = 1 if Northern zone and 0 otherwise

eastern_zone = 1 if Eastern zone and 0 otherwise

western_zone = 1 if Western zone and 0 otherwise

southern_zone = 1 if Southern zone and 0 otherwise

shighlands_zone = 1 if Southern highlands zone and 0 otherwise

central_zone = 1 if Central zone and 0 otherwise

lake_zone1 = 1 if Lake zone 1 and 0 otherwise

lake_zone2= 1 if Lake zone2 and 0 otherwise

ln(IMR) = Natural logarithm of IMR

3.8.2 Variable description

3.8.2.1 Variable description for Probit model

The variables that were used in the probit model were classified into two groups where social factors like age, gender, marital status, household size, education, and adult equivalent. Other variables included in the model such as farm size, organic fertilizer, distance from farm to the market (km), extension services (visits) and others were classified as economic factors as summarized in (Table 7).

Table 7: Variable description and expected signs of the coefficients of Probit model

Variable	Description	Expected sign
X_1	Age of the household head (years)	+
X_2	Gender of the household (dummy)	+
X_3	Marital status of the household head (dummy)	+/-
X_4	Household size	+
X_5	Education(number of years of schooling)	+/-
X_6	Farm size(acre)	+/-
X_7	Proportion of land allocated to maize production	+
X_8	The use of Organic fertilizer (dummy)	+
X_9	The use of Inorganic fertilizer (dummy)	+
X_{10}	Distance from homestead to the farm (km)	-
X_{11}	Distance from the farm to the road (km)	-
X_{12}	Distance from the farm to the market (km)	-
X_{13}	Extension services (number of visits)	+
X_{14}	Adult equivalent	+
northern_zone	Northern zone	+/-
eastern_zone	Eastern zone	+/-
western_zone	Western zone	+/-
southern_zone	Southern zone	+/-
shighlands_zone	Southern Highlands zone	+/-
lake_zone1	Lake zone1	+/-
lake_zone2	Lake zone2	+/-
central_zone	Central zone	+/-

3.8.2.2 Variable description for Ordinary Least Square and Multiple Linear Regression

The variables in the two models were also classified into two groups, namely: household characteristics and farm specific characteristics. Household characteristics include all social and demographic factors such as age, gender, marital status, household size, education and Adult equivalent and farm specific includes all the remaining variables used in the OLS and multiple linear regression as summarized in (Table 8) and (Table 9) respectively.

Table 8: Variable description and expected signs of the coefficients of OLS

Variable	Description	Expected sign
$\ln(X_1)$	Natural logarithm of age (years)	+
X_2	Gender (dummy)	+
X_3	Marital status (dummy)	+/-
$\ln(X_4)$	Natural logarithm of household size	+
$\ln(X_5)$	Natural logarithm of education (number of years of schooling)	+
$\ln(X_6)$	Natural logarithm of Farm size (acre)	+/-
$\ln(X_7)$	Natural logarithm of Proportion of allocated to improved maize seed varieties (acre)	+
X_8	Organic fertilizer(dummy)	+
X_9	Inorganic fertilizer(dummy)	+
X_{10}	Quantity of herbicides	+
X_{11}	Extension services(visits)	+
X_{12}	Distance from farm to homestead(km)	-
X_{13}	Distance from the farm to the road(km)	-
X_{14}	Distance from the farm to the market(km)	-
$\ln(X_{15})$	Natural logarithm of adult equivalent	+
northern_zone	Northern zone	+/-
eastern_zone	Eastern zone	+/-
western_zone	Western zone	+/-
southern_zone	Southern zone	+/-
shighlands_zone	Southern highlands zone	+/-
lake_zone1	Lake zone1	+/-
lake_zone2	Lake zone2	+/-
central_zone	Cental zone	+/-
ln(IMR)	Natural logarithm of IMR	+/-

Table 9: Variable description and expected signs for the coefficients of multiple linear regression

Variable	Description	Expected sign
$\ln(X_1)$	Natural logarithm of age (years)	-
X_2	Gender (dummy)	-
X_3	Marital status (dummy)	+/-
$\ln(X_4)$	Natural logarithm of household size	-
$\ln(X_5)$	Natural logarithm of education(number of years of schooling)	-
$\ln(X_6)$	Natural logarithm of farm size (acre)	-
X_7	Herbicides	-
X_8	Extsension services (number of visits)	-
X_9	Distance from the farm to the homestead (km)	+
X_{10}	Distance from the farm to the road (km)	+
X_{11}	Distance From the farm to the market (km)	+
$\ln(X_{12})$	Natural logarithm of adult equivalent	-
northern_zone	Northern zone	+/-
eastern_zone	Eastern zone	+/-
western_zone	Western zone	+/-
southern_zone	Southern zone	+/-
shighlands_zone	Southern highlands zone	+/-
central_zone	Central zone	+/-
lake_zone1	Lake zone 1	+/-
lake_zone2	Lake zone2	+/-
ln(IMR)	Natural logarithm of IMR	+/-

3.9 Data Analysis

The excel data in a comma delaminated format were imported in STATA version13 for data analysis. STATA was used for econometric analysis of the probit model (adoption), OLS (adoption intensity) and Multiple linear regression (production risk). The software was also used in diagnostic tests for heteroskedacity, skewness, kurtosis, omitted variables and specification errors. Moreover, STATA was used to conduct post estimation analysis Average Marginal Effects (AME) (dy/dx) for the probit model and elasticity (ey/ex) and semi-elasticity (ey/dx) for both adoption intensity and production risk functions using the fitted values of the estimated functions.

Excel is another software which was used in the data analysis. It was used to create dummy variables for gender of the household head, marital status of the household head, to create an agro-ecological zones and their dummies. Also, it was used in descriptive statistics such as standard deviation and variance which were used in generating the production risk variable.

3.10 Diagnostic Tests

In this study different diagnostic tests were conducted to prove the validity of the models used using the powers of the fitted values for the adoption equation, adoption intensity equation and production risk equation. Diagnostic tests for heteroskedasticity, skewness and kurtosis, omitted variables, specification errors and collinearity were done.

The results proved the existence of heteroskedasticity in the adoption intensity equation at Chi2(1) = 12.15 and P= 0.00. The existence of heteroskedasticity in the adoption intensity indicates the presence of production risk. The problem was addressed to obtain robust coefficients for all equations.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Social and Demographic Characteristics

Out of the 2 124 smallholder farmers from different agro-ecological zones in Tanzania mainland and Zanzibar only 43.79% adopted improved maize seed varieties. The youngest head of the household was 13 years and the oldest head of the household was 93 years and the mean age of the household head was 46.43 years. Most of the household heads were males because larger percent of the households were monogamous married (47.18%), polygamous married (13.47%) or living together (20.20%). While others, such as separated, divorced, never married and widow(er) were only 19.15%. The mean household size was 6. The most frequent level of education of the household heads was college/university which was about 49.81% of the total number of the household heads (Table 10).

Table 10: Description of the social and demographic characteristics of the smallholder farmers in Tanzania (n=2 124)

Variable	Category	Frequency	Percent
Age	13-17	14	0.66
	18-45	1 085	51.08
	46-60	569	26.79
	60+	456	21.47
Gender	Male	1 535	72.27
	Female	589	27.72
Marital status	Polygamists	429	20.20
	Monogamists	1 002	47.18
	Living together	286	13.47
	Single	41	1.93
	Divorced	151	7.11
	Widow(er)	215	10.12
Education level	Primary	698	32.91
	Secondary (O level)	87	4.10
	Secondary (A level)	277	13.04
	Tertiary (college/ university)	1 058	49.81
Household size	Age groups in the household		
	Children less or equal to 5	2 264	17.32
	Children from 6 to 10 years	1 942	14.86
	Children from 11 to 17 years	2 704	20.69
	Adults from 18 to 65 years	5 617	42.97
	Seniors above 65 years	545	4.17

4.2 Economic and other Characteristics

4.2.1 Farm size

Farm size is a factor that indicates the level of resource endowment of the smallholder farmers. Most of the smallholder farmers used only a small portion of their land in maize production and thus make it possible for them to rent the remaining area and earn income. The farm size, area under maize and area harvested were larger for adopters of improved maize seed varieties than non adopters, however the difference in the area harvested was very small. The highest mean farm size and area under maize were in Lake zone 2 averaged at 16.37acres and 11.53acres for adopters and 15.53acres and 6.47acres for non adopters respectively. On the other hand, the highest mean of the area harvested was 4.88acres in the Lake zone 2 and 4.76acres in the Western zone for adopters and non-adopters of improved maize seed varieties respectively as shown in (Fig. 2).

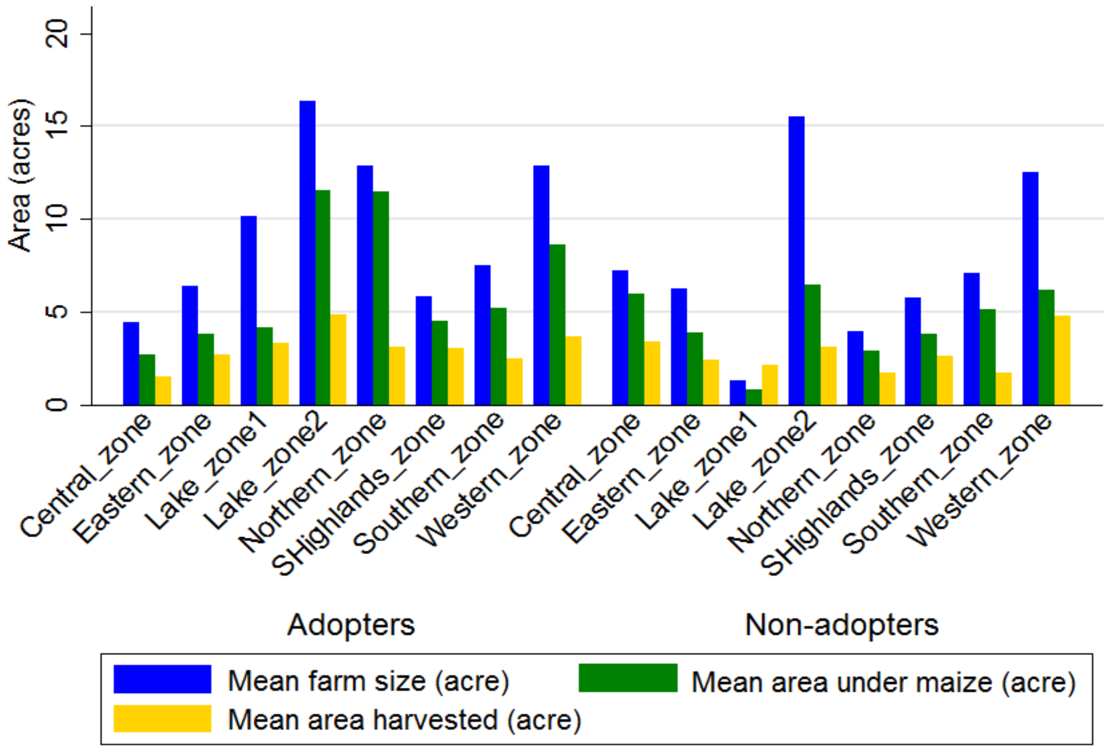

Figure 2: Trend in farm size and area under maize production in Tanzania

4.2.2 Extension services

Provision of extension services is very crucial to facilitate the adoption and the use of improved maize seed varieties and other important inputs in maize production. In Tanzania, the provision of extension services is still unsatisfactory. According to DTMA (2014) Tanzania has limited extension capacity to create enough awareness about improved maize technologies and production practices. For example extension agent to farm household ratio in Tanzania is 1:2500 which is very low when compared to 1:476 in Ethiopia, 1:1000 in Kenya and 1:1603 in Malawi. In this study 1 870 (88.04%) smallholder farmers out of 2 124 did not receive any extension visits. The highest mean number of visits was 0. 92 in the Southern highlands zone and 0.62 in the Central zone for adopters and non-adopters of improved maize seed varieties respectively. This implies that adopters of improved maize seed had more information on improved maize seed varieties than non- adopters as shown in (Fig. 3).

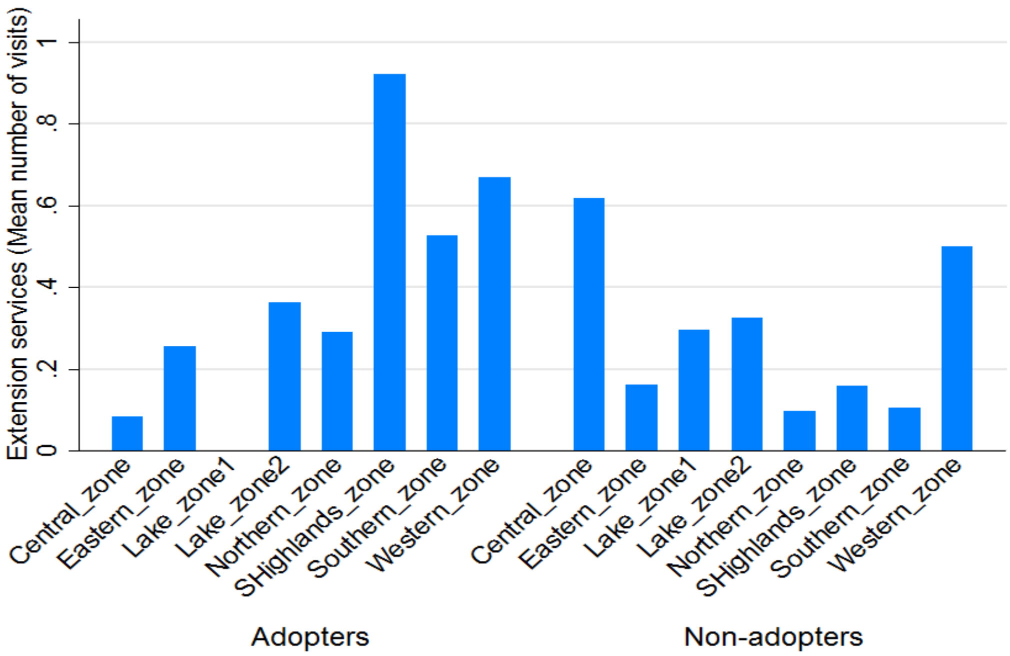

Figure 3: Provision of extension services

4.2.3 Fertilizer use

The use of both inorganic and organic fertilizer is still very low in maize production. Out of the 2 124 smallholder farmers only 429 (20.20%) used inorganic fertilizer while 1 695 (79.80%) did not apply it. For adopters of improved maize seed varieties the mean use of inorganic fertilizer was relatively higher than that of non-adopters especially in the Western zone where the mean use was about 116.17kgs followed by the Southern highlands and Northern zones with means of about 86.69kgs and 25.15kgs respectively. For non-adopters of improved maize seed varieties the highest mean quantity of inorganic fertilizer used recorded were in two agro-ecological zones, namely the Western zone (50.57kgs) and Southern highlands zone (47.85kgs) (Fig. 4).

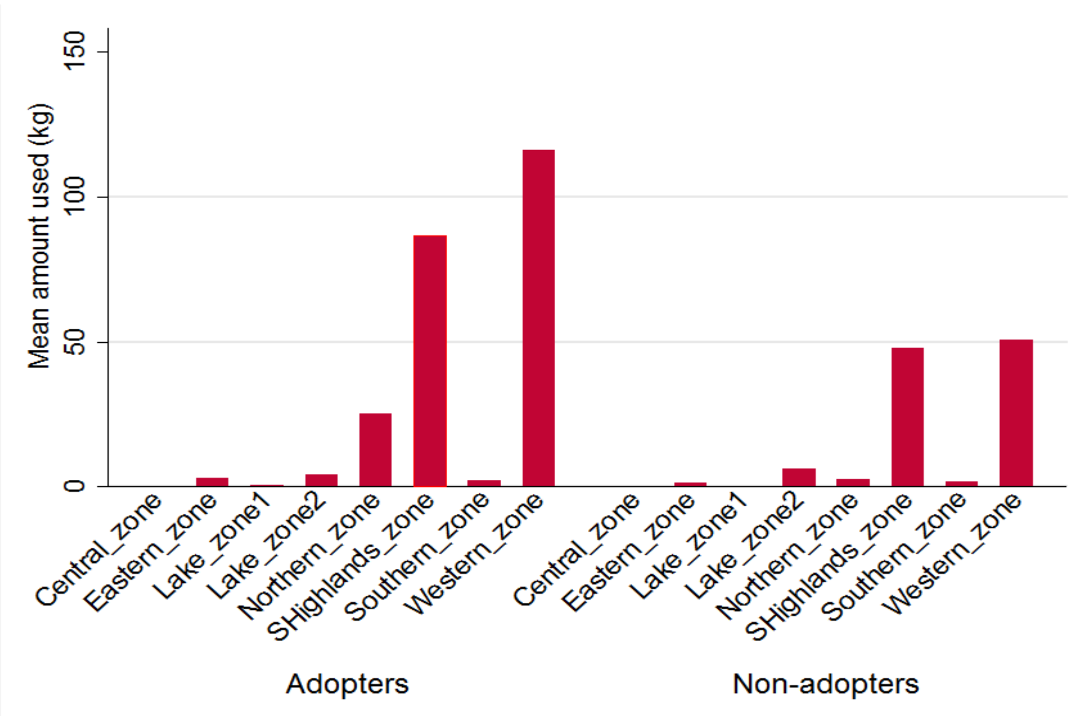

Figure 4: Inorganic fertilizer used in maize production

As for inorganic fertilizers, the use of organic fertilizer was also very low inspite of its importance in reducing yield variability. Out of the 2 124 smallholder farmers covered by the study only 23.45% used organic fertilizer (13.23% for adopters of improved maize seed varieties and 10.22% non–adopters) (Table 11).

Table 11: The use of organic fertilizer in maize production (kgs) (n=2 124)

S/N		Organic fertilizer	Frequency (n)	Percent (%)
1.	Adopters	Used	281	13.23
		Not used	649	30.55
	Sub-total		**930**	**43.78**
2.	Non-adopters	Used	217	10.22
		Not used	977	46.00
	Sub-total		**1 194**	**56.22**
	Grand total		**2 124**	**100.00**

4.2.4 Seed use

The most common improved maize seed varieties grown in Tanzania were categorized into two categories. The first is improved maize seed varieties which include improved recycled seeds, certified seed, quality declared seeds and other maize seed used that did not fall into that category were classified as traditional seeds. The data show that only 43.79% of the rural smallholder farmers used improved maize seed varieties while the remaining used traditional seeds (Fig. 5).

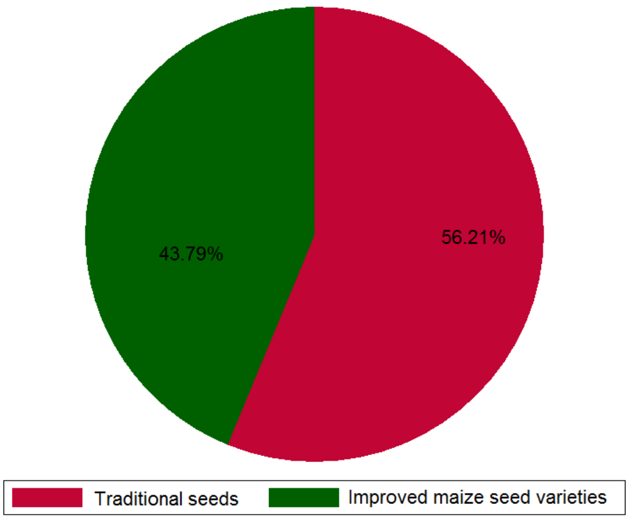

Figure 5: Types of seed used

4.2.5 Distance

Distance from homestead to the farm, from the farm to the main road and from farm to the market are other variables which affect adoption and diffusion of improved maize varieties due to their influence on smallholder farmers daily activities, transport cost and access to market respectively. Therefore, distant farms were expected to be less likely associated with the adoption and diffusion of improved maize seed varieties due to poor farm management, high transport cost and market inaccessibility which limit farmers' accessibility to inputs at the appropriate time. Thus, increase production risk which might result to decrease in maize yield.

Different from expectation, far farms are associated with the adoption of improved maize seed varieties. For example, the highest mean distance from the homestead to farm for adopters was 8.93km in the Southern highlands zone, 7.35km in the Eastern zone and 7.26km in the Northern zone when compared to 4.99km (Southern highlands zone), 4.04km (Western zone) and 3.69km (Northern zone) for non-adopters. The accessibility of infrastructure such as roads is evidenced by short distance from the farm to the road where the distant roads have the mean distance averaged at 4.54km in the Southern zone for adopters and 4.37km in the Central zone for non-adopters. The most inaccessible markets were found in the Western zone for the adopters and Central zone for non adopters with the mean distance from farm to market averaged at 16.28km and 20.79km for adopters and non adopters of improved maize seed varieties respectively as shown in (Fig. 6).

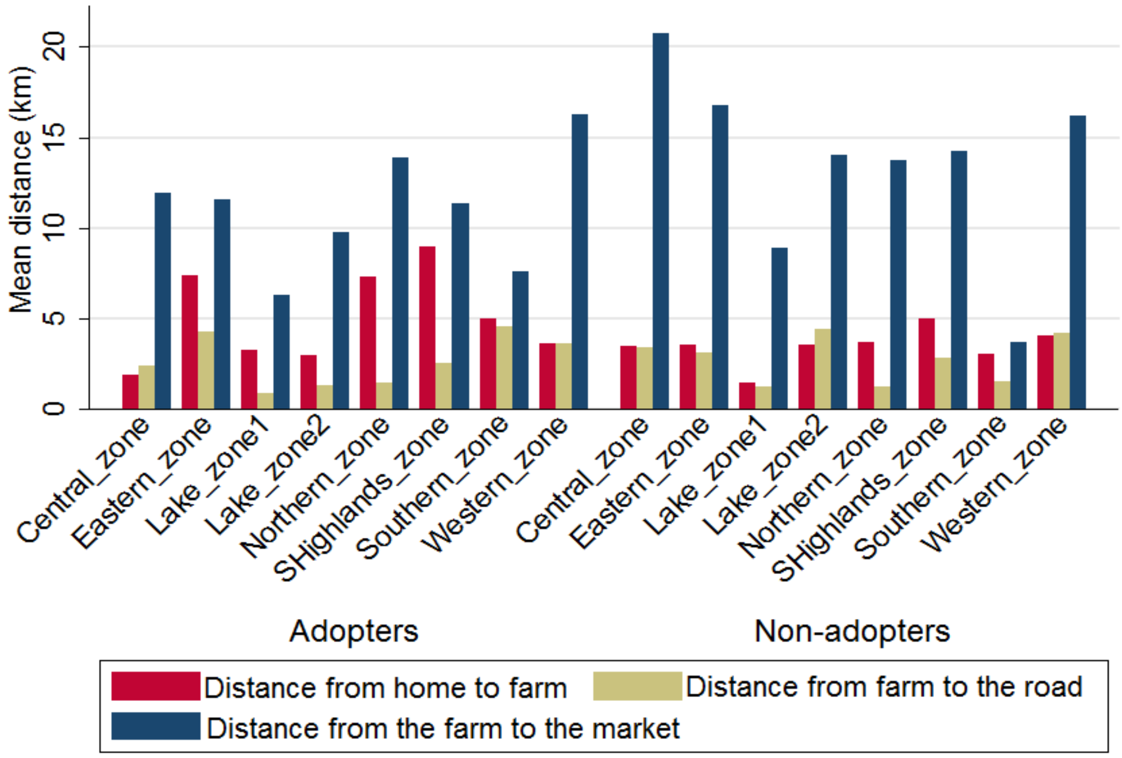

Figure 6: Distance classification

4.2.6 Agro-ecological zones

Location is one of the factors that affect adoption and maize production in Tanzania. In Tanzania different areas have different weather condition and distribution of rainfall, which affect maize production in different areas inversely. For example, in Tanzania mainland Lake zone and Northern zone comprise of regions which receive Bimodal rainfall in a year, while other zone, such as the Southern zone, Southern highlands zone, Western zone and Central zone are Uni-modal regions and hence they receive Uni-modal rain in a year (Hamisi, 2013; and Beregu *et al*., 2015). These differences cause variation in the achievements made in the maize sub-sector in different agro-ecological zones. Regions were grouped to form agro-ecological zones based on rainfall patterns (Unimodal or Bimodal), time of its occurence, location and similarity in weather as shown in (Table 12).

Table 12: Classification of Agro-ecological zone in the United Republic of Tanzania

S/N	Regions	Agro-ecological zones
1.	Arusha, Kilimanjaro and Manyara	Northern zone
2.	Mwanza, Kagera, Mara and Shinyanga	Lake zone 2
3.	Kigoma, Tabora and Rukwa	Western zone
4.	Dodoma and Singida	Central zone
5.	Tanga, Pwani, Mororgoro, Kaskazini Unguja, Kusini Pemba and Mjini Magharibi	Eastern zone
6.	Lindi and Mtwara	Southern zone
7.	Mbeya, Iringa and Ruvuma	Southern highlands zone
8.	Kagera	Lake zone 1

4.3 Factors Affecting Adoption and Diffusion of Improved Maize Seed Varieties in Tanzania

The results of the probit model (Table 13) show that farm size, proportion of land allocated to maize production, organic fertilizer, distance from the farm to homestead, distance from the farm to market and agro-ecological zones specifically farms location in the Eastern zone and Southern highlands zone affect adoption and diffusion of improved maize seed varieties significantly at different significance level respectively. In addition, farm size, proportion of land allocated to maize production and distance from the farm to homestead influenced the adoption and diffusion of improved maize seed varieties positively, whereas organic fertilizer, distance from the farm to market, farms located in the Eastern zone and Southern highlands zone were found to be influencing adoption and diffusion of improved maize seed varieties negatively.

Table 13: Results from the Probit model

Adoption	**Robust Coefficient**	**Average Marginal Effects**	**Std. Err.**	**z**	**P>z**
Age	0.0011	0.0004	0.0019	0.58	0.563
Gender	-0.0967	-0.0367	0.0979	-0.99	0.323
Marital status	0.0769	0.0291	0.0922	0.83	0.405
Household size	0.0001	0.0000	0.0069	0.01	0.990
Education	0.0005	0.0002	0.0043	0.11	0.915
Farm size	0.0034	0.0013	0.0014	2.40	0.016 **
Proportion of land allocated to improved maize seed varieties	0.4085	0.1549	0.0805	5.07	0.000 ***
Organic fertilizer	-0.3952	-0.1499	0.0887	-4.46	0.000 ***
Inorganic fertilizer	0.0524	0.0199	0.0920	0.57	0.569
Distance from homestead to the farm	0.0062	0.0024	0.0026	2.43	0.015 **
Distance from the farm to the road	-0.0077	-0.0029	0.0056	-1.38	0.169
Distance from the farm to the market	-0.0044	-0.0017	0.0020	-2.17	0.030 **
Extension services	0.0167	0.0063	0.0261	0.64	0.522
Adult equivalent	0.0064	0.0024	0.0081	0.79	0.432
AGRO-ECOLOGICAL ZONES (dummy variables)					
Northern zone	-0.1542	-0.0585	0.1583	-0.97	0.330
Eastern zone	-0.3944	-0.1495	0.1405	-2.81	0.005 ***
Western zone	-0.0800	-0.0303	0.1311	-0.61	0.542
Southern zone	-0.1627	-0.0617	0.1411	-1.15	0.249
Southern highlands zone	-0.2253	-0.0855	0.1383	-1.63	0.103 *
Lake zone1	-0.2597	-0.0985	0.2084	-1.25	0.213
Lake zone2	-0.1355	-0.0514	0.1401	-0.97	0.333
Constant	0.3368		0.2335	1.44	0.149
Probit Regression					
Number of observation		2 124			
Wald chi2 (21)		97.01			
Prob > chi2		0.0000			
Log pseudolikelihood		-1 404.7296			

Note: ***, ** and * significant at 0.01, 0.05 and 0.10 levels respectively

As expected, farm size influenced adoption and diffusion of improved maize seed varieties positively ($P<0.05$). This implies that farmers with larger farms were more likely to adopt improved maize seed varieties compared to the farmers with small farms. This might be due to the fact that farmers with larger farms are more flexible and they are able to allocate part of their farms to try new technologies. The results are in line with that of Akinbode and Bamire (2015) who reported similar results. In contrast to the study findings, Baruwa *et al*. (2015) study on adoption of improved maize varieties among farming households in Osun State reported that farm size was more likely to decrease the likelihood of adoption of improved maize varieties.

As expected, the proportion of land allocated to maize production was also found to be influencing adoption and diffusion of improved maize seed varieties positively ($P<0.01$). This implies that farmers who allocated part of their farms on maize production were more likely to adopt improved maize seed varieties. This might be due to the fact that most of the farmers tend to allocate the size of the farm that they are able to manage and thus, increasing the probability of smallholder farmers to adopt and diffuse improved maize seed varieties.

Different from expectations, the use of organic fertilizer influenced adoption of improved maize seed varieties negatively ($P<0.01$). This implies that smallholder farmers who used organic fertilizer were less likely to adopt improved maize seed varieties. This might be due to lack of knowledge on how to use organic fertilizer and inadequate availability because most of the livestock in Tanzania are kept nomadically. A nomadic way of keeping animals tends to hinder the use of manure in farming activities because the pastoralists are not settled in one place. Similar results were found by Sserunkuuma. (2005) study on the adoption and impact of improved maize and land management technologies in Uganda who reported that farmers who use animal manure and crop rotation are less likely to adopt improved seeds.

Different from expectations, smallholder farmers with farms located far from the homesteads were more likely to adopt improved maize seed varieties ($P<0.05$). This might be due to the fact that farmers with farms far away from their homesteads tend to have less visits to the farm compared to near farms as a result, they tend to adopt new agricultural technologies such as improved maize seed varieties so as to increase yield. As argued by Juma *et al*. (2009) far farms are directly related to intensity of using new agricultural technologies such as fertilizer application because farmers tend to substitute fertilizer for manure as the household farms distance increases.

Distance from farm to market is another determinant of adoption of improved maize seed varieties. As expected, distance from the farm to the market influenced the adoption and diffusion of improved maize seed varieties negatively ($P<0.05$). The results suggest that smallholder farmers who were far away from the markets were less likely to adopt improved maize seed varieties because long distance to market erodes the returns to smallholder farmers due to high costs of transporting outputs to the markets. Poorly functioning input and output markets erode the profitability of a technology adoption to the farmer and hence discouraging technology uptake Jack (2011). Different studies (eg. by Sserunkuuma 2005; Langyintuo and Mekuria 2008; and Letaa *et al*. 2014) also found a similar relationship between distance distance to the market and adoption of technology. The study results were inconsistent with Salasya *et al.* (2007) who found a positive correlation between the distance to the market and adoption of stress-tolerant maize hybrid (WH 502) in western Kenya.

Agro-ecological zones specifically farms located in the Eastern zone and Southern highlands zone influenced adoption and diffusion of improved maize seed varieties negatively at ($P<0.01$) and ($P<0.10$) respectively. This implies that smallholder farmers with farms located in the Eastern zone and Southern highlands zone were less likely to adopt improved maize seed varieties. This might be due to rainfall variability, which causes farmers to be uncertain to make decisions on whether to adopt improved maize seed varieties or not. In addition, Hamisi (2013) study of rainfall trends and variability over Tanzania reported decreasing trends of rainfall for both Eastern zone and Southern highlands zone.

4.4 Factors Affecting the Intensity of Adopting Improved maize seed Varieties

The results of analysis of the determinants of the adoption intensity for smallholder farmers who adopted improved maize seed varieties show that farm size, proportion of land allocated to improved maize seed varieties, the use of organic fertilizer, quantity of herbicides, adult equivalent and agro-ecological zones specifically farms located in Western zone were statistically significant. The proportion of land allocated to improved maize seed varieties, quantity of herbicides and farms located in Western zone influenced the adoption intensity of improved maize seed varieties positively, whereas farm size, the use of organic fertilizer and adult equivalent were found to be negatively related to the adoption intensity (Table 14).

Table 14: Results from the OLS equation

ln(yield)	Robust Coefficient	Elasticity or semielasticity	Std. Err.	t	P>t	
ln(age)	0.1062	0.0777	0.1035	1.03	0.305	
Gender(dummy)	0.0812	0.0108	0.1250	0.65	0.516	
Marital status(dummy)	-0.0097	-0.0015	0.1104	-0.09	0.930	
ln(household size)	0.0619	0.0193	0.0567	1.09	0.275	
ln(education)	-0.0306	-0.0113	0.0293	-1.04	0.297	
ln(Farm size)	-0.4228	-0.1388	0.0304	-13.93	0.000	***
ln(Proportion of allocated to improved maize seed varieties)	-0.9586	0.0735	0.0531	-18.04	0.000	***
Organic fertilizer(dummy)	-0.2919	-0.0964	0.1412	-2.07	0.039	**
Inorganic fertilizer(dummy)	-0.0055	-0.0002	0.1244	-0.04	0.965	
Herbicides	0.0005	0.0014	0.0002	2.09	0.037	**
Extension services(visits)	0.0241	0.0018	0.0338	0.71	0.476	
Distance from farm to homestead	0.0001	0.0001	0.0034	0.03	0.976	
Distance from the farm to the road	-0.0009	-0.0004	0.0063	-0.14	0.886	
Distance from the farm to the market	0.0016	0.0038	0.0028	0.59	0.556	
ln(adult equivalent)	-0.1020	-0.0289	0.0542	-1.88	0.060	*
Northern zone	0.2939	0.0045	0.1837	1.60	0.110	
Eastern zone	-0.0461	-0.0008	0.2177	-0.21	0.832	
Western zone	0.3409	0.0158	0.1525	2.24	0.026	**
Southern zone	0.0605	0.0015	0.1616	0.37	0.708	
Southern highlands zone	0.0465	0.0019	0.1717	0.27	0.786	
Lake zone	0.1126	0.0006	0.1978	0.57	0.569	
Lake zone	-0.0398	-0.0017	0.1626	-0.24	0.807	
ln(Inverse Mills Ratio)	0.0683	-0.0025	0.3043	0.22	0.822	
Constant	5.5124		0.5419	10.17	0.000	
Linear Regression						
F(23, 906)		29.98				
Prob > F		0.0000				
R-squared		0.4322				
Adj R-squared		0.4177				
Root MSE		1.0458				

Note: ***, ** and * significant at 0.01, 0.05 and 0.10 levels respectively

The results showed that the farm size was negatively related to adoption intensity of improved maize seed varieties (P<0.01). This can be attributed to the fact that most smallholder farmers in Tanzania planted maize crop only on small portions of their total farm holdings and not the whole farm. This outcome was not expected and is inconsistent with the study conducted by Akinbode and Bamire (2015) who reported that the coefficient of farm size was statistically significant and positively related to the use intensity of improved maize varieties.

As expected, the adoption intensity increased with the proportion of land allocated to the production of improved maize seed varieties (P<0.01). The results showed that farmers who allocated part of their farm to improved maize seed varieties were more likely to have higher adoption intensity. This might be due to the fact that smallholder farmers who had large farms were more flexible in decision making because farmers tend to allocate only the small portion of the total land size that they are able to manage and hence resulting to increase in the maize mean yield (kg/acre). The study results are supported by Fufa and Hassan (2003) who reported that land allocated to maize production for adopters of improved maize technology was significant and positively related to maize mean yield (adoption intensity).

Different from expectations, the use of organic fertilizer influenced adoption intensity of improved maize seed varieties negatively (P<0.05). This means that smallholder farmers who used organic fertilizer were more likely to have low adoption intensity. The negative effect could be attributed due to low and improper use of organic fertilizer which result to adverse results. The results are supported by Sserunkuuma (2005) study on adoption and impact of improved maize and land management technologies in Uganda who also reported that households that use animal manure were less likely to adopt improved seeds as a result low adoption intensity. In addition, Wanda (2009) argued that inferior magnitude of its impact on output could be attributed due to the limited availability of nutrients in animal manure to that support plant growth. The study result was inconsistent with other studies such as Banerjee *et al*. (2014) study on determinants of yield variability in India who reported that organic manure was significant and positively correlated to overall maize yield and maize yield in the summer season.

As expected, quantity of herbicides was found to be positively related to the adoption intensity of improved maize seed varieties ($P<0.05$). This might be due to the fact that herbicides are among the maize inputs that are adopted as a package with improved maize seed varieties and hence their use are expected to decrease the effect of production risk such as diseases, pests and weeds and increase the adoption intensity in terms of mean yield. The results are supported by Banerjee *et al*. (2014) study on determinants of yield variability in India who reported that insecticides (kg/ha) was significant and positively correlated with summer season maize yield, which was less resource intensive.

Different from expectations, adult equivalent influenced adoption intensity of improved maize seed varieties negatively ($P<0.10$). The study findings were inconsistent with Banerjee *et al*. (2014) who reported that family members working in the farm were positively correlated with overall maize yield. This might be due to the fact that not all adult labours available in the household engage in farming activities.

As expected, farms located in the Western zone were positively related to the adoption intensity of improved maize seed varieties ($P<0.05$). This might be due to the fact the zone which comprises of Tabora, Rukwa and Kigoma regions have a favourable weather for maize production which attract farmers to adopt improved maize seed varieties. The results are supported by Hamisi (2013) study of rainfall trends and variability over Tanzania which reported that low rainfall variability was found in the unimodal areas in the Western zone in Kigoma region and Sumbawanga in Rukwa region.

4.5 Factors Affecting Production Risk under Improved Maize Production System

The results of the analysis of factors influencing production risk are presented in (Table 15). The results show that age, gender, education, farm size, quantity of herbicides, extension services and adult equivalent were found to be influencing production risk significantly. The quantity of herbicides, age and adult equivalent were found to be influencing production risk positively, whereas gender, education, farm size and extension services were found to be negatively related to production risk.

Table 15: Results from the Multiple Linear Regression equation

ln(production risk)	Robust Coefficient	Elasticity or Semielasticity	Std. Err.	t	P>t
ln(age)	-0.3654	1.9441	0.1988	-1.84	0.066 *
Gender (dummy)	0.3285	-0.4034	0.1944	1.69	0.091 *
Marital status (dummy)	-0.1290	0.1661	0.2097	-0.62	0.539
ln(household size)	0.0487	-0.1016	0.1185	0.41	0.681
ln(education)	0.1072	-0.3513	0.0612	1.75	0.081 *
ln(farm size)	0.1869	-0.4691	0.0582	3.21	0.001 ***
Herbicides	-0.0024	0.0191	0.0006	-3.79	0.000 ***
Extsension services	0.1013	-0.1436	0.0558	1.82	0.070 *
Distance from the farm to the homestead	0.0016	-0.1983	0.0032	0.49	0.623
Distance from the farm to the road	-0.0016	0.0073	0.0098	-0.17	0.868
Distance from the farm to the market	-0.0043	0.0613	0.0048	-0.88	0.377
ln(adult equivalent)	-0.3202	0.5811	0.1136	-2.82	0.005 ***
AGRO-ECOLOGICAL ZONES (dummy variables)					
Northern zone	-0.0178	0.0012	0.3246	-0.05	0.956
Eastern zone	0.4155	-0.0430	0.3291	1.26	0.207
Western zone	0.2211	-0.0721	0.2786	0.79	0.428
Southern zone	0.1919	-0.0208	0.3005	0.64	0.523
Southern highlands zone	0.0771	-0.0168	0.3126	0.25	0.805
Central zone	-0.1408	0.0034	0.3635	-0.39	0.699
Lake zone2	0.1868	-0.1098	0.2900	0.64	0.520
ln(Inverse Mills Ratio)	-0.0731	-0.0838	0.2828	-0.26	0.796
Constant	-0.1594		0.8657	-0.18	0.854
Linear regression					
Number of observations		930			
F(20, 909)		3.1000			
Prob > F		0.0000			
R-squared		0.0487			
Root MSE		2.1207			

Note:***, ** and * significant at 0.01, 0.05 and 0.10 levels respectively

Age of the household head influenced production risk positively (P<0.10). This implies that production risk tends to increase as farmers get older. This might be due to the fact that most of the older farmers are less educated when compared to younger ones. The difference in level of education causes them to be less aware and uninformed about the use of new technologies, their benefits and possible shortcomings. This result is consistent with Akinbode and Bamire (2015) who reported that age influenced adoption of improved maize seed varieties negatively and thus, age of the household head was more likely to be a risk increasing factor.

As expected, gender of the household head was found to be negatively associated with production risk ($P<0.10$). The negative effect of gender might be due to the factor that male household heads have more access to resources and also are entitled to ownership of land than females. Therefore, male headed households are able to adopt improved maize seed varieties and other agricultural input like inorganic fertilizer and herbicides which decrease production risk. The results are inconsistent with Guttormsen and Roll (2013) who reported a positive relationship between sex and production risk.

As expected, level of education of the household head influenced production risk negatively ($P<0.10$). Similar results were found by Guttormsen and Roll (2013), they reported that learning was negatively associated with production risk. This implies that education helps farmers to understand information about a technology which in turn facilitated adoption of a technology. Education gives the farmer the ability to perceive, interpret and respond to a new information much faster, which promote the farmers' ability to react to problems that arises during production at the appropriate time and thus, education is a risk decreasing factor.

As expected, farm size influenced production risk negatively ($P<0.01$). This implies that smallholder farmers with larger farms were more likely to influence production risk negatively. This might be due to fact that farmers with larger farms are more flexible in decision making on which input to use and also they are more likely to use small portion of their farms to try adoption of a new risk reducing agricultural technology and thus, farm size is a risk decreasing variable among the adopters of improved maize seed varieties. The study results are inconsistent with Fufa and Hassan (2003) study findings which reported that size of the plot for adopters was insignificant and negatively related to production risk.

Different from expectations, quantity of herbicides influenced production risk positively (P<0.01). The results imply that increase in quantity of herbicides used was more likely to increase production risk. This might be due to the fact that poor smallholder farmers are vulnerable to production risk and hence they tend to use herbicides when it is the only way possible to increase production. The study results are consistent with Guttormsen and Roll (2013) The study results were also supported by Just and Pope (1979) who argued that according to the traditional econometric specifications of stochastic production function, any input that had a positive effect on the mean output, then a positive effect on the variability of output (production risk) was also imposed. Similarly, Kaliba *et al.* (2000) reported that relatively poor farmers were more likely to use complementary inputs such as inorganic fertilizer and herbicides to increase total production from the farm as they have no other alternatives.

As expected, extension services influenced production risk negatively (P<0.10). This means that an increase in the number of visits from extension agents was found to be negatively related to production risk and thus extension services is a risk decreasing factor. This might be due to the fact that frequent visits of extension agents increase farmers' awareness about new innovations which decrease production risk. The study results are in line with Guttormsen and Roll (2013) who reported the same results. In additon, Kaliba *et al.* (2000) argued that the availability of extension service in the area was a good indicator of farmers' knowledge of agricultural information since the major source of agricultural information in the study was the extension personnel.

Different from prior expectation, adult equivalent was found to be statistically significant and positively related to production risk (kg/acre) (P<0.01). Adult equivalent was expected to be associated with efficient farming activities such as weeding, ridge fertilization and harvesting, which reduce some of the risks faced by smallholder farmers such as weed reduction. But in this study adult equivalent was found to be positively related to production risk, this might be due to the fact that most of the adult labours in the smallholder farmers' households were not providing their labour in farming activities specifically production of improved maize seed varieties. In contrast to this study result Fufa and Hassan (2003) reported that for the adopters planting labour and cultivation labour were insignificant with positive and negative effect to production risk respectively. Also, different results were obtained by Wanda (2009) study in Uganda who reported that labour was negatively related to yield variability of a crop (production risk).

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary and Conclusion

This study focused on improved maize seed varieties production system because they are poorly adopted regardless of their potential for yield increases. While a number of studies have analyzed the improved maize seed varieties adoption behaviour of rural smallholder farmers in many developing countries, empirical work on the determinants of production risk under improved maize seed production systems in the United Republic of Tanzania is scarce. The main objective of this study was to assess determinants of production risk associated with smallholder farmers who adopted improved maize seed varieties in Tanzania. Specifically, the study focused on identifying determinants of production risk which affects maize production using improved seed varieties so as to come up with strategies to achieve food security. The specific objectives were to: evaluate factors affecting the adoption and diffusion of improved maize seed varieties, identify factors affecting the intensity of adoption of improved maize seed varieties and determine factors that increase production risk under improved maize production system.

To address the three objectives, the following three hypotheses were put forward (a) Socio-economic characteristics do not influence the adoption and diffusion of improved maize seed varieties; (b) household and farm specific characteristics do not affect the intensity of adopting improved maize seed varieties among smallholder farmers and (c) household and farm specific characteristics do not affect the production risk for smallholder farmers who adopted improved maize seed varieties among smallholder farmers. Joint hypothesis testing was used for each specific hypothesis using Chi-square for hypothesis 1 and F-test for hypothesis 2 and hypothesis 3 respectively. For all three hypotheses, there were enough evidence to reject the null hypotheses at (Wald chi2 (21) = 97.01 and P= 0.00), (F (23, 906) = 31.55 and P=0. 00) and (F (20, 909) = 3.10 and P = 0.00) respectively.

Generally, based on the study findings and the tested hypotheses both household characteristics and farm specific characteristics influenced production risk significantly. The study results show that age of the household head, quantity of herbicides used and adult equivalent influenced production risk positively (risk increasing factors), whereas gender of the household head, education, farm size and extension services influenced production risk negatively (risk decreasing factors). In case of adoption and adoption intensity equations, the study results indicated that factors other than social factors and household characteristics with the exception of adult equivalent influenced the adoption and intensity of adopting improved maize seed varieties in Tanzania respectively.

Despite the fact that maize technologies that give maize high yield levels such as quantity of herbicides, should be given much emphasis on technology development, researchers should take into account of their risk effect. For example quantity of herbicides in this study was found to be positively related to both adoption intensity and production risk among smallholder farmers who adopted improved maize seed varieties.

The role of education has been clearly shown in this study where most of the smallholder farmers who adopted improved maize seed varieties were educated. The factor was insignificant for both adoption and adoption intensity of improved maize seed varieties, but significant and negatively related to production risk and thus, it is a risk decreasing factor.

The provision of extension services in terms of number of visits by extension agent was very low with a mean number of visits less than 1 for both adopters and non-adopters of improved maize seed varieties. The factor was found to be insignificant for both adoption and adoption intensity of improved maize seed varieties. Whereas, despite its inadequate supply extension services had an important role in minimizing the effect of production risk on maize production among smallholder farmers who adopted improved maize seed varieties.

The adoption and adoption intensity of improved maize seed varieties decreased with the use of organic fertilizers. This might be attributed due to low use of organic fertilizer caused by transportation cost from the place where animals are kept to the farm and lack of appropriate nutrient for the marginalized farms.

Farm size was the only factor that affected adoption, adoption intensity and production risk equations significantly. It has a positive effect for both adoption and adoption intensity equations, but negatively related to production risk. This implies that farmers with larger farms were less vulnerable to production risk compared to the one with small farms because larger farms are a symbol of smallholder farmers resource endowment.

Distance was another factor which influenced the smallholder farmers' decision on adopting improved maize seed varieties where distance from the homestead to the farm was significant and positively associated with the adoption of improved maize seed varieties. Whereas, distance from the farm to the markets was negatively related to adoption and diffusion of improved maize seed varieties. The negative effect of distance to market might be due to fact that far market center tends to limit the famers accessibility to market as a result smallholder farmers fail to obtain inputs such as improved maize seed, fertilizer, herbicides on time and limit access to markets for output after the harvest.

5.2 Recommendations

Based on the major findings of the study the following recommendations are drawn:

i) The government should improve the provision of extension services in terms of the number of visits and quality of extension services by increasing the number of manpower and improving access of loans and other financial resources to smallholder farmers.

ii) More researches on improved maize seed varieties should be conducted so as to produce new varieties which are resistant to weather related risks in each agro-ecological zone in order to increase maize production in different agro-ecological zones.

iii) The government should facilitate the availability of improved maize technologies such as improved maize seed varieties like recycled improved seed, quality assured seeds and others so that they should be readily available to smallholder farmers near to their places to promote its adoption and diffusion.

iv) More research and extension services must be directed towards promoting farming practices which enhance soil fertility such as the use of organic manure, crop residual management and soil conservation to promote maize production in the country.

v) Also the government through extension staff should promote the use of insecticide, pesticides and other biological stress control measures in maize production so as to reduce maize loss and increase food security in the country.

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APPENDICES

Appendix 1: Summary of all quantitative variables for all smallholder farmers in the United Republic of Tanzania (n=2 124)

Quantitative variables	Mean	Std. Err.	[95% Conf. Interval]	
Age of the household head	46.4261	0.3652	45.7100	47.1422
Household size	6.1544	0.0899	5.9781	6.3309
Extension visits	0.3734	0.0237	0.3269	0.4198
Extension quality	1.0457	0.0680	0.9123	1.1790
Plot size	10.0553	0.5420	8.9923	11.1182
Proportion of land allocated to maize	0.7287	0.0076	0.7137	0.7437
Area under maize production	6.3230	0.3915	5.5553	7.0907
Quantity harvested	1 161.0300	63.8925	1 035.7310	1286.3280
Yield (kg/acre)	564.9302	30.0679	505.9646	623.8957
Production risk (kg/acre)	0.9199	0.0354	0.8504	0.9893
Quantity of inorganic fertilizer (kg)	34.0405	3.1501	27.8629	40.2180
Quantity of herbicides	14.4361	2.5186	9.4969	19.3753
Distance from the plot to home (km)	4.4311	0.3935	3.6595	5.2027
Distance from the plot to the road (km)	2.8828	0.1486	2.5913	3.1742
Distance from the plot to the market (km)	12.7946	0.3263	12.1547	13.4345
Total days used in weeding	53.2750	1.1523	51.0151	55.5348
Total days used in ridge fertilization	13.1036	0.5145	12.0947	14.1125
hired labour in total days	6.6761	0.4044	5.8830	7.4692
Adult equivalent	5.1010	0.0752	4.9536	5.2484
Inverse Mills Ratio	0.9267	0.0062	0.9145	0.9390

Appendix 2: Summary of all quantitative variables for smallholder farmers who used improved maize seed varieties in the United Republic of Tanzania (n = 930)

Quantitative variables	Mean	Std. Err.	[95% Conf. Interval]	
Age of the household head (years)	44.9817	0.5275	43.9465	46.0170
Household size	6.3903	0.1241	6.1468	6.6338
Extension services (number of visits)	0.4978	0.0404	0.4186	0.5771
Extension quality	1.3667	0.1144	1.1421	1.5912
Plot size (acre)	11.3487	0.9599	9.4648	13.2325
Proportion of land allocated to maize Production	0.7688	0.0109	0.7474	0.7901
Area under maize production (acre)	8.0631	0.8364	6.4218	9.7045
Quantity harvested (kg)	1 337.1510	86.1977	1 167.9870	1 506.3160
Yield (kg/acre)	499.8539	32.2711	436.5211	563.1867
Production risk	0.8083	0.0389	0.7321	0.8846
Quantity inorganic fertilizer (kg)	44.4527	5.8995	32.8747	56.0307
Quantity of herbicides	15.5427	2.7829	10.0812	21.0042
Distance from the plot to home(km)	5.09543	0.8374	3.4520	6.7389
Distance from the plot to the road (km)	2.5431	0.2217	2.1081	2.9781
Distance from the plot to the market (km)	11.8657	0.4512	10.9803	12.7511
Total days used in weeding	55.6387	1.7248	52.2538	59.0237
Total days used in ridge fertilization	15.8677	0.8432	14.2130	17.5225
Hired labour in total days	8.1172	0.7431	6.6589	9.5755
Adult equivalent	5.3442	0.1049	5.1383	5.5501
Inverse Mills Ratio	0.8213	0.0091	0.8035	0.8392

Appendix 3: Summary of all quantitative variables for smallholder farmers who did not use improved maize seed varieties in the United Republic of Tanzania (n = 930)

Quantitative variables	Mean	Std. Err.	[95% Conf. Interval]	
Age of the household head	47.5511	0.5009	46.5684	48.5338
Household size	5.9707	0.1273	5.7210	6.2204
Extension services (number of visits)	0.2764	0.0278	0.2219	0.3309
Extension quality	0.7956	0.0811	0.6365	0.9548
Plot size	9.0478	0.6075	7.8559	10.2398
Proportion of land allocated to maize production	0.6975	0.0105	0.6769	0.7181
Area area under maize production (acre)	4.9676	0.2394	4.4979	5.4373
Quantity harvested (kgs)	1 023.8490	91.5439	844.2444	1 203.4540
Yield (kgs/acre)	615.6177	47.1741	523.0643	708.1711
Production risk (kgs/acre)	1.0068	0.0551	0.8986	1.1149
Quantity of inorganic fertilizer (kgs)	25.9305	3.1900	19.6718	32.1892
Quantity of herbicides	13.5741	3.9220	5.8793	21.2689
Distance from the plot to home (km)	3.9136	0.2534	3.4164	4.4108
Distance from the plot to the road (km)	3.1473	0.1999	2.7551	3.5396
Distance from the plot to the market (km)	13.5181	0.4611	12.6134	14.4228
Total days used in weeding	51.4338	1.5469	48.3990	54.4687
Total days used in ridge fertilization	10.9506	0.6307	9.7132	12.1879
Hired labour in total days	5.5536	0.4248	4.7202	6.3870
Adult equivalent	4.9116	0.1055	4.7045	5.1186
Inverse Mills Ratio	1.00889	0.0077	0.9937	1.0240

Appendix 4: Summary of all qualitative variables for all smallholder farmers producing maize in the United Republic of Tanzania (n = 2 124)

S/N	Variable	Dummy variable	Adoption		Total
			Adopters	Non-adopters	
1.	Gender of the household head	Male	832	703	1535
		Female	362	227	589
2.	Marital of the household head	Polygamous, monogamous or living together	266	789	1055
		Divorced, separated, never married and widow(er)	928	141	1069
3.	Inorganic fertilizer	Use	207	222	429
		Non-use	987	708	1695
4.	Organic fertilizer	Use	217	281	498
		Non-use	977	649	1626

Appendix 5: Summary of agro-ecological zones variables for smallholder farmers producing maize in the United Republic of Tanzania (n = 2 124)

S/N	Agro-ecological zones	Regions	Frequency
1.	Northern zone	Arusha, Kilimanjaro and Manyara	162
2.	Southern zone	Lindi and Mtwara	245
3.	Western zone	Kigoma, Tabora and Rukwa	422
4.	Eastern zone	Tanga, Morogoro, Pwani, Kaskazini Unguja, Kusini Pemba and Mjini Magharibi	200
5.	Southern highlands zone	Mbeya, Iringa and Ruvuma	530
6.	Central zone	Singida and Dodoma	117
7.	Lake zone 2	Mwanza, Mara and Shinyanga	416
8.	Lake zone 1	Kagera	32
	Total number of smallholder farmers		**2124**