EFFECT OF BIOFORTIFIED BEANS ADOPTION ON SOCIO - ECONOMIC WELFARE ON FARMERS IN EASTERN RWANDA

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MASTER OF SCIENCE

(Agriculture-Applied Economics)

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY.

2017

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A Thesis submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science in Agriculture and Applied Economics in the Jomo Kenyatta University of Agriculture and Technology.

2017

DECLARATION

This thesis research is my original work and has not been submitted to any University for the award of a degree.

Signature………………………………………………Date……………………………..

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This thesis research has been submitted for examination with our approval as University supervisors.

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DEDICATION

This thesis is dedicated to

My beloved Mother MUKARUSHEMA Costasie

ACKNOWLEDGEMENT

This work is a result of combined efforts, attention, advices and experiences of people who have contributed directly or indirectly to its recognition. Thanks to their multidimensional assistance.

First and foremost, I extend my pleasure to the Government of Rwanda through the Ministry of education for supporting the education sector all over the country.

Special thanks to Dr Mbabazi Mbabazize, who agreed to lead this research work. Their invaluable guidance and advice that have helped me to deliver this quality work is appreciated

My thanks goes to Edouard RURANGWA (PhD Student and Senior Scientist in RAB), who helped a lot with his technical expertise in guiding me in study. I appreciated your great efforts that will always be remembered in my career life. I appreciated it and may God bless you much.

I am very thankful to the lecturers from the Jomo Kenyatta University of Agriculture and Technology (JKUAT-Kigali campus), to the Faculty of Agriculture Science and Applied Economics who trained me in the courses of my studies.

I thank all fellow classmates for the love they have shown me during this Masters' studies specially Mr. Eric Ntaganira, Alfred Mwesigye, Ufitimana Chantal, Nyirahorana Concile, Rugema Egide, Pamphile Bakundukize among.

ABSTRACT

Common bean has emerged to be an important staple food for the majority of household in Rwanda. Its productivity is a function of the usage of improved inputs like seeds, fertilizers, combined by farm management practices; it is this regard that biofertified beans have been introduced as improved varieties. Adoption of biofortified beans is important because of its high productivity, high nutritional levels, and high income crop compared to ordinary field bean. However adoption of biofortified beans is still remaining low. This study is initiated with the objective of assessing the effect of adoption of biofortified beans on the social economic welfare of farmers in Nyagatare district in Eastern province of Rwanda. The method that used is stratified survey with 197 households' heads' respondents selected by multi stage random sampling and cluster sampling. Thereafter qualitative and quantitative methods of data collection were used to gather the data. Data was analyzed using probit model for finding out the factors influenced adoption of biofortified beans and Propensity Score Match to determine the effect of adoption on bean farm yield and income between adopters and non-adopters groups. The results showed that, farmers' group membership, livestock holdings, agricultural extension services, total land holdings and total land bean size have influenced the adoption of biofortified beans. The results showed that in 2016 A, 2015 B, 2015 A and 2014 B, the mean bean yields were 1527.059 kg ha^{-1}, 1440.247 kg ha^{-1}, 1661.36 kg ha^{-1} and 814.44 $kgha^{-1}$ in adopters group while in non-adopters group, the bean yield were 840.4444 $kgha^{-1}$, 825.4918 $kgha^{-1}$, 831.23 $kgha^{-1}$ and 426.92 kg ha^{-1} respectively. The ATT in 2016 A, 2015 B, 2015 A and 2014 B was 673.49, 620.24, 809.74 and 397.74 respectively. Those results were statistically significant at 95% of confidence level. In those four agricultural seasons, the farmers' incomes were calculated based on price and quantity of bean sold. The analysis showed a highly significant difference between the income from sales of beans among adopters and non-adopters at 95% of confidence level. This research shows that bean yield and income are higher in adopters' group more than non-adopters. The research recommends that farmers should be grouped into farmers groups and consolidates their small pieces of land to bigger parcels for enhanced biofortified beans cultivation.

Key words: *Adoption, Biofortified beans, PSM, ATT, overlapping and backyard farmers*

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LIST OF ACRONYMS

ATE	Average Treatment Effect
CAADP	Comprehensive Africa Agriculture Development Program
CIA	Conditional Independence Assumption
CIAT	International Center for Tropical Agriculture
CIMMIYT	International Maize and Wheat Improvement Center
CIP	Crop Intensification Program
DAP	Di-amino phosphate
DRC	Democratic Republic of Congo
EDPRS	Economic Development Poverty Reduction Strategies
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GPS	Global Positioning System
HH	Household
HIB	High Iron Bean
IITA	International Institute for Tropical Agriculture
ISAR	Rwanda Agricultural Research Institute
MINALOC	Ministry of Local Government
NGOs	None Government Organizations
NISR	National Institute of Statistics of Rwanda
NPK	Nitrogen Phosphorous Potassium
PABRA	Pa African Bean Research Alliance
ppm	parts per million
RAB	Rwanda Agricultural Board
RWF	Rwandan Francs
SSA	Sub-Saharan Africa
SPAT	Strategical Plan for Agricultural Transformation
TIA	Trabalho de Inquerito Agricola
USAID	United States Agency for International Development

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DEFINITION OF KEY CONCEPTS

Adoption

Adoption process is the change that takes place within individual with regards to innovation from the moment that they first become aware of the innovation to the final decision to use it or not (Ray, 2001). Adoption is a mental process through which an individual passes from first knowledge of an innovation to the decision to adopt or reject and to confirmation of this decision (Van den Ban and Hawkins, 1998).

Biofortification

Is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology. Biofortification differs from conventional fortification in that biofortification aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops. Biofortification may therefore present a way to reach populations where supplementation and conventional fortification activities may be difficult to implement and/or limited.

Biofortified beans

They are improved bean varieties which contain high level of iron and protein, higher than the indigenous bean varieties including other improved bean varieties.

CHAPTER ONE

INTRODUCTION

I.1. Background Information

Common bean *(Phaseolus vulgaris* L.*)* is the world's most important food legume for direct human consumption. It is estimated that the crop meets more than 50% of dietary protein requirements of households in Sub-Saharan Africa (Broughton *et al*., 2003; Wortman *et al*., 2004). The annual *per capita* consumption of common bean is higher among low-income people who cannot afford to buy nutritious food stuff, such as meats and fish (Beebe *et al*., 2013; Broughton *et al*., 2003). Additionally, its consumption also varies by region. For instance, in eastern Africa, the *per capita* consumption of 50 to 60 kg year-1 in Rwanda, Kenya and Uganda is considerably higher than in Latin America where *per capita* consumption is 4 and 17 kg year-1 in Colombia and Brazil, respectively (Beebe *et al*., 2013; Broughton *et al.*, 2003). In addition to its subsistence value, common bean is an important commercial crop contributing significant incomes to the majority of the rural peasants in SSA (Wortman *et al*., 2004). The crop occupies more than 3.5 million hectares in sub-Saharan Africa, accounting for about 25% of the global production but production is concentrated in the densely populated areas of East Africa, the lakes region and the highlands of southern Africa (CIAT-CGIAR, 2004).

In developing countries, new agricultural technologies have the potential to reduce poverty and food shortage through increased agricultural productivity and ensured food security (Bandeira and Rasul, 2005; Cornejo and McBridge, 2002). According to Uaiene *et al.* (2009), Agricultural technologies currently available include improved varities, fertilizer, pesticide, improved farm storage techniques, and small scale irrigation technologies (e.g., treadle pumps). Unfortunately, while available in principle, households' awareness of and access to these new technologies is distinctly limited in practice. To encourage households to adopt new agricultural technologies and increase agricultural productivity, the government and non-government organizations may need to increase the number of extension agents and expand their diffusion programs (Gemo, 2006).

Improved varieties (e.g., improved beans) have the potential to increase production, as well as increase the income and improve the standard of living for farm households. Unfortunately, the rate of agricultural technology adoption in remains low. For example, Uaiene *et al.* (2009), in his analysis of TIA (Trabalho de Inquerito Agricola), (2005) survey data, report that approximately seven and 11% of agricultural households planted improved bean varieties, respectively. Furthermore, they report that less than five percent of households applied fertilizer and pesticide to their food crops. Improved bean varieties have a potential to increase agricultural productivity if they were widely diffused and adopted. However, deciding if they should adopt improved varieties, households compare the benefits and costs of improved varieties with traditional varieties.

Countries need to increase bean production to be food secure and increase nutrition for all populations, especially those that live in rural areas. A few empirical studies, such as from Uaiene *et al.* (2009), Zavale *et al.* (2005) and Bandeira and Rasul (2005) reported that one of the factors that affect low production of beans in Mozambique is the lack of use of improved varieties. Common bean is an important subsistence crop for smallholding farmers in Rwanda. It is often referred to as the meat of the poor because of its high protein content and affordability. Beans are also vital sources of micronutrients such as iron, reducing iron deficiency caused by the lack of diversity in the starch-based diets of the poor. Rwanda has one of the highest per capita bean consumption in the world (Kalyebara and Buruchara, 2008), confirming that bean is a key crop for food security. Beans provide 32 and 65 percent of calories and protein intake in the Rwandan diet, whereas protein sourced from animal provides only 4 percent of the protein intake (Asare-Marfo *et al.*, 2011 and CIAT, 2004).

Previous studies have found that nearly all rural households in Rwanda cultivate beans (Asare-Marfo, *et al.*, 2011, Larochelle, *et al.*, 2013). Beans are grown twice a year in many farming systems. They are intercropped with banana, cassava, maize, peas, and others, and grown in different agro-ecological conditions. To accommodate this environmental diversity, two bean technologies are available to farmers bush and climbing beans. Climbing beans are grown in the high and medium altitudes and bush bean are usually used in mid and low altitudes. Climbing beans grow vertically, requiring staking material, and are harvested over a more continuous period compared to bush beans. This vertical growth property confers climbing beans a yield advantage over bush beans and makes them less likely to be intercropped. (Asare-Marfo, *et al.*, 2011)

Beans are food/nutrition security crop and source of cash income. As a short-duration crop (2.5 - 4 moths), they are also a key for helping to shorten the hunger periods and for providing quick cash. Their early maturity and capacity to provide a range of food products (leaves as well as, fresh pods and dry grain) also helps provide a more balanced diet to vulnerable community members (the under-five, pregnant mothers and chronically ill people). In some countries of the Great Lakes Region namely Rwanda, Burundi and east Democratic Republic of Congo (DRC), the bean consumption is estimated at 40 kg per year per person (Spilsbury *et al.*, 2004). In the recent years, bean consumption is on the rise as result of the increasing scarcity of animal proteins and increasing poverty among the urban and rural poor (Asare-Marfo, *et al.*, 2011). Beans are mainly grown by small scale farmers with a very minimum input use except seed.

Despite a slight increasing yield trend, beans productivity and yield levels at the farm level have remained relatively low and even decreasing in some areas (FAO, 2005). This contributes to lower bean availability and accessibility to the majority of households. Farmers are increasingly interested in improved bean varieties which respond to their priority needs to increase productivity (i.e. drought and disease/pest tolerance) and also with good marketability, good cooking/eating qualities. One way to address this situation is to carry out participatory bean breeding with farmers, facilitate them to identify their preferred varieties and ultimately access seeds of these varieties.

The production of bean has been affected by land size allocated to bean production, production assets, group membership and type of seed variety planted significantly influence output; while cost of transport, quantity consumed at home, quantity stored for food, market price and storage losses influence marketable supply (Asare-Marfo, *et al*., 2011). Improved bean production will go a long way in solving the problems of food security, poverty, malnutrition as well as increase revenue generation and employment. Improved accessibility of markets is critical for increased rural incomes in smallholder farming.

At the household farmer level, the access has accessed to the sufficient quantities of seeds of their preferred varieties with adequate physical quality, at the right time of planting (Sperling and Cooper, 2003). As the majority of small scale farmers (poor and marginalized) operate in low input systems, their seed security is not guaranteed when they produce enough food and put some in reserve to be used as seeds for the next season.

Common bean is a major staple food in Rwanda; thus increasing its production and marketing has the potential for raising incomes of the farming households. Surpluses are now becoming more common largely due to the increased use of climbing and bush beans varieties which are high yielding, high tolerance to diseases and climate change and adaptability to different level of soil fertility. These varieties have seen average yields increase by 40 percent over the last decade with minimal expansion of cultivated land. This has aided a transition in Rwanda from net importer, to self-sufficiency, and now exporter (USAID, 2013).

Biofortified bean varieties represent high content in Iron (40% more iron than typical bean), high adaptability and tolerance to different variation of soil conditions and climate change and high yielding (Lister, 2012, & RAB, 2012). Seeds are basic agricultural input. More importantly quality seeds of any preferred varieties are basis of improved agricultural productivity since they respond to farmers needs for both their increasing productivity and crop uses (Pelmer, 2005).

To enhance production of biofortified beans and earning income, the farmers should within their existing land holdings, expand proportion of land under biofortified bean production, adoption of best practices and using improved inputs, and actively participate in farmer group's activities for easier access to inputs, credit and markets (Asare-Marfo, *et al.*, 2011)..

Growing for domestic consumption and export opportunities with neighboring countries due to integration of Rwanda into East Africa Community have been identified as key avenues for growth and underscore the importance of continued intensification of bean production (USAID, 2013). The improved varieties offer resistance to important diseases, are tolerant to low soil fertility, and possess desirable seed and plant characters (Chirwa *et al.*, 2007). Commercialization and improved market access are critical for improving rural farm incomes (Key *et al.*, 2000). Smallholder market participation is highly influenced by factors of production as well as transaction costs (Abdulai and Birachi, 2009. The analysis of constraints hindering use of improved varieties with stakeholders revealed that the main constraint to adoption of bean improved varieties was associated with limited accessibility to seeds (PABRA, 2005).

This research has investigated the factors influencing the adoption of biofortified bean varieties in Nyagatare district, eastern province which used to grow bush bean. This research also has assessed the effects of the adoption of those beans on bean farm production to the farmers' adopters while analyzing the economic effect to adopters compared to non-adopters.

1.2. Problem Statement

Adoption of biofortified beans production is of considerable importance because it is expected to improve bean productivity, increase income, and reduces hidden hunger and improving rural livelihoods as it is recognized as an important source of human dietary protein and calories (Asare-Marfo, *et al.*, 2011). The study in rural and urban markets revealed that biofortified bean varieties are widely available in Rwanda (Murekezi, 2013).The adoption level of biofortified bean varieties was low. The study of Assessing the adoption of Biofortified bean varieties and their impact on Iron intake and other livelihood outcomes in Rwanda, 2016, showed that the adoption level was 28% of bean growers while 93% of households were bean growers (Assare-Mafumo *et al.*, 2016) In general perspective in Rwanda, the average bean yields is still low. The average of bush bean and climbing beans were 731.4 kg/ha and 1024.6 kg/ha respectively in 2014 A (NISR, 2014). While the potencitial yield of bofortified bean varieties are 2 to 3 tons per Hectare and 3 to 4 tons per hectare for bush and climbing respectively (RAB, 2012). However as pertains to biofertified beans, limited studies have been conducted on the adoption of biofortified bean varieties and their socio-economic effect on bean farmers in Rwanda. Moreover, previous studies on biofortified beans were focused mainly on adoption rate (Asare-Marfo, *et al.*, 2011; Larochelle, *et al.*, 2016; Assare-Mafumo *et al.*, 2016). Therefore, this study was conducted to examine factors influencing the adoption of biofortified beans varieties and their socio-economic effect on the bean farmers in Nyagatare District eastern Rwanda to bridge the existing knowledge gap and guide further research on the improvement of their production.

I.3. Research objectives

I.3.1. General Objective

The main objective of this research is to determine effect of biofortified beans adoption on socio-economic welfare on bean farmers in eastern Rwanda.

I.3.2. Specific objectives

1. To find out the factors influencing adoption of biofortified bean production

2. To determine the effect of adoption of biofortified beans on bean farm yield

3. To determine the effect of biofortified beans' adoptions on farmers' income.

I.4. Hypotheses

1. H_o: The adoption of biofortified beans is not influenced by socio-economic factors
2. H_o: The adoption of biofortified beans doesn't increase bean farm yield.
3. H_o: Adoption of biofortified beans does not increase farmers' income.

I.5. Justification of the study

This study will indicate opportunities in growing biofortified beans through which farmers will maximize their profit. It will provide also clear image on factors influencing adoption of biofortified beans and the ways to follow to fill the gap.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter summarizes the production of biofortified in Rwanda, empirical studies relevant to this study, theoretical framework and conceptual frame work of this study.

2.1. Biofortified beans production in Rwanda

In Rwanda, bean is the crop that receives the most research attention, followed by sweet potato and banana (Karangwa, 2007). The bean research program at RAB, formally Institut des Sciences Agronomiques du Rwanda (ISAR), in collaboration with international partners such as International Center for Tropical Agriculture (CIAT) and Harvest Plus, has released nearly 100 bean varieties over the last four decades (PABRA, 2012; RAB, 2012). By that partnership, ten biofortified bean varieties (Table 4. 1) have been released from those 100 varieties (Harvest Plus, 2013). Rwanda ranks number 1 out of 81 countries globally, for introduction of Biofortified bean varieties (Asare-Marfo *et al.*, 2013). Biofortified beans varieties have 40% more iron than typical bean varieties. Previous studies indicated that most farmers who sell beans do so immediately after harvest and may later purchase beans for food and even seed. Most (88%) of farmers cite their social networks (neighbors, extended family and friends) as their main sources of information about new varieties (Harvest Plus, 2013). The majority of seed "recyclers" and new seed acquirers got their (original) seeds from local markets. Beans are being sold to primary traders on rural markets at small distances from the farm. Wholesalers are based in and around Kigali and receive their supplies from a network of traders. Typically, retailers collect beans from the wholesalers, but they may also collect them directly from primary traders. The value chain of beans in Rwanda are describe as follow: a) Input Supply-Production-Consumption, b) Commercial cultivation in rural areas: Input Supply-Production-Primary trader-Consumption, c) Commercial cultivation of beans for urban areas: Input Supply-Production-Primary trader-Wholesale-Retail-Consumption (Harvest Plus, 2013).

Adoption of biofortified beans is currently highest in the Northern and Western regions where climbing varieties account for over 80% of production (USAID, 2013). Adoption is lower in Southern and Eastern regions and production volumes derived from these varieties are 50 and 10% respectively (USAID, 2013). An added benefit of these climbing varieties is their high biomass content and nitrogen fixing properties, both of which can enhance soil fertility. Overall, the virtues of this versatile crop, in terms of food security, diet, and environmental sustainability are manifest.

Table 4. 1: Characteristics of ten Biofortified beans varieties grown in Rwanda

Names	Type	Yield Potential	Maturity	Adaptation	Iron content
RWV 3316	Climbing	4 T/ha	110 days	High altitude	91.6 ppm
RWV 3006	Climbing	3.8 T/ha	110 days	High altitude	91.7 ppm
Mac 44	Climbing	3.5 T/ha	87 days	Mid to low altitude	78 ppm
RWR 2245	Bush	2.5 T/ha	87 days	Mid to low altitude	75 ppm
RWR 2154	Bush	2.5 T/ha	87 days	Mid to low altitude	75 ppm
RWV 1129	Climbing	3.5 T/ha	110 days	Mid to high altitude	81 ppm
Cab 2	Climbing	3 T/ha	115 days	High altitude	94.8 ppm
RWV 3317	Climbing	4 T/ha	110 days	High altitude	74 ppm
RWV 2887	Climbing	3.5 T/ha	106 days	Mid to high altitude	93.7 ppm
Mac 42	Climbing	3.5 T/ha	81 days	Mid to high altitude	91 ppm

Source: RAB Bean information guide, 2012

2.2. Empirical Studies relevant to this study

2.2.1 Introduction

The rapid responses to new agricultural technologies in some developing countries has resulted in a sustainable agricultural development and increased agricultural productivity, which has contributed to overall economic growth, ensuring food security, and reducing poverty (Prabhu, P., 2010). The farm-level new technological adoption is an important factor affecting the level of economic return to agricultural research. Factors affecting farm-level adoption include off-farm economic constraint and opportunities that are communicated through off-farm input and output markets (Mathenge, M. K., and Tschirley, D., 2007).

Also, the rate of new technology adoption at the farm-level depends on the extent to which the new technology enables farmers to respond to the evolving preferences of off-farm clients for different product characteristics, as reflected in market prices (Helder, L., 2010).

In general, these factors are classified into four categories: household demographical characteristics, socio-economic factors, institutional factors, farmers' acceptance of technologies, and economic attributes. Many agricultural technology adoption studies have shown that while a factor may be associated positively in a region, the same factor may have an inverse (or no) association with other studies or in different regions/countries. Adoption studies attempt to explain the association between various factors and farmers' adoption behaviors, and estimate the magnitude and the significance of the estimated parameters.

2.2.2. Empirical Studies

Boughton and Staatz (1993), using a sub-sector approach to design agriculture research in Mali, argued that farm-level adoption of improved varieties is an important factor affecting the level of economic return to agricultural research. Factors affecting farm-level adoption included off-farm economic constraint and opportunities that were communicated through off-farm inputs and outputs market. The rate of technology adoption at the farm-level depended on the extent to which the technology enabled farmers to respond to evolving off-farm clients' preferences for different product characteristics (e.g.quality, seasonal availability and lot size), as reflected in market prices.

Waluse, (2012) who conducted the research on determinants of common bean productivityand efficiency on smallholder's farmers in eastern Uganda found that the factors influencing common bean productivity and efficiency were plot size, ordinary seeds, certified seeds and planting fertilizer.

Doss (2003), made a distinction between discrete and continuous technology adopters among typical farmers who used either unimproved or improved inputs. The author defined a farmer as being an adopter if he or she was found to be using any improved materials. With respect to the adoption of improved varieties, discrete adoption referred to a farmer who stopped using a local (traditional) variety and adopted an improved variety. In contrast, continuous adoption referred to situations where farmers increasingly planted more land to improved varieties, while continuing to grow some local varieties.

Farmers' technological adoption behavior is associated with many factors. In a study of the adoption of agricultural and forestry technologies by smallholder in tropical areas, Pattanayak *et al.* (2003), classified factors associated with technological adoption into four categories: preferences and resource endowments, market incentives, biophysical factors, and risk and uncertainty. Doss *et al*. (2003), in the study of the adoption of maize and wheat technologies in eastern Africa, proposed a similar framework. They classified factors associated with farmers' adoption decisions into four categories: farmers' socio-demography characteristics, institutional factors, farmers' perception of the characteristics of technologies, and economic attributes.

According to Doss *et al*. (2003), numerous studies of technologies adoption in developing countries have used farmers' socio-demography characteristics (e.g, household heads' gender, age, education and household size) to explain household adoption behaviors. A few of these studies reported that the rate of technology adoption was higher among male-headed households, compared to female-headed households because of discrimination (i.e., women have less access to external inputs, services, and information) due to socio-cultural values.

Adesina and Forson (1995), who studied farmers' adoption of new improved sorghum varieties in Burkina Faso and Guinea, reported that both young and old sorghum farmers in Burkina Faso adopt new technology. Young farmers adopted the technology because they had long term plans and were willing to take risks. On the other hand, old farmers adopted it because they had accumulated capital or had greater access to credit, due to their age. However, the effect of farming experience (measured by the age of the household head) was not always positively associated with farmers' adoption behaviors. For example, Zavale *et al*. (2005) reported that older farmers in Mozambique were less likely to adopt improved maize variety than younger farmers.

Birachi *et al*. (2011) conducted a research on factors influencing smallholder farmers' bean production and supply to market in burundi revealed that production losses, land size allocated to bean production, production assets, group membership and type of seed variety planted significantly influence output.

Zavale *et al.* (2005) and Uaiene *et al.* (2009) reported that the level of education attained by households in Mozambique was positively associated with households' adoption behaviors. The authors suggested that education positively influenced households to quickly respond to their current low agricultural productivity by adopting new agricultural technologies that increased productivity, household income and its standard of living. However they also reported that most household heads in Mozambique were illiterate or had attended school for only a few years.

Institutional factors (e.g., having access to extension services, credit, roads, price information from markets, being a member of an agricultural association) have been widely used to assess farmers' adoption behavior. Pattanayak *et al*. (2003) argued that access to extension services provided by the government, NGOs, and other stakeholders played a very important role in the adoption of new improved varieties. Farmers who are exposed to information about new improved varieties by extension agents (through training, group discussion, plots demonstration, and other form of information delivery) tend to adopt them. An empirical study by Boughton and Staatz (1993) suggested that in Mali, the farm-level adoption rates for improved maize varieties could be significantly increased by an extension program that tailors varietals promotion to individual farmers' needs and circumstances.

Abdulai and Birachi, (2009) in a study on smallholder milk farmers in Kenya and Ouma *et al*. (2010) in a study on banana producers in Central Africa (Burundi, the Democratic Republic of Congo (DRC) and Rwanda), find that distance to market place, means of transport, source of information and the geographical location of the household have direct effects on the level of transaction costs that producers face.

2.2.3. Farmers' Perception of Characteristics of new improved varieties

Feeder *et al.* (1985) argued that yield performance (or expected yield of new varieties) is one of the characteristics of improved varieties that affect farmers' adoption behaviors. Several empirical studies show that the adoption rate of improved varieties is high, if the varieties meet farmers' expectations. An improved variety will be adopted at exceptionally high rates, if the new variety is technically and economically superior to local varieties. Improved varieties are technically superior if they produce higher yield to traditional varieties. For example, Adesina and Forson (1995) reported that farmers in Burkina Faso adopted a modern sorghum variety because it gave high yield, compared to the traditional sorghum variety that farmers planted in previous agricultural years.

Martel *et al.* (2000) argued that bean farmers always compare the new bean variety to their current varieties. Farmers are more likely to adopt a new bean variety if it performs well under different environmental conditions, shows economic profitability, and is tolerant to disease and insects.

Adegbola and Gardebroek (2007), analyzed the effect of information sources on improved maize seeds adoption and modification in Benin, reported that in addition to considering yields, direct costs, and profits associated with improved maize seeds, farmers also consider seed characteristics that reduce risks, because damages from insects and/or disease during maize production and storage can result in substantial yield losses and poor grain quality. In some circumstances, these losses not only increase the risk of food insecurity for the farmers' households, but may also decrease farmers' income if the losses in quantity are not sufficiently compensated for by a price increased due to deficit in national supply. With respect to risks, several other studies report that farmers also consider environmental aspects, such as whether or not the improved varieties were developed for local climate and soil fertility conditions (Ramirez, 2003), or for variations in local agro-ecological patterns (Doss, 2003).

Gichangi, *et al*., 2012 conducted the research of Assessment of Production and Marketing of Climbing Beans by Smallholder Farmers in Nyanza Region, Kenya, have found that, the level of adoption of improved variety influence the amount of yield obtained. In economics, mathematical probability analysis are conducted to explain what value people assign to the utilities for alternative outcomes of and seek to maximize their expected utility. In psychology, observations are made to describe human judgment process and how people make alternative judgments based on their perception. According to Dunn (1984), decision-making is an ubiquitous activity inherent in the behaviour of individuals or society. Decision can be categorized as intuitive, programmed, and analysed. Those choices that individuals make without conscious thought as to the alternatives and the relative evaluation are known as intuitive decisions. Whereas programmed decision-making are which in principle are capable of being automated. There are certain decisions that one has to analyze possible outcomes and their consequences (Gebre-Mariam, 2012). When an individual has alternatives each with significant consequences, and that he or she in unsure about which choice is the best, a decision problem exists. A decision problem consists of: (i) alternatives available to the decision maker, (ii) state of nature (rainfall, price etc), (iii) probability attached to the state of nature influencing the decision problem (iv) consequence of action, (v) process of conducting experiments to obtain additional income, (vi) process of conducting additional information about the likelihood of outcome given the state of nature, and (vii) the strategy for actions which are conditional on the experimental outcome observed (Dunn, 1984). The distinction between farmers producing improved varieties or old or both is key for study farmer's behaviour which is very complex when the environment is highly unpredictable. Decision-making takes different aspects.

According to the Rational Decision-making Model; a model in which decisions are made systematically and based consistently on the principle of economic rationality people strive to maximize their individual economic outcomes (Taher, 1996 and Mendola, 2007). Information about all possible alternatives, their outcomes and the preference of decision makers is assumed available. To describe the characteristics of the farmers' decision-making some author refers to the characteristics of farm management. Various statements identified the factors influencing the decision-making process in farm management. Taher (1996) emphasized the community influence on the farmer. He argued that decisions in farming will be determined not only by the goal of maximizing the benefit or of reducing the risk, but also by willingness to accept criticism from the community (depending very much on a farmer's social position in different groups).

2.3.4. Risks and Economic Attributes

Farmers have heterogeneous beliefs about new improved varieties and the economic profitability of new improved varieties is uncertain. Early adopters are farmers who adopt first, while late-adopters wait and observe the experiences of early-adopters. After obtaining information about the new improved varieties from early-adopters, they decide whether or not to adopt the new improved varieties based on the economic profitability (Shampine, 1998; Basley and Case, 1993). According to Feder *et al*. (1985) and Adegbola and Gardebroek (2007), farmers who are aware of a certain new improved varieties component will decide whether or not to adopt it by evaluating the expected economic profitability or benefit that they anticipated will be gained, taking into account the initial investment and variable costs. A new improved variety is more likely to be adopted if the gain or profit exceeds the aggregate investment and variable costs.

Furthermore, they argued that the new improved varieties adoption rate varies over time because socioeconomic groups have different adoption behaviors and farmers' adoption decisions for the next growing period depends on the initial impact of the technology, profitability, and other farmers previous experience. Researchers of technological adoption studies often use economic attributes variables (e.g., farm size, land tenure, farm location, farmers' growing other cash crops, and adoption of other complementary technologies like fertilizer) to explain farmers' adoption behaviors.

2.3.5. Propensity Score Matching

The observable variables eliminate sample selection bias (Heckman and Navarro, 2004). PSM constructs a statistical comparison group by matching every individual observation of adopters with an observation with similar characteristics from the group of non-adopters. In essence, matching models create the conditions of an experiment in which adopters and non-adopters are randomly assigned, allowing for the identification of a causal link between action choice and outcome variables. The seminal explanation of the PSM method is available from Rosenbaum and Rubin (1983), and its strengths and weaknesses are elaborated, for example, by Dehejia and Wahba (2002), Heckman *et al.* (1998), Caliendo and Kopeinig (2008), and Smith and Todd (2005). Propensity score matching is a two-step procedure. The main purpose of the propensity score estimation is to balance the observed distribution of covariates across the groups of adopters and non-adopters (Lee, 2008). The balancing test is normally required after matching to ascertain whether the differences in the covariates in the two groups in the matched sample have been eliminated, in which case, the matched comparison group can be considered a plausible counterfactual (Abdulai A., 2010). Although several versions of balancing tests exist in the literature, the most widely used is the mean absolute standardized bias (MASB) between adopters and non-adopters suggested by Rosenbaum and Rubin (1985), in which they recommend that a standardized difference of greater than 20 per cent should be considered too large and an indicator that the matching process has failed. Additionally, Sianesi (2004) proposed a comparison of the pseudo R2 and p-values of the likelihood ratio test of the joint significance of all the regressors obtained from the Probit analysis before and after matching the samples. After matching, there should be no systematic differences in the distribution of covariates between the two groups. As a result, the pseudo-R2 should be lower and the joint significance of covariates should be rejected (or the p-values of the likelihood ratio should be insignificant). Despite the fact that propensity score matching tries to compare the difference between the farm yield/income variables of adopters and non-adopters with similar inherent characteristics, it cannot correct unobservable bias because propensity score matching only controls for observed variables (to the extent that they are perfectly measured). If there are unobserved variables that simultaneously affect the adoption decision and the farm yield/income variables, a selection or hidden bias problem might arise; to which matching estimators are not robust (Rosenbaum, 2002). This article use endogenous switching regression model to account for hidden bias that affect biofortified beans adoption and production decisions as developed by Laure (2007).

2.3. Theoretical frame work for adoption

The study of improved agricultural technology adoption has received attention of researchers and policy makers expecting that the adoption of agricultural innovation would improve production. A household level adoption study considers the decision made by the household head to include new or improved variety in usual farming practice. The decision made to adopt or otherwise depend on different factors. Farmers' decision to adopt improved varieties is assumed to be the product of a complex preference comparison made by a farm household. To adopt or not to adopt a technology is often a discrete choice. Discrete choice models have widely been used in estimating models that involve discrete economic decision-making processes (Guerrem and Moon, 2004).

The two commonly used discrete choice models in the adoption studies are the probit and logit models. The results from the two models are very similar since the normal and logistic distributions from which the models are derived are very similar except for the fact that the logistic distribution has slightly flatter tails (Gujarati and Porter, 2009). The dependent variable which is normally used with these models is dichotomous in nature, taking the values 1 or 0, a qualitative variable which is incorporated into the regression model as dummy variable. In this case the value 1 indicates a farmer who adopts biofortified bean varieties while the value 0 indicates the farmer who does not adopt.

Adopters of biofortified beans are defined as farmers who planted biofortified beans seed in one of the four agricultural cropping seasons considered (2016 A, 2015 B&A and 2014 B) non-adopters are defined as farmers who did not plant the biofortified bean variety in those seasons.

The other models used to study adoption are the Tobit model and Heckman procedure known as Double-Hurdle models. The Double-Hurdle model and the Tobit model are alternatively used to identify factors which affect adoption and the intensity of adoption (Berhanu and Swinton, 2003; Mignouna *et al.*, 2011; Alene *et al.*, 2000). These two models differ from the above two due to the assumption that factors that affect the farmers' choice of an option should not necessarily be the same as those that affect the intensity of use. This is because the decision to choose a particular maize option is obviously associated with some threshold effects. Hence, only the Probit model was employed in this study as to the taste and convenience of the researcher.

2.4. Conceptual framework

Practical experiences and observations of the reality have shown that, one factor may enhance adoption of one technology in one specific area for certain period of time while it may create hindrance for other locations Tesfaye *et al.* (2001). Because of these reasons, it is difficult to develop a one and unified adoption model in technology adoption process for all specific locations. Hence, the conceptual framework presented in Figure 2.3 shows the most important variables expected to influence the adoption of biofortified beans in Nyagatare district.

The conceptual framework for this study is based on household characteristics, farm characteristics, institutional factors and behavioral factors for determining the determinants which affect the decision to adopt biofortified beans production or otherwise. The adoption would result in good farm yield in adopters which resulted to increase bean farmers' income. The framework is operationalized and demonstrated how various factors inter-relate to influence biofortified beans production and hence the income of producers (Figure 2. 1).

Institutional factors are expected to influence the biofortified bean varieties: The nearness to the market, group membership and extension service are hypothesized to have a positive influence on biofortified beans adoption as far as increasing the production. This is because nearness to the market increases access to inputs. While group membership is expected to help farmers to mitigate problems associated with market imperfections. Access to extension service provides farmers with information on better methods of farming and improved technologies that improve their productivity. With respect to socio-economic characteristics of the farmer, it is hypothesized that age of the farmer negatively affects production efficiency. This is because older farmers are risk averse making them late adopters of better agricultural technologies. Gender of the farmer is also supposed to have a negative relationship because female farmers are faced with more challenges compared to the male farmers in terms of access to information and resources. Schooling is expected to have mixed results since; on the one hand, educated farmers committed in farming may be able to take up improved technologies faster because they understand the benefits associated with the technology, hence increasing the adoption level as well as the increasing their production. On the other hand, educated farmers may be more engaged in other income generating activities and avail less attention to their farms, hence lowering their production. Farm size is also hypothesised to have a positive influence in production, with larger farmers expected to portray economies of scale in their farming operations compared to smaller farms. Behavioral factors like: crop resistance to diseases, flooding and drought, adaptation, nutrients content, seed (color, size, taste, cooking time, shape, maturity period) and the price of biofortified beans on market, are key catalysts of the adoption.

Transaction cost including asset specificity, uncertainty and risks are factors affecting adoption. If biofortified bean, seeds are easily affected by weevils easily, seed rooting, seedlings are easily affected by climate change are affected in a short time, poor storage can reduce the adoption of those beans.

A farm that is technically, allocativelly and economically efficient and the adoption of farmers is high are therefore expected to realize higher bean output per hectare compared to one that is less efficient in production and non-adopters. But on the other hand, such a firm is hypothesised to incur less production costs leading to higher returns from the enterprise. This therefore has positive spillover effects on the income of the biofortified beans production households. Improved income of the households then provides a feedback effect in form of increased access to production inputs and relevant lessons to policy makers.

Independent and dependant variables

By the first objective "Find out the determinants of adoption of biofortified beans" the dependent variables will be the adoption of production of biofortified beans varieties and otherwise, that are determined by the following independent variables: marital status of respondent, household size, sex of household head, education of respondent, age of respondent, trainings, livestock, group membership, gender, experience, farm holding size, bean land size and distance to the nearest market.

The second objective has been analyzed as follow: dependent variable was bean yield explanatory variables: the adoption of biofortified bean or not in every agricultural season considered.

By the 3rd objective: the dependent variable was farmer income determined by amount of money received by farmers from sales of beans while the explanatory variable were the total bean sold considering the total quantity of bean sold on different market available to the farmers and selling price.

The effects of adoption of biofortified beans to the farm yield and farmers' income in those agricultural seasons were determined using propensity score matching.

Table 4. 2: The variables of the study

Independent variables	Intermediate variables	Dependent variables
Demographic characteristics, Farm characteristics and Institution characteristics	Government and NGOs policies Institution support	Adoption of biofortified beans Farm yield Farmers income

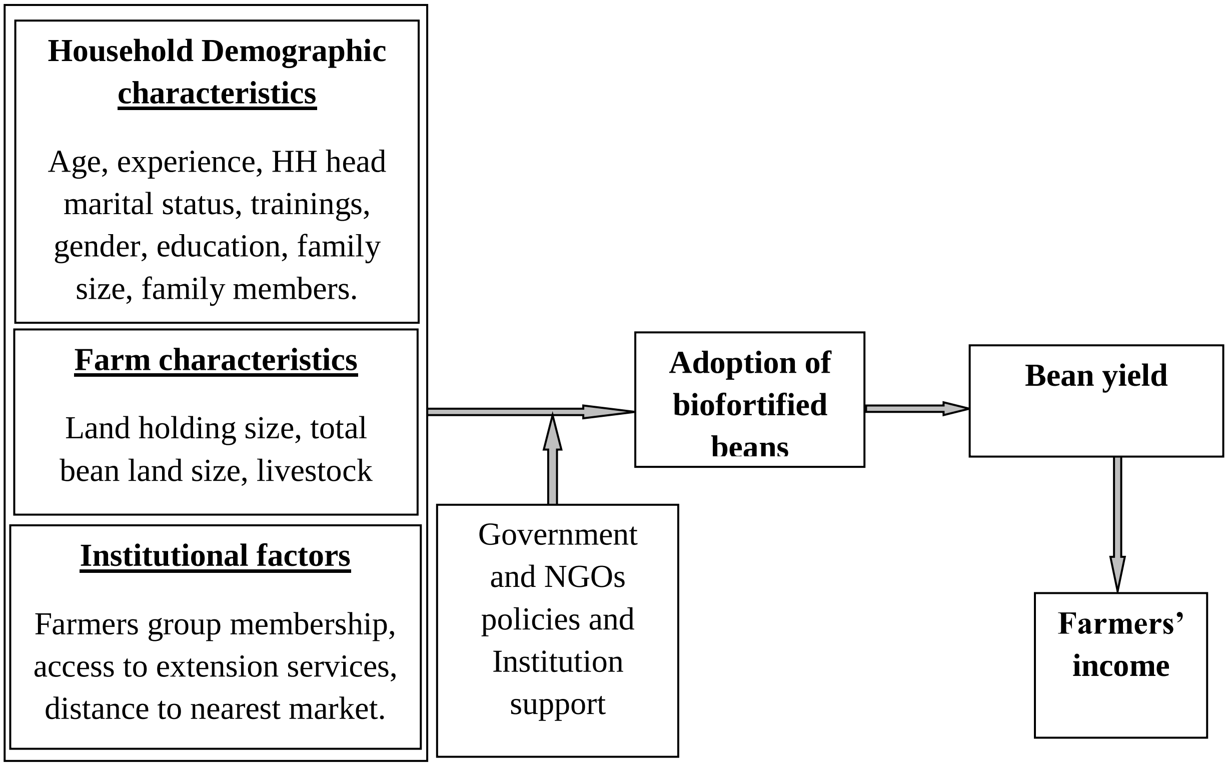

Figure 1: Conceptual frame work of the study

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Study Area

This research was conducted in eastern province of Rwanda in Nyagatare District. Nyagatare district grows bush bean. The targeted groups were: farmer cooperatives growing biofortified beans working with RAB and Harvest plus or not and individual farmers working with/not with RAB or Harvest Plus in the same areas with those cooperatives growing beans.

3.2. Description of the study area

Nyagatare district is the largest and second most populated district in Rwanda. It is located in Eastern Province. Nyagatare occupies the northeastern extremity of Rwanda bordering Uganda in the North, Tanzania in the East, Gatsibo District in the South, and Gicumbi District of the Northern Province in the West. See the map of this district on Figure 3.2. Nyagatare has an area of 1741 km^2 that makes it the largest district in Rwanda. With a population of 466,944 in 2012, Nyagatare is the second most populated district of Rwanda only after Gasabo District of Kigali City with 530,907 inhabitants. This is an 83% increase from 2002 since the population was only 255,104. This sharp rise in the population is due to the major movement of the population from other parts of the country in search of land (MINALOC, 2012).

The District of Nyagatare is characterized, in general, by lowly inclined hills separated by dry valleys for a long period of the year (June–October). The District is located in the granite low valley whose altitude is 1513.5m. This kind of topographical layout constitutes an important potentiality for modern and mechanized agriculture.

Following the government policy in place, and following the agro ecological conditions, beans and maize, have been chosen as priority crops to be grown in Nyagatare, since 2007 (CIP, 2007)

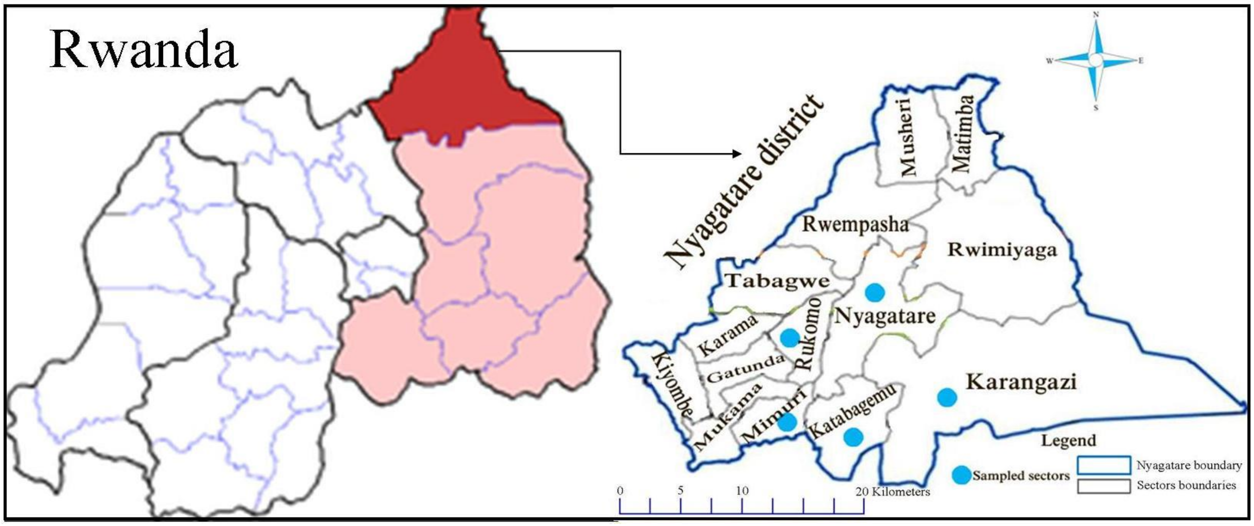

Figure 2: Rwanda and Nyagatare district map
Source: National Institute of Statistics of Rwanda, 2010

The agricultural police in Rwanda is putting in place are geared to shifting from subsistence agriculture to commercial agriculture. For this reason the government prioritized the use of improved varieties and maximizing the use of inputs so as to get as high yield possible. The biofortified beans varieties as improved bean varieties rich in iron and protein are disseminated for the purpose of getting high yield and fighting against malnutrition.

The biofortified bean grown in Nyagatare is the variety named RWR 2245 (Figure 3.3). It is a bush bean variety, grown in low and medium altitude zones, with a yield of 2.5 Mt/ha and is resistant pests and diseases (RAB, 2012). The reason why RAB in partnership with Harvest Plus have made efforts to disseminate this variety in Nyagatare district (Newtimes, 2014).

Figure 3: RWR 2245: Biofortified bean variety disseminated in Nyagatare district

3.3. Sampling design

The population of interest were cooperatives cultivating biofortified bean varieties working with RAB and Harvest Plus or not and individual farmers working/not with RAB or Harvest Plus growing beans in the same areas with those cooperatives in different sectors of Nyagatare district. The sample unity was farmers' household heads. The sample size was derived from a formula by Anderson *et al*. (2008) as follows:

$$n = \frac{z^2 pq}{d^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where n is the minimum sample size; Z is 1.96 at 95% confidence level; P is the population proportion i.e. assume that the proportion of bean producers in the area that is 92%. While **d** is the margin of error (acceptable error) which is assumed to be 0.05 and q is a weighting variable computed as (1-P).

$$n = \frac{\mathbf{1.96^2 \text{ x } (0.85 \text{ x } 0.15)}}{\mathbf{0.05^2}} = \mathbf{195.9} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Accordingly, a minimum sample size calculated is 196 households as shown above, but this has been increased to a total sample size of 197 to minimize the errors in the data.

3.4. Data collection

Primary data have been collected through personal and face-to-face interview using the questionnaire (Appendix). Totally, 197 randomly selected household heads have been covered under the survey in four sectors of Nyagatare district: Karangazi, Katabagemu, Mimuli and Rukomo (Figure 3.1). The interview schedule was first tested at the farm level on 10 randomly selected farm households. Pre-test enabled to know whether farmers would clearly understand the interview schedule. As a result, some unnecessary questions have been deleted but those found important have been incorporated in the final version of the interview schedule.

3.5. Empirical models

3.5.1. Probit model

In this study, farmers who were growing RWR 2245 were considered as adopters while farmers who were not growing biofortified bean variety (RWR 2245) in 2016 A, and growing other varieties not biofortified ones were considered as non-adopters.

The adoption status choice was studied through a binary choice model where it is assumed that the decision of the i^{th} farmer to adopt or not depends on an unobservable variable Ii that is determined by more than one explanatory variable, represented by Xi.

The main models commonly used to analyze factors influencing such binary dependent variables include the Logit and the Probit model (Gujarat and Porter, 2009). Both models are estimated by maximum likelihood and the only difference between the two is that the Logit model assumes a logistic distribution while the Probit assumes the cumulative normal function. The analysis has employed probit binary.

The regression model has illustrated as follows;

$Ii=\beta1+\beta2Xi$………………………………………………..…………………………………. (1)

Where Xi represents a set of independent variables influencing the decision of ith farmer. The unobservable variable Ii is related to the actual decision to adopt Y=1 if the farmer adopter and Y=0 otherwise, such that assuming that the unobservable variable Ii is normally distributed with the similar mean and variance, the probability that the farmer will decide to make any of the above decision can be expressed as:

$Pi=P(Y=1/X)=P(Zi\leq\beta1+\beta2i)\ F(\beta1+\beta2Xi)$…………………………………………….(2)

Where P(Y = 1/ X) is the probability that a farmer will adopt given the values of the explanatory variables and Zi is the standard normal variable. F is the standard normal cumulative distribution function, while β1 is the constant term and β2 is the coefficient to be estimated.

If X represent a vector of determinants of the farmer's decision then the basic form of binomial Probit model with I as the predictor variable is reduced to;

$$Y = \beta o + \beta iX1 + \beta 2X2 \text{..........} \beta jXj + \mathcal{E} \text{……………………………………………}(3)$$

Where βo is the constant term….βj and β1 are the coefficients to be estimated, Ɛ is the error term and X1 and Xj are the explanatory variables.

Thus, the function has been expressed generally as:

Y = f (Marital status of respondent, Household size, Sex of household head, Education of respondent, Age of respondent, human capital investments , group membership, distance to market, gender, experience, farm size, livestock, extension services(trainings), of the farmer to the variety)

The Probit Model was been used for the first objective of "Finding out the factors influencing adoption of biofortified bean varieties"

And the last 2 objectives : "determining the effect of adoption of biofortified beans on bean farm yield" and "determining the effect of adoption of biofortified beans on farmers' income" have been analyzed using propensity score matching.

3.5.2. Propensity score matching

First, a probability model for adoption of biofortified bean varieties is estimated to calculate the probability (or propensity scores) of adoption for each observation. In the second step, each adopter is matched to a non-adopter with similar propensity score values, in order to estimate the average treatment effect for the treated (ATT). Several matching methods have been developed to match adopters with non-adopters of similar propensity scores. Asymptotically, all matching methods should yield the same results. Following Heckman *et al*. (1997), let Y_1 be the value of Farm yield/ Farmer income when the household i is subject to treatment (P =1) and Y_0 be the same variable when it does not adopt biofortified bean variety (P = 0) . The observed biofortified bean yield/ Farmers income is

$$Y = PY_1 + (1 - P)Y_0 \text{ ……………………………………………………..}(1)$$

when (P =1) we observe Y_1 ; when (P = 0) we observe Y_0 The average effect of treatment on the treated (ATT) is defined as

$$ATT = E(Y_1 – Y_0 /P = 1) = E(Y_1 /P = 1) − E(Y_0 /P = 1)……………………….........(2)$$

Therefore, matching estimation assumes counterfactual analysis by matching treatment and control. The primary assumption underlying matching estimators is the Conditional Independence Assumption (CIA) which assumes that the decision to adopt is random conditional on observed covariates X.

In notation, $(Y_1, Y_0) \perp P/ X$……………………………………………………………(3)

The CIA requires that the set of X's should contain all the variables that jointly influence the farm yield/ farmers income indicators with no-treatment as well as the selection into treatment. Under the CIA, ATT can be computed as follows:

$$ATT = E (Y_1 – Y_0) / X, C = 1) = E (Y_1 /X,C = 1) − E(Y_0 /X,C = 1)………………….(4)$$

where Y_1 is treated farm yield/farmers income, Y_0 is untreated farm yield/farmers income, C indicates treatment status and is equal to 1 if the individual receives treatment and 0 otherwise. Matching the adopters based on observed covariates might not be desirable or difficult to match when the set of covariates are large. In order to reduce curse of dimensionality, Rosenbaum and Rubin (1983) suggested instead of matching along X, one can match along P(X), a single index variable that summarizes covariates. This index is known as propensity score (response probability). It is the conditional probability that the households i participate given covariates:

$P(X) = Pr (P = 1) / X$……………………………………………………………………….(5)

The ATT in equation (4) can then be written as

$ATT = E (Y_1 / P (X), P = 1) – E (Y_0 /P(X), P = 1$…………………………………………….(6)

More specifically, the ATT is the difference between two terms with the first term being the farm yield/income indicator for the treated group which is observable and the second term being the farm yield/income indicator for the treated group had it not been treated, representing a counterfactual situation which is unobservable and needs to be treated.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Descriptive results

4.1.1 Household demographic characteristics

Characteristics like age, gender, family size and education level of the household heads are very important proxy indicators for individual behaviors and are commonly used as explanatory variables for adoption decisions. This section deals with these variables.

The selected sample consisted of 197 of which 107 (54.31%) have been adopted the cultivation of biofortified beans and 90(45.69%) non-adopters as it is described in Table 4. 3.

Table 4. 3: Adoption of biofortified beans in sampled farmers

Full		**Adopters**		**Non-adopters**	
No	**%**	**No**	**%**	**No**	**%**
197	**100**	107	54.31	90	45.69

The sampled people were all bean growers and household heads. Among adopters group, 53(58.1%) were male and 53(51.0%) were female. While in non-adopters group 39(41.9%) were male and 54(49.0%) were female. The analysis has shown that there was no statistical significant difference (P =0.318) between gender in adopting the biofortified beans. Meaning that to be a male or female has no influence to the decision to adopt or not. Among the interviewed farmers 13 were single, 140 were married and 44 were widowed; 100% single were adopters, 140(71%) married; 85 (60.7%) were adopters and 55 (39.3%) were not, among 44 widowed; 9(20.4%) were adopters and 35(79.6%) were not. It is seen that the marital status has influenced the adoption of biofortified beans at confidence level of 95% with P<0.001. See Table 4. 4.

Table 4. 4: Household personal and demographic Characteristics of Adopters and non-adopters (summary statistics variables)

Variable	Category	Total No	%	Adopters No	%	Non-adopters No	%	t- test P-value
Household head's gender	Male	93	47.2	54	58.1	39	41.9	0.9966
	Female	104	52.8	53	51	51.0	49.0	0.318
Household head's marital status	Single	13	6.6	13	100.0	0	0.0	6.1584
	Married	140	71.07	85	60.7	55	39.3	<0.001*
	Widowed	44	22.33	9	20.4	35	79.6	

N=197, *, significant at 5% of level of significance

As it is indicated in Table 4. 5, the mean age of all the sampled farmers was 39.03 years, with the mean age for adopters and non-adopters farmers being 36.72 and 41.77 years respectively. It is thus evident that adopters' farmers had a higher prime age than non-adopters farmers. Similarly, t-tests were significant at 5% level, which revealed that adopters' farmers had a significantly lower mean age than non-adopters farmers.

Table 4. 5: Household personal and demographic characteristics of adopters and non-adopters (summary statistics variables)

Variable	Unit	Pooled		Adopters		Non-adopters		t-value
		Mean	SD	Mean	SD	Mean	SD	P-value
Household head's age	Years	39.03	8.32	36.72	8.14	41.77	7.719	4.4384 <0.001*
Household head's education	Years	6.52	2.84	7.16	2.43	5.75	3.11	-3.5736 0.0002*
Family Size of household	Heads	4.82	1.90	4.47	2.00	5.24	1.70	2.8677 0.0023*
Household member under 16 years	Heads	1.62	1.08	1.62	1.25	1.62	0.82	-0.0023 0.4898
Household members between 16-65 years	Heads	3.28	1.44	3.00	1.41	3.62	1.40	3.0372 0.0014*
Household members above 65 years	Heads	0	0	0		0 0	0	

*, significant at 5% of level of significance

It was observed that the mean total household size was 4.82 members, where 4.47 and 5.24 members of adopters and non-adopters groups respectively at P<0.001 with statistical difference among groups at 5% of level. The mean of members between 16 and 65 years old were 3.6 and 3.0 in adopters and non-adopters group respectively with statistical significant difference (P=0.0014). See Table 4. 4. The results further showed that majority of the sampled farmers acquired only 6 years of formal education. The mean age for adopters group were 7 years while for non-adopters group were 5 years of school. Those ages have been recorded considering the total number of years in school from first year of primary. The results showed a significant difference with P= 0.001 at 95% degree of confidence. See Table 4. 5.

4.1.2 Farm characteristics

Total land holding and Total bean areas

The results in Table 4. 6 presented, the mean of land holding were 2.59 ha and 0.84 ha for adopters and non adopters respectively. It was statistically significant at 5% of level with P=0.0006, which means that the bigger the land, the more the adoption of growing biofortified beans increases. The mean total bean size were 4.03 ha and 1.19 ha for adopters and non-adopters respectively. The total bean farm size becomes bigger than the total land holding because some farmers lease some land to grow beans. Also the mean total bean areas showed significant statistical difference at 5% of level with P<0.001, which means that the average for bean cultivation areas of adopters group were significantly greater than non-adopters.

Livestock

As it is described in Table 4. 6, the mean of livestock were 9.18 and 5.58 of adopters and non adopters respectively. It is statistically significant of P=0.0139 at 5% of level. Livestock is a source of income and farm yard manure for use in growing crops including beans. This significance shows that more the livestock, the more the adoption increases.

Table 4. 6: farm characteristics of biofortified beans adopters and non-adopters (summary statistics variables)

Variable	Unit	Pooled		Adopters		Non-adopters		t-test
		Mean	SD	Mean	SD	Mean	SD	P-value
Livestock	Number	7.54	11.46	9.18	12.43	5.58	9.90	-8.7342 0.0139*
Land holding	Hectare	1.79	3.77	2.59	4.39	0.84	2.58	-3.3127 0.0006*
Total land bean areas	Hectare	2.73	3.78	4.03	4.51	1.19	1.67	-5.6502 <0.001*

*, significant at 5% of level of significance

4.1.3. Institutional factors

Farmers' group membership

It was found that 90 (97.8%) adopters were member of farmers group (cooperative) and 17 (16.2%) were not in farmers group while 2 (2.2%) non adopters were in cooperative and 88 (83.8%) were no in cooperatives with a strong statistical significant of P<0.001 at 95%. As indicated in Table 4. 7, participate in farmers group has influenced the decision to adopt to grow biofortified beans. Meaning that farmers group help farmers to gain information and extension services easily.

Table 4. 7: Institutional characteristics of biofortified beans adopters and non-adopters

Variable	Unit	Pooled		Adopters		Non-adopters		P-value
		Mean	SD	Mean	SD	Mean	SD	
Extension services (trainings)	No	1.40	2.22	2.47	2.47	0.12	0.70	<0.001*
Distance to the nearest market	Minutes	51.77	34.89	51.77	36.37	51.77	33.26	0.0004 0.4998
Variable	**Category**	**Total**		**Adopters**		**Non-adopters**		**t- test**
		No	**%**	**No**	**%**	**No**	**%**	**P-value**
Farmers group	Yes	92	46.7	90	97.8	2	2.2	19.8308
membership	No	105	53.3	17	16.2	88	83.8	<0.001*

*, significant at 5% of level of significance

The distance between household resident and the nearest market

The results in Table 4. 7 present findings and, the mean distance to the nearest market by walking were 51 minutes for both adopters and non-adopters. They were no statistical significant difference between the two groups as the sample design was to consider the neighboring adopters and non-adopters. The analysis showed P=1.000 at 5% of level.

Extension services

The Extension services have been measured by counting different training on bean value chain gained by farmers. The results shows that the mean of training gained were 2.47 and 0.12 by adopters and non-adopters respectively (Table 4. 7). It was statistical significant difference with P<0.001 at 5% of level. This significance difference is the same as found by Pattanayak *et al*. (2003) who argued that as long as farmers exposed to information about new technologies by extension agents (through training, group discussion, plots demonstration, and other form of information delivery) tend to adopt new technologies.

Factors influencing adoption of biofortified beans

As shown in Table 4. 8, the analysis of Probit model of significant factors influencing biofortified bean adoption among adopters and non adopters only, family members hold between 16 and 65 of years old, farmers group membership, extension serves measured by trainings gained by bean farmers, total land bean size and total land holding are significant with P values 0.0015, <0.001, 0.0354, 0.0032 and 0.0202 respectively at 5% of level on adoption of biofortified beans. Farmers' membership has influence the adoption of biofortified beans. It means that, as far as farmers are not in farmers' group, the adoption decreases and vice-versa. Also considering the government policy in place, in many rural areas of Rwanda, farmers are sensitized to be organized through in which, different agriculture information are given to the farmers (CIP, 2007).

The total land holding size influences adoption and it has influence on adoption of biofortified bean variety in Nyagatare district which due to that the policy in place regarding to land consolidation and growing one chosen crop (CIP, 2007).

Table 4. 8: Maximum Likelihood estimates for factors affecting biofortified beans adoption

Variables	Coef.	Std. Err.	P>|z|
Household head's gender	1.5937	0.7372	0.1306
Household head's age	0.0301	0.0259	0.2438
Household head's marital status	0.1876	0.3007	0.5328
Household family size (heads)	0.4238	0.2475	0.0869
Family members between 16-65 age	-1.0719	0.3369	0.0015*
Farmers'group membership	-0.7616	0.1889	0.001*
Extension services (trainings)	1.8654	0.4913	<0.0001*
Household head's education (years)	-0.1103	0.0752	0.1425
Total livestock in the household	-0.0579	0.0275	0.0354*
Distance to the nearest market	0.0031	0.0062	0.6229
Total land holding	-0.5495	0.1865	0.0032*
Total bean size	0.6584	0.2835	0.0202*
Probit regression	Log likelihood = -20.93534		
Number of observation: 197	Wald chi2(12) = 44.93		
	Prob > chi2 = 0.0000		

*, significant at 5% level of significance

The findings also implies that extension service as a source of information regarding biofortified beans has a positive influence on the farmers' adoption decision as Alene *et al*. (2000) have stated that extension services are among the prime movers of the agricultural sector and have been considered as major means of technology dissemination.

These figures show that the difference in livestock ownership between adopters and non-adopters was statistically significant which imply that having large number of livestock is correlated with adopting biofortified bean in Nyagatare district. Similar results were reported by Mulugeta (2009) that livestock ownership affects farmers in adopting old coffee stumping technology in dale woreda, Ethiopia. This implies that possession of large number of livestock served as a proxy for the capacity of bearing risks in using credit. Livestock may also serve as a proxy for oxen ownership, which could be important for farm operations of small holder farmers.

Total land holding has positive influence on biofortified beans which means as far as you hold a big land, the adoption of biofortified beans increases. This confirms the output from the government policy in place on land consolidation and cultivates one chosen crop (CIP, 2007)

4.2. The effect of adoption of biofortified beans on bean farm yield

4.2.1 Effect of biofortified beans adoption on bean farm yield for season A, 2016

In agriculture season 2016 A, the sampled farmers 197, only 102 have grown beans where adopters were 52 and non adopters were 50. The average yield in adopters group was 1527.059 kg ha^{-1} while in non adopters group, the average yield was 840.4444 kg ha^{1}. The analysis showed a statistical significant difference between those two groups with P <0.001 at 95% of confidence level This means, the farmers who have grown the biofortified bean variety (RWR 2245) obtained high yield than the farmers grown non biofortified bean varieties. This also shows that the average yield of bean has increased in this 2016 A agriculture season compared to the low yield published by NISR (2013) where the average bean yield was 731.4 kg ha^{-1} for bush bean in 2013 B. See Table 4. 9.

With the percentage of bean yield increase of 80%, the analysis from propensity score matching has shown the ATT (ATET) were 673.4913 kg ha^{-1} while the ATE was 660.2295 kg ha^{-1}. This means that the adopters were better of getting 660.2295 kg ha^{-1} more than non-adopters while the average treatment effect on treated were 673.4913 kg ha^{-1}, and they were statistical significant with P<0.001 at 5% of level. See Table 4. 10.

4.1.2 Effect of biofortified beans adoption on bean farm yield for season B, 2015

As it is shown in the Table 4. 9, In agriculture season B 2015, beans have been grown by 196 farmers in 197 sample size meaning that only one farmer did not grow beans in sampled population with 106 and 90 adopters and non-adopters respectively.

The average yield in adopters group was 1440.247 kg/ ha while in non adopters group, the average yield was 825.4918 kg ha^{-1} with the 75% of yield increase between adopters and non-adopters. The statistical significant of P<0.001 at 95% of confidence level between adopters and non adopters, was realized (Table 4. 9). The ATT and ATE were 620.2469 kg $ha^{-1}$and 621.0001 kg ha^{-1} surplus in yield between adopters and non-adopters. See Table 4. 10. This yield is also higher than that published by NISR (2013). But it has not yet reached the potential yield of 2Mt presented by Harvest Plus. Where the potential yield between 2000 to 2500 kg/ha for biofortified bean can be realized (Lister K., 2012 and RAB, 2012)

Table 4. 9: Effect of adoption of Biofortified beans on adopters and non-adopters' bean farm yield in 4 agriculture seasons (Analysis of t test with equal variances)

Season	Pooled		Adopters		Non-adopters		Diff		t-test
	Obs	Mean (Kg ha^{-1})	Obs	Mean (Kg ha^{-1})	Obs	Mean (Kg ha^{-1})	Mean (Kg ha^{-1})	%	P-value
2016 A	102	1190.483	52	1527.059	50	840.4444	686.6142	80	8.9858 <0.001*
2015 B	196	1157.962	106	1440.247	90	825.4918	614.7556	75	14.450 <0.001*
2015 A	99	1224.811	47	1661.363	52	830.235	831.1277	100	13.032 <0.001*
2014 B	197	621.672	99	814.4494	98	426.9274	387.522	91	3.3686 0.0005*

*, significant at 5% of level

Table 4. 10: Estimation of treatment effect analysis based on matching algorithms on farmers bean yield (the surplus of yield in favor of adopters against non-adopters)

Season	Surplus	AI Robust						
		Obs	Coef.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
2016 A	ATET	102	673.4913	81.12328	8.30	0.000	514.4925	832.49
	ATE	102	660.2295	83.02714	7.95	0.000	497.4993	822.9597
2015 B	ATET	196	620.2469	40.71277	15.23	0.000	540.4513	700.0425
	ATE	196	621.0001	40.94257	15.17	0.000	540.7541	701.2461
2015 A	ATET	99	809.7473	66.92813	12.10	0.000	678.5705	940.924
	ATE	99	799.7833	66.40426	12.04	0.000	669.6334	929.9333
2014 B	ATET	197	397.7493	116.0828	3.43	0.001	170.2312	625.2674
	ATE	197	367.4302	111.1734	3.31	0.001	149.5344	585.326

Estimator: Propensity-Score Matching   Treatment model: Probit   Number of matches (m) = (5)

4.1.3 Effect of biofortified beans adoption on bean farm yield for agriculture season 2015 A

For 2015 A, only 98 farmers in the sample of 197 farmers have grown beans with 47 and 52 of adopters and non-adopters respectively. The average yield of 1609.748 and 831.0185 kg/ha has been realized among adopters and non-adopters respectively. See Table 4. 8. The ATET and ATE were 809.7473 kg $ha^{-1}$and 799.7833 kg ha^{-1}respectively. Thus, the farmers' adopters have benefited more yield than non-adopters. The P value was less than 0.001 at confidence interval of 95%. It was found that the RWR 2245 growers have more yield than those farmers growing non biofortified ones with double increased yield between adopters and non-adopters (100%). See Table 4. 9. This yield found is greater than that published by NISR (2013). However, it has not yet reached the potential yield of 2Mt presented by Harvest Plus. Where the potential yield between 2000 to 2500 kg/ha for biofortified bean can be realized (Lister K., 2012 and RAB, 2012. See the Table 4. 9 and 10.

4.1.4 Effect of biofortified beans adoption on bean farm yield for season 2014 B

In 2014 B, both sampled farmers have grown beans with 90 and 107 adopters and non-adopters respectively. The average yield of adopters was 1088.993 kg ha^{-1} while it was 732.6473 kg ha^{-1} for non-adopters. There was statistical significant difference among both groups with $P<0.001$ where the ATET and ATE were 397.7493 kg ha^{-1} and 367.4302 kg ha^{-1} respectively. It means that even if the mean yields are low compared to the previous season, the adopters' farmers benefited more. This yield of 732.6473 kg ha^{-1} from non adopters group is similar to the average yield of 731.4 kg ha^{-1} published by NISR, 2013 B. See the Table 4.s 9 and 10.

The yields found in both seasons, were high in adopters groups more than non adopters with the percentage increase of 91%. This yield increase in adopters group is in accordance with the findings by Gichangi, *et al*. (2012) conducted a research on Assessment of Production and Marketing of Climbing Beans by Smallholder Farmers in Nyanza Region, Kenya, said that, the level of adoption of improved variety influence the amount of yield obtained. This justify the hypothesis, that we reject Ho saying that the adoption of biofortified beans has no effect on bean farm yield and accept the H1 that adoption of biofortified beans has effect on the bean farm yield.

4.3. The effect of adoption of biofortified beans on adopters and non-adopters' income

4.3.1 The effect of adoption of biofortified beans on bean price

This effect was determined based on the quantity of bean produced, the quantity of bean sold and the price of bean in different selling areas. Some famers have sold their bean yield directly at Harvest Plus, at cooperatives, at nearest market and at the nearest business center. The mean price was determined by the total amount of money received from sales of bean divided by the total quantity of bean sold in different kind of market season by season. The results found showed that, in 2016 A, 2015 B, 2015 A and 2014 B the average price received by farmers adopters from sales of biofortified beans were 488.1223 RWF/kg, 486.5092 Rwandan Francs (RWF)/kg, 491.5155 RWF/kg and 388.7595 RWF/kg respectively. Those prices of beans in last 3 seasons were in the same range and differed from the price of beans the first season. This means in 2014 B, farmers adopters growing biofortified beans as they did before getting them. With time they realized the better biofortified beans so thous the prices increased. See Table 4. 11. In the group of non adopters, the prices of bean production in 2016 A, 2015 B, 2015 A and 2014 B were 295 RWF/kg, 295.7906 RWF/kg, 298 RWF/kg and 285.0924 RWF/kg respectively. The variability of the price of bean was not big. A small change was caused by the change of weather and the availability of beans on market. As it is observed the price of biofortified bean is higher than other bean varieties grown in Nyangatare District. See the Table 4. 10.

Table 4. 11: Effect of adoption of Biofortified beans on price of bean (analysis of t test with equal variances)

Season	Unit	Pooled		Adopters		Non-adopters		Diff	t test
		Obs	Mean	Obs	Mean	Obs	Mean		P-value
2016 A	Rwandan francs	102	367.7102	52	487.1721	38	207.3798	279.7923	23.754 <0.001*
2015 B	Rwandan francs	196	406.0054	106	487.1069	90	295.7906	191.3163	43.207 <0.001*
2015 A	Rwandan francs	81	407.8977	46	491.5155	35	298	193.5155	38.819 <0.001*
2014 B	Rwandan francs	175	343.8556	99	388.9668	76	285.0924	103.8744	5.767 <0.001*

*, significant at 5% of level of significance

4.3.2. The effect of adoption of biofortified beans on adopters and non-adopters' income

The amount of money received from sales of beans depended on the quantity of bean harvested, the quantity sold and availability of market. The mean income observed from money earned from sales of bean in adopters group, in 2016 A, 2015 B, 2015 A and 2014 B were 689462.8 RWF, 644919.4 RWF, 741714.3 RWF and 431959.8 RWF respectively. While the means income in non-adoption group in 2016 A, 2015 B, 2015 A and 2014 B were 39454 RWF, 52710.11 RWF, 37090.38 RWF and 58668.04 RWF respectively. The ATET and ATE which measure the surplus of money in favor of adopters, were 820847.5 and 701218 Rwandan francs respectively in 2016 A, 1,153,805 and 1,150,131 RWF respectively in 2015 B, 996919.9 and 834456.4 RWF respectively in 2015 A and 730460.5 and 722503.1 RWF. See Table 4. 12. The analysis showed a statistical significance among the two groups with P<0.001 at 95% level of significant. This leads us to reject null hypothesis (Ho) that states that adoption of biofortified beans does not increase farmers' income. Those are very big difference between money earned among those two groups (see the graphs, 2 to 5) as they describe the location of income earned by the total bean yield sold.

Table 4. 12: Effect of adoption of Biofortified beans on farmers' income (analysis of t test with equal variances from sales of bean)

Season	Unit	Pooled		Adopters		Non-adopters		Diff	t test
		Obs	Mean	Obs	Mean	Obs	Mean		P-value
2016 A	Rwandan francs	102	442783.8	52	844822.1	50	24664	820158.1	6.0885 <0.001
2015 B	Rwandan francs	196	675433.4	106	1204658	90	52124.44	1152534	6.5391 <0.001
2015 A	Rwandan francs	81	514310.1	46	1042298	35	37090.38	733876.9	6.0730 <0.001
2014 B	Rwandan francs	197	440441.9	99	805517.7	98	71640.82	733876.9	5.3963 <0.001

*, significant at 5% level of significance

4.3.3 Overlapping assumption checking, income in both four seasons

As it is described in Table 4. 12, there is a very big difference between the means of income between the two groups. That is the reason why the test of the effect of adoption of biofortified bean to the income of the groups using propensity score matching, have been overlapped due to backyard farmers (that have less than 100 ms of farm, that to be matched with those hold big land is impossible). This is because, the non-adopters group produced on small scale land, get less yield, sold very low quantity on the low price, all of those resulted in the very big difference of income earned compared to adopters group. This caused the overlapping of the income analysis. See Fugure 4, 5, 6 and 7 generated by propensity score matching analysis in every single season.

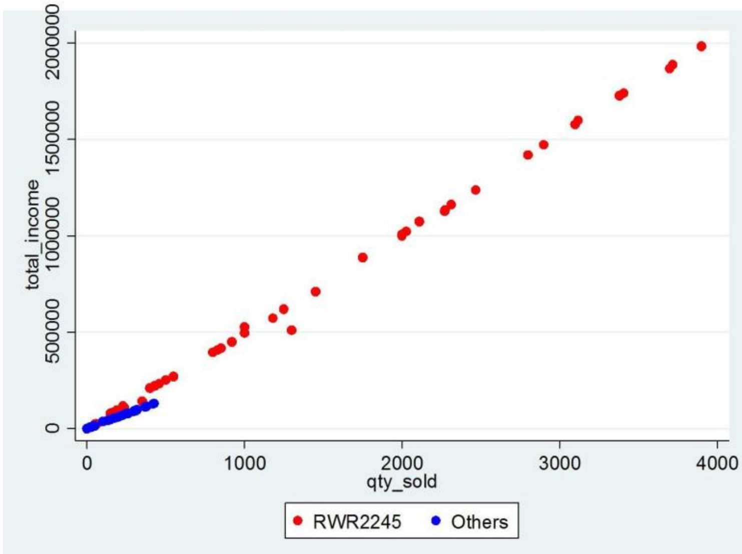

Figure 4: The distribution of income gained from sale of beans in 2016 A

RWR2245: Biofortified bean variety grown in Nyagatare. **qty_sold**: quantity (kg) of bean sold in 2016A. **total_income:** total money (Rwandan francs) earned from sales of bean in 2016 A

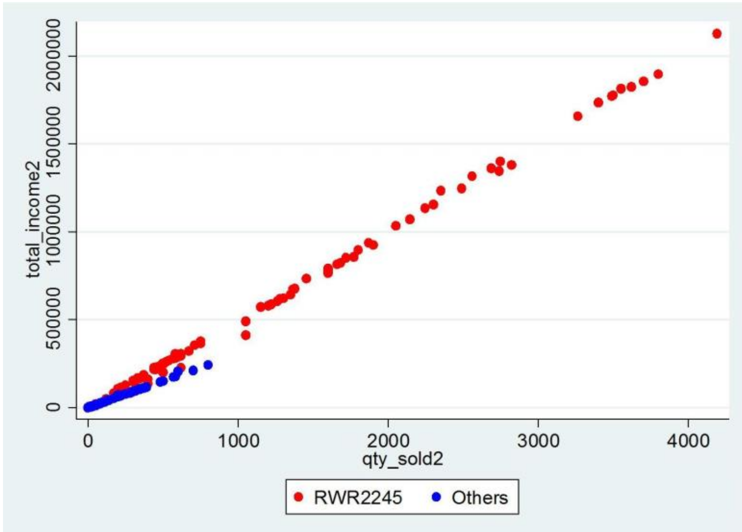

Figure 5: The distribution of income gained from sale of beans in 2015 B

RWR2245: Biofertified bean variety grown in Nyagatare. **qty_sold2**: quantity (kg) of bean sold in 2015 B. **total_income2:** total money (Rwandan francs) earned from sales of bean in 2015 B

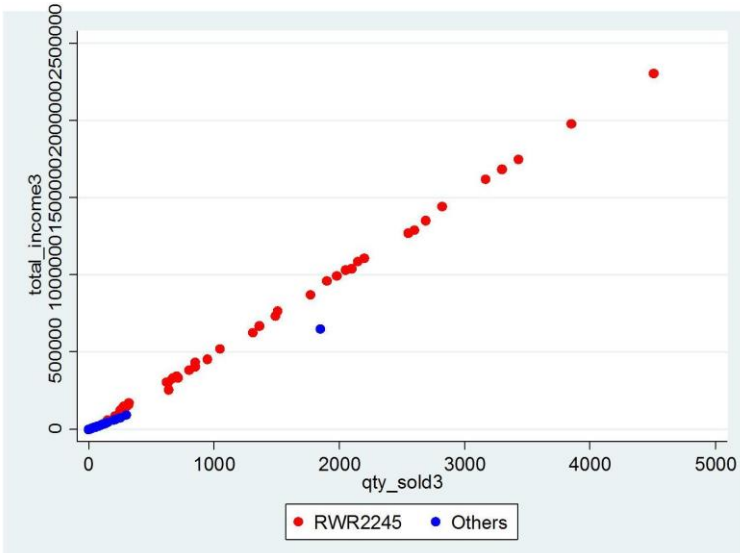

Figure 6: The **distribution** of income gained from sale of beans in 2015 A

RWR2245: Biofertified bean variety grown in Nyagatare. **qty_sold3**: quantity (kg) of bean sold in 2015 A. **total_income3:** total money (Rwandan francs) earned from sales of bean in 2015 A

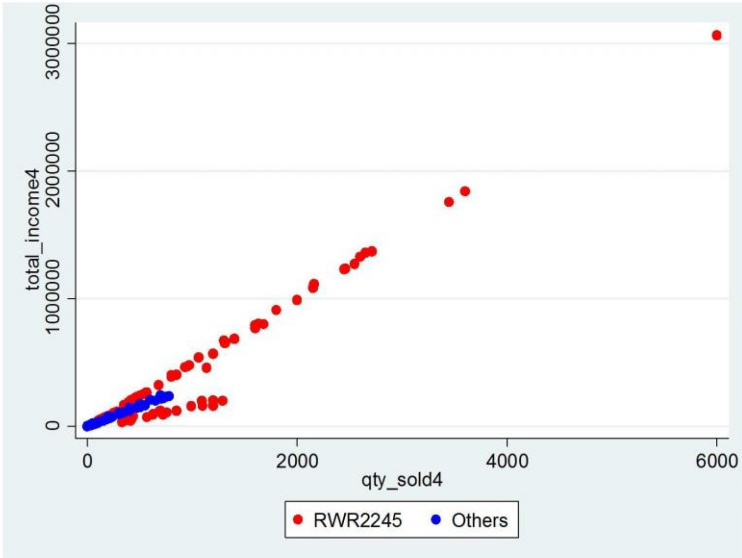

Figure 7: The distribution of income gained from sale of beans in 2014 B

RWR2245: Biofertified bean variety grown in Nyagatare. **qty_sold4**: quantity (kg) of bean sold in 2014 B. **total_income4:** total money (Rwandan Francs) earned from sales of bean in 2014 B

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

The aim of this study was to determine the effect of biofortified beans adotion to the the socio-economic warfare on farmers in eastern Rwanda in Nyagatare district. The first objective was to find out the factors inlua=ence=ing the adoption of biofortified beans. The second objective was to determine the effect of biofortified beans to the farmers bean yield and the last was to determine the effect of biofortified beans on farmers' income.

The study was conducted in Katabagemu, Karangazi, Mimuri, Nyagatare and Rukomo sectors of Nyagatare district. The sample size was 197 household bean farmers selected using a multi-stage sampling technique. For the data collection, a personally administered structured questionnaire was used to conduct interviews, with a focus on household heads. Probit model was employed to find out the factors influencing adoption of biofortified beans, and Propensity Score Matching to determine the effect of biofrtified beans on bean farm yield and then income. The analysis of factors influencing biofortified beans adoption has shown that farmers' group membership, livestock holdings, agricultural extension services, total land holdings and total land bean size have statistically significant influenced biofortified beans production at 95% level of significance with P=0.001; <0.0001; 0.0032; 0.0202 respectively.

The determination of the effect of biofortified beans adoption on bean farm yield with descriptive statistics and PSM has been done in four successive agricultural cropping seasons; 2016A, 2015B, 2015A and 2014B. In 2016A, the average bean yield was 1527.059 kg ha^{-1} and 840.444 kg ha^{-1} in biofortified beans adopters group and non adopters group respectively with ATT= 673.49 and the increase of 80%. In 2015B, the average bean yield 1440.247 kg ha^{-1} and 825.49 kg ha^{-1} in adopters group and non adopters group respectively with ATT=620.24 and the increase of 75%. In 2015A, the average bean farm yield was 166.363 kg ha^{-1} and 830.23 kg ha^{-1} in adopters group and non adopters group respectively with ATT=809.74 and the increase of 100%. While in 2014 B, the average bean farm yield was 814.44 kg ha^{-1} and 426.92 kg ha^{-1} in adopters group and non-adopters group respectively with ATT=397.74 and the increase of 91%.

The determination of the effect of biofortified beans adoption on farmers income from sells of bean with descriptive statistics and PSM has been done in four successive agricultural cropping seasons; 2016A, 2015B, 2015A and 2014B. In 2016A, the average income was 844,822 RWF and 24,664 RWF in biofortified beans adopters group and non adopters group respectively. In 2015B, the average income was 1,204,658 RWF and 52,124 RWF in adopters group and non-adopters group respectively. In 2015A, the average income was 1,042,298 RWF and 37,090 in adopters group and non-adopters group respectively. While in 2014 B, the average bean farm yield was 805,517 RWF and 71,640 RWF in adopters group and non-adopters group respectively. It has observed a very big difference of the income earned from the sales of bean between adopters and non- adopters which caused the overlap the analysis of the effect using PSM. This is due to the backyard farmers found in non -adopters group who produced on small scale land, get less yield, sold very low quantity on very low price, resulting to very big difference of income earned between two groups.

5.2. Conclusion

The aim of this study was to determine the factors affecting biofortified bean varieties in Nyagatare district in Rwanda. It was based first on finding out the factors influencing adoption of biofortified beans, and then determining the effect of adoption of biofortified beans on bean farm yield while determining the effect of increased yield on farmers' income.

The results from data analyzed using probit model has shown that farmers' group membership, livestock holdings, agricultural extension services, total land holdings and total land bean size have statistically significant influenced biofortified beans production at 95% level of significance.

The mean yield in different four seasons considered 2016 A, 2015 B, 2015 A and 2014 B have been shown the statistical significant difference between adopters and non-adopters with significant average total effect at 95%. The mean yield in all four seasons in this study was found to be 86% for the yield increase in adopters.

The analysis has shown that the price of biofortified beans were high in each four agricultural seasons comparing to the price of indigenous beans. With propensity score matching, the average total effect between the farm bean productivity was statistical significant among adopters and non-adopters at 95% of level, and also the effect of income from sales of beans, was statistical significant among adopters and non-adopters at 95% of level.

5.3. Recommendation

In view of the major findings and the above conclusions, the following recommendations are drawn: farmers are encouraged to form farmers associations so that to access extension services regarding to the best practices of growing biofortified beans properly. Farmers are also advised to increase the size of land on which they grow biofortified beans, to consolidate their small pieces of land to bigger parcels for enhanced biofortified beans cultivation. The government and NGOs to sensitize, create awareness, facilitate the access and mobilize farmers to adopt the biofortified beans so that farmers can improve their agricultural productivity and incomes.

5.4. Areas for further research

This study has found out the factors which affect the adoption of biofortified beans in the study area. However, it didn’t analyze the cost of production of biofortified beans in the study area. Thus, further studies are recommended to analyze the cost of production of biofortified bean varieties so that to make the cost benefit analysis of biofortified beans in the study area.

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APPENDIX

Questionnaire

Aimable Nsengiyumva

The questionnaire for Thesis from

Jomo Kenyata University of Agriculture and Technology (JKUAT)

Date: ______________________________

Questionnaire No: ________________________

Name of respondent: _________________________

Contact____

District: ____

Sector: _________________________________

Dear sir/madam! I am Aimable Nsengiyumva a student in Master of Science in Agriculture Science and Applied Economics, at JKUAT-Kigali Campus**)** doing research on Impact of adoption of Biofortified bean on farmers income.

You are one of the chosen few to assist in filling this questionnaire and this work is voluntary. Your every response to this academic contribution will be treated with confidentiality.

The research is purely for academic purposes.

Thank you for accepting to fill this questionnaire

Yours faithfully

Aimable Nsengiyumva

Tel: 0788640019/0722640019

Mode of Responding: Use one tick or more than one tick where appropriate to respondent to the questions.

A. General information

1. Demographic characteristics of Respondents

Sex of respondent:

0. Male ☐

1. Female ☐

2. Age of respondent? ________________________

Marital status of respondents:

0. Single ☐ 1. Married ☐ 2. Divorced ☐ 3. Widowed ☐

2. House hold size

2.1. What is the total number of house hold members do you have? ________________

2.2. Out of the total number of house hold? ________________

2.3. How many are below 16 years old? ____________________

2.4. How many are between 16-65 years old? _____________

2.5. How many are above 65 years old? ________________

3. Education background

3.1. How many years have you spent in school_________________?

4. Location characteristics

4.1. What distance is your house to the nearest road in walking minutes? __________

4.2. What distance is your house to the nearest market in walking minutes? ___________

4.3. What distance is your house to the nearest financial institution in walking minutes? ______

5. Farm characteristics

5.1. What is the total area (all plots) your household hold (ha)? __________________

5.2 What is the proportion of land in ha used for farming? ______________________

5.3. What is the total areas cultivated bean (in ha) in the season 2014 B? __________________

5.4. What is the total areas cultivated bean (in ha) in the season 2015 A? ___________________

5.5. What is the total areas cultivated bean (in ha) in the season 2015 B?______________________

5.6. What is the total areas cultivated bean (in ha) in the season 2016 A?______________________

5.7. What distance is your household to farm in walking minutes? __________________

6. Biofortified bean adoption History (Showing the sample)

6.1. Have you ever seen or heard of this variety? (Showing the variety): Yes _____ No______

6.2. How many years have you been growing this variety (Showing the variety)? _____________

6.3. What quantity of planting material did you plant in your first growing season? ____________

6.4. Do you current grow this variety? Yes ☐ No ☐

7. Social capital

7.1. Are you a member of the farmers group (association or cooperative)?

0. Farmers' association ☐ 1. Farmers' Cooperative ☐ 2. Savings' group ☐

3. Religious group ☐

7.2. Are you an active member, inactive member or not a member of the following types of organizations? Tick one

0. Non active member ☐ 1. Active member ☐ 2. in Management ☐

7.2. In a typical month how often do you meet? __________________

8. Specific human investment

8.1. How many trainings have you received on the following?

Fill with the number of the institution

Skills	Number of trainings
Farm management	
Breeding	
Disease management	
Farm records	
Use of inputs	
Use of improved seeds	
Access to services	
Market accessibility	

9. Bean Production (in previous 4 seasons)

Bean Production	**Ticking**	
Did you cultivate beans in the following seasons?		
Season A 2016		
Bean area cultivated		
Quantity of Seed cultivate		
How much did you spend on planting material in total		
What variety did you planted?		
What quantity did you harvest?		
Is this variety biofortified bean varieties (Showing samples)	No	Yes
What quantity did you consume?		
What quantity did you sell?		
At what Price / kg?		
What quantity did you save as seeds for next season?		
Season B 2015		

Bean area cultivated		
Quantity of Seed cultivate		
How much did you spend on planting material in total		
What variety did you planted?		
What quantity did you harvest?		
Is this variety biofortified bean varieties (Showing samples)	Yes	No
What quantity did you consumed?		
What quantity did you sold?		
At what Price / kg?		
What quantity did you saved as seeds for the next season?		
Season A 2015		
Bean area cultivated		
Quantity of Seed cultivate		
How much did you spend on planting material in total		
What variety did you planted?		
What quantity did you harvest?		
Is this variety biofortified bean varieties (Showing samples)	Yes	No
What quantity did you consumed?		
What quantity did you sold?		
At what Price / kg?		
What quantity did you saved as seeds for the next season?		
Bean area cultivated		
Season B 2014		
Bean area cultivated		
Quantity of Seed cultivate		
What variety did you planted?		
How much did you spend on planting material in total		
What quantity did you harvest?		
Is this variety biofortified bean varieties (Showing samples)	Yes	No
What quantity did you consumed?		

What quantity did you sold?	
At what Price / kg?	
What quantity did you saved as seeds for next season?	

10. Marketing transaction

Season	Quantity produced in kg/tones	Sold					Given as Gift
		Sold at farm gate	Sold at cooperative	Sold at local business center	Sold at market	Sold at Harvest Plus	
2014 A							
2014 B							
2015 A							
2015 B							
2016 A							

11. Price

11.1. How have the price of bean production been in the following seasons

Season	**Price [Rfw/kg]**
A 2016	
B 2015	
A 2015	
B 2014	
A 2014	

12. Revenues

Amount received/earned in the last 4 seasons (in Rwf) from sales of beans

Season	Amount received
2014 B	
2015 A	
2015 B	
2016 A	

13. Institutional support

In terms of frequency how often did you receive the following extension services in last four seasons from the following institutions? Using the number of provider below

0. MINAGRI 1. Harvest Plus 2. Cooperative 3. Agro-dealers

Skills	**Provider**	**Number of trainings**
Farm management		
Disease management		
Farm records		
Use of inputs		
Use of improved seeds		
Access to services		
Market accessibility		

Thank you for your time!