# FARM LIVELIHOOD IMPACT OF APRON STAR 42 WS – DRESSED BEAN SEEDS AND ITS COMMERCIALIZATION VIABILITY IN MBEYA AND MBOZI DISTRICTS, TANZANIA

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

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## ABSTRACT

Commercializing the subsistence agriculture is essential for improving the smallholder farmers' productivity in Sub-Saharan African countries including Tanzania. However, without an adoption of productivity enhancing technologies such as improved seeds, realization of such an improvement is inevitable. Arguably, for smallholder farmers to adopt new technologies, they need to feel its impact on their livelihoods. This study assesses the adoption, commercialization and impact of the bean seeds dressing chemical – the APRON STAR 42 WS on smallholder farmers' food security and nutrition status, income, and bean yield. A two-stage sampling with stratification was applied to randomly select a sample of 203 farm households. The propensity score matching was employed to isolate the impact attributable to adoption of the treated bean seeds among farm households. Assessment of the decision and extent of commercialization adopted the Tobit and Cragg's double hurdle models. Results indicate that adoption level is about 37%, and farm size, household size, access extension services and perceived yield effects are significantly influencing farmers' adoption decision of improved seeds. Significant difference in favour of adopters was found on income, yield, and food security and nutrition statuses. The variables education, farm size, extension services access, output, and education; and household size, extension services access, and output were found significant on influencing decision and extent of commercialization, respectively. Income, consumption, price of local seeds, and own price elasticities of seeds demand were also found significant. Thus, it is firstly recommended that, agricultural input intervention initiatives should emanate from farmers' needs in order to make the promotion efforts of productivity enhancing agricultural technologies efficacious. Secondly, to stimulate the dormant use of improved seeds, an effective stimulant is own seed price, though with consideration of production costs to ensure mutual benefits between farmers and seeds producers.

## DECLARATION

I, **Eward Mushi**, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my original work, done within the period of registration and that it has neither been submitted nor been concurrently submitted for a higher degree award in any other Institution.

**Eward Mushi** **Date**

**(MSc. Candidate)**

The above declaration is confirmed by;

**Dr. F. J. Mishili** **Date**

**(Supervisor)**

## COPYRIGHT

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# DEDICATION

I dedicate this dissertation to the founder of our nation the late Mwalimu Julius Kambarage Nyerere whose love to our motherland Tanzania was undoubtedly real.

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## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AERC | African Economic Research Consortium |
| ASA | Agricultural Seed Agency |
| ASDP II | Agricultural Sector Development Programme – Second Phase |
| ATT | Average Treatment Effect on the Treated |
| BMGF | Bill and Melinda Gates Foundation |
| CBOs | Community Based Organizations |
| CI | Commercialization Index |
| CIAT | International Center for Tropical Agriculture |
| CMAAE | Collaborative Masters Programme of Agricultural and Applied Economics |
| CSI | Coping Strategies Index |
| DfID | Department for International Development |
| DRD | Division of Research and Development |
| ESSAF | Eastern and Southern Africa Farmers' Forum |
| FAO | Food and Agriculture Organization of the United Nations |
| FCS | Food Consumption Score |
| FSN | Food Security and Nutrition |
| GM | Gross Margin |
| HDDS | Household Dietary Diversity Score |
| HFIAS | Household Food Insecurity Access Scale |
| HHS | Household Hunger Scale |
| IEG | Independent Evaluation Group |
| IFPRI | International Food Policy Research Institute |
| Kg | Kilogram |
| KM | Kernel Matching |

| | |
|---|---|
| MAFC | Ministry of Agriculture, Food and Cooperatives |
| MVIWATA | *Mtandao wa Vikundi vya Wakulima Tanzania* |
| NGOs | Non – Government Organizations |
| NNM | Nearest Neighbour Matching |
| PSM | Propensity Score Matching |
| QDS | Quality Declared Seeds |
| rCSI | Reduced Coping Strategies Index |
| SAFS | Self – Assessment Measures of Food Security |
| SAGCOT | Southern Agricultural Growth Corridor of Tanzania |
| SID | Society for International Development |
| SIIL | Sustainable Intensification Innovation Lab |
| SSA | Sub – Saharan Africa |
| TANSEED | Tanzania Seed Company Limited |
| TARI | Tanzania Agricultural Research Institute |
| TASTA | Tanzania Seed Trade Association |
| TFA | Tanganyika Farmers Organization |
| TOSCI | Tanzania Official Seed Certification Institute |
| TR | Total Revenue |
| TVC | Total Variable Cost |
| TZS | Tanzanian Shillings |
| UNDP | United Nations Development Programme |
| URT | United Republic of Tanzania |
| VBAA | Village Based Agricultural Advisors |
| VIF | Variance Inflation Factor |
| WFP | World Food Programme |

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background Information

The ultimate objective of rural development interventions should be improving the people's wellbeing because wellbeing is among the key indicators of development in any society. The status of wellbeing is assessed in various ways including income and food security. Income is one of the direct measures of wellbeing (Awotide *et al.*, 2015; Adebayo *eta l.*, 2015; Hailu *et al.*, 2014; Scoones, 1998). It is obvious that a household with an adequate income can easily meet its needs including buying valuable assets.

However, the question remains on whether all agricultural development interventions have impact on farmers' wellbeing or not. The best entry point to understand this question is through studying the intervention impact on the way farmers organize their lives, put it differently, the farmers' livelihoods impact of adopting various agricultural technologies (Scoones, 1998; De Haan, 2012; Department for International Development (DfID), 1999).

In sub – Saharan Africa (SSA), agriculture is considered the most important area of intervention in order to improve incomes of people because the livelihoods of people in the region depend largely on agriculture (Collier and Deacon, 2010). Moreover, despite the rapid population growth and urbanization in the region, a significant number of people still live in rural areas, and their livelihoods depend on small - scale farming (Duda *et al.*, 2018; Wenban-Smith *et al.*, 2016). In Tanzania for example, agriculture provides livelihood to about 70% of the population and employs about 65.5% of Tanzanians (URT, 2017). Thus, initiatives that tend to improve agriculture in rural areas are translated into improvement of farm households' livelihoods.

Therefore, it makes sense to argue that, the overall success or failure of agricultural interventions should be evaluated against the change of wellbeing of the targeted population. Given this importance of rural agriculture, the focus of many agriculture interventions has been on increasing smallholder farmers' productivity through promoting adoption of new technologies including seeds of improved varieties because it is the productivity that primarily determine farm income, holding the market price unchanged.

The present study is in the argument that the central problem of African agricultural challenges is low and unstable productivity. An overview of the agriculture sector in the continent suggests that the recurrent food crises and Africa being a net food importer are essentially a result of failure of the agriculture system to sustainably increase and maintain crop productivity among others (Rakotoarisoa *et al*., 2012; Devereux, 2009). The thinking is on the same line with Collier and Dercon (2010) argument that, for Africa to achieve the economic development in the next 50 years (now 41 years), increasing agricultural productivity is inevitable.

According to Deacon (2010), for Africa to realize the green revolution, agricultural productivity – enhancing technologies and innovations are to be promoted and adopted. These technologies include farm mechanization, use of quality seeds of improved varieties, fertilizer application, and control of crops pests and diseases. Adoption of improved technologies eventually leads to increased farm productivity, and finally the green revolution is realized.

One of the major reasons for low productivity among smallholder farmers in SSA and Tanzania in particular is low level of use and/or adoption of agricultural productivity enhancing technologies (Ronner, and Giller, 2013; De Luque and Creamer, 2014). These technologies include improved seed varieties, good farming practices, irrigation and fertilizers, which are generally considered as productivity enhancing factors (Kinuthia and Mabaya, 2017; Xavery *et al.*, 2008; Shenkalwa *et al.*, 2013). Thus, a number of agricultural interventions to promote the use of these technologies have been implemented to bring about the commonly called green revolution in SSA.

In 2015, the International Centre for Tropical Agriculture (CIAT) implemented a project whose objective was to improve productivity of beans through introduction of new technologies in selected villages in Mbeya and Mbozi districts – the study areas, and in Njombe, Manyara, Arusha, and Kilimanjaro regions. The project also aimed to address other challenges such as diseases and pests, poor quality, lack of access to quality seeds and market for the produced grains. The new technologies were; quality seeds of improved bean varieties, seed dressing chemical (APRON STAR 42 WS), and good agronomic practices like use of fertilizers, and planting in lines.

In this study, reference is made to the combination of all these technologies and practices as the “APRON STAR 42 WS – dressed bean seeds” or simply the “APRON STAR 42 WS”. Important traits of the bean seeds dressed by APRON STAR 42 WS include high yield, drought tolerance, nutritional values, and disease resistance. In the following season, the bean seeds, which were treated with APRON STAR 42 WS were supplied to some of villages through seed companies and agro – dealers for farmers to buy them. The motive of this study therefore, is to assess the impact of adopting APRON STAR 42 WS on livelihoods of farm households in the study area and establish the causal relationship between the farmers’ perceived livelihood outcomes attributable to APRON STAR 42 WS dressed bean seeds and the adoption decision.

In Tanzania, bean is among the priority crops identified in the national Agricultural Sector Development Programme (ASDP II). The criteria used include the viability of commercialization, scaling up and scaling out, and availability of technology to improve productivity and profitability (URT, 2017). According to Bill and Melinda Gates Foundation (BMGF) (2012) and Kalyebara (2008), beans serve as the main source of protein to majority of Tanzanians. Therefore, based on the national agriculture development roadmap this study has been done at the right time.

Nonetheless, literature on adoption studies indicate that there is generally low adoption rate and/or use of improved agricultural technologies in SSA especially in beans production (Kinuthia and Mabaya, 2017). In Tanzania, the use of certified seeds is only 5% (ASARECA/KIT, 2014) and farmers use in average use 9 kg/ha of fertilizer, a rate which is below the recommended standard rate (SAGCOT in Ronner and Giller, 2013). This suggests that there is a potential of improving the bean productivity if at all the use of improved agricultural technologies is adopted.

The literature further identifies many factors influencing adoption, but the purpose of this study is to explore the economic aspects of adoption impacts at household level to see if they influence choice decisions regarding the use of the new technology. The motive behind aligning to this aspect is that limited knowledge exists in agricultural technology adoption literature and the smallholder farmers’ livelihood and economic effects attributable to agricultural technology interventions. Findings of this study therefore contributes to the body of knowledge on farm livelihoods impact of adopting agricultural technologies and innovations and the influence of such perceived or experienced effects on adoption decision.

The basic question of this study therefore is whether the APRON STAR 42 WS – dressed bean seeds have impacts on livelihoods of farm households or not, and if yes, does such impacts influence their adoptions decision? Further investigation is made on the commercial orientation of the bean farmers in the study area, specifically the bean commercialization, and its driving forces. The common assumption under crop commercialization is that, when farmers tend to sell larger proportion of their seasonal produce for a particular crop, they are orienting themselves towards the market, and hence driven by market signals (Gebremedhin and Jaleta, 2010; Jaleta *et al.*, 2009; Martey *et al.*, 2012).

In addition, as farmers becomes more commercial oriented, they increase purchase of improved inputs to increase productivity in order to meet the market demand. Commercializing the agriculture and its related technologies is important for the technology sustainability because if farmers are engaged in the inputs purchase, the productivity enhancing technologies (inputs), in this context the APRON STAR 42 WS – dressed bean seeds will last longer even after the project/intervention has phased out.

## 1.2 Problem Statement and Justification

Smallholder farmers produce for both own consumption and for sale, thus, behaving rationally, they are expected to seek to maximize utility and profit respectively from their produce by choosing better technologies which enhance productivity and hence yield and income. In both objectives, a farmer has to make decision. When maximizing utility farmers are constrained by income and time, thus are to choose some combination of products given the available income and time (Nicholson and Snyder, 2008).

Similarly, in profit maximization, they need to decide on the least cost combination of resources (Debertin, 1986). Farmers also have their own criteria of assessment when choosing agricultural technologies. Therefore, it is important to assess the driving forces of farmers' decisions regarding the use agricultural technologies before deciding to commercialize particular technologies. Based on the farmers' dual objectives (profit and utility maximization), the expectation is that, if behaving rationally they will always choose technologies that meet the objectives.

Generally, farmers will choose to adopt technologies that have positive impact on their lives. Even so, research interest on new bean seeds has been focusing much on high yield varieties and their adoption (Hamzakaza *et al*., 2014; Nwachukwu, 2017; Maredia *et al*., 2014), rather than either on impacts of these technologies on farmers' livelihoods or on their profitability in particular. Consequently, there are agricultural technology interventions whose impacts on households' farm livelihoods are less known.

In this study however, it is argued that, not all local agricultural technologies are not beneficial to a particular setting. It is still important to consider and think of agricultural frugal innovations in discussions about the adoption of new agricultural technologies. It is from this argument that the present study takes the comparative approach to establish the livelihood differences between users of traditional practices and adopters of the new technology.

The present study argues that probably some local agricultural technologies are beneficial to famers' lives such that farmers' see no need of adopting the new ones. It is this line of thinking that brings the importance studying farm livelihood impact of agricultural technologies, in this case the APRON STAR 42 WS – dressed bean seeds in order to tell whether the technology matters to farmers or not.

The existing knowledge on adoption of new agricultural technologies do not provide sufficient reasons for the persisting low adoption rate of new technologies despite role they play in increasing productivity. This is because researches have been coming up with similar factors yet the problem is still there. The literature is rich of knowledge on driving forces of adopting new agricultural technologies (Hamzakaza *et al*., 2014; Mwangi and Kariuki 2015), and the role of those technologies in increasing productivity (Nwachukwu, 2017; Maredia *et al*., 2014) but poor on impacts of these technologies on farmers livelihoods and how the experienced impacts influence adoption decision. Studying the livelihood impact of agricultural technologies is worth because despite providing the effectiveness of intervention it provides justification for commercialization.

Even though some studies assume that profitability is not an important criterion in adopting new agricultural technologies (Mpogole and Kadigi, 2012), it is important to note that high yield varieties are not necessarily profitable. Seeds may be of high yield but may also be associated with high cost of production (seed production) compared with the local ones hence reducing the margin. Hence thinking of farming as a business for the interest of orienting farmers in commercial farming, farm profitability should not be underestimated. In addition, thinking on the line of agricultural economics paradigm, farmers (of all scales) are/should be operating rationally like any other economic entity.

The present study argues that in order to make the use of APRON STAR 42 WS – dressed bean seeds sustainable, assessing its demand and the farmers' commercial orientation regarding the particular crop (bean) is necessary. Arguably, it is not certain whether all improved seeds have commercialization potential and whether farmers' demand for them really exists. Thus, this study finds it important to analyze yield level, income, and food security situation as livelihoods' impacts attributable to APRON STAR 42 WS – dressed bean seeds, and assess the commercialization potential of the same. This line of thought provides an additional insight and direction of understanding the problem of low adoption rate persistence among smallholder farmers in the adoption and impact assessment literature.

## 1.3 Objectives of the Study

### 1.3.1 Overall objective

The overall objective of this study was to assess whether the use of APRON STAR 42 WS - dressed bean seeds is viable for commercialization and important on improving the livelihoods of smallholder bean farmers in Mbeya rural and Mbozi Districts.

### 1.3.2 Specific Objectives

Specifically, this study intended to:

i) Assess the effect of APRON STAR 42 WS – dressed bean seeds on bean yield and possible farm income among bean smallholder farmers in the study area.

ii) Assess the effect of APRON STAR 42 WS – dressed bean seeds on household food security and nutrition status among bean smallholder farmers in the study area.

iii) Determine the factors influencing adoption of APRON STAR 42 – dressed bean seeds among stallholder farmers in the study area.

iv) Analyze the driving forces for smallholder farmers' decision and extent of bean commercialization in the study area.

v) Analyze the factors influencing demand for ARON STAR 42 WS – dressed bean seeds and in the study area

## 1.4 Research Questions

In correspondence with the specific objectives, the present study answers the following questions:

i) How does the Apron Star 42 WS - dressed bean seeds affect smallholder farmers' yield and income in the study area?

ii) How does the Apron Star 42 WS - dressed bean seeds affect the food security and nutrition status of smallholder farmers in the study area?

iii) What are the factors influencing the adoption of APRON STAR 42 WS – dressed bean seeds in the study area?

iv) What are the forces driving the smallholder farmers decision and extent of bean commercialization in the study area?

v) Does the own seed price, bean (output/yield) price, prices of other bean seeds (local seeds), and income affect demand of the APRON STAR 42 WS – dressed bean seeds in the study area?

## 1.5 Organization of the Study

This dissertation is divided into five chapters. In the second chapter, a review of relevant literature with emphasis on the SSA has been made. The chapter is categorized into operationalization of key terms, theoretical and conceptual framework, review of the seed sector in Tanzania, review of empirical studies, and review of empirical methods.

The third chapter provides a detailed description of the design and methods employed by the study. The chapter specifies the study area, sampling design, methods of data collection, and data analysis techniques. The fourth chapter presents and discusses results of the present study. The fifth chapter provides a summary, conclusions, recommendations and policy implications of the study based on the results presented. Moreover, in the last, a list of references cited in this study and appendices are provided.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

## 2.1 Operationalization of Key Terms

### 2.1.1 APRON STAR 42 WS

APRON STAR 42 WS is the tradename for the seed treatment product to control early season pests and diseases in crops such as French beans, snow peas, sugar snaps, and runner beans (Lwehabura J. and Rubyogo, J. C., personal communication, 2018). As used in the present study, APRON STAR 42 WS – dressed bean seeds refer to the bean seeds treated by the chemical and introduced to the study area through the project namely Sustainable Intensification Innovation Lab (SIIL), whose aim was to improve beans productivity through introduction of new technologies. The bean varieties referred to this study that were treated by APRON STAR 42 WS are Uyole Njano and Uyole 93 developed by Tanzania Agricultural Research Institute (TARI) – Uyole.

The chemical application to the seeds is in various ways namely dust application, pre-wetting method and slurry application. In dust application, the indicated amounts of seeds are mixed with the required amount of APRON STAR 42 WS chemical in a bag and shaked well until all seeds are uniformly covered. The pre-wetting method involves wetting the seeds prior to mixing with the chemical, whereas slurry application involves mixing all water, seeds and the chemical at once at specific rates. According to Syngenta (Personal communication, 2018), the extensive testing of the chemical all over Africa has confirmed the broad efficacy against diseases and insects on a broad range of crops.

### 2.1.2 The Concept of Adoption

In an agricultural context, Feder *et al*. (1985) defines adoption as “the integration of an innovation into farmers’ normal farming activities over an extended period of time”. It is a relatively long process, which starts from being aware of the new innovation to actually adopting or start using it (Rodgers, 1983). However, “a new technology is new to a particular place or group of farmers” (Mwangi and Kariuki, 2015). According to Simtowe (2011), the perceived attributes of the technology condition the adoption behaviours of farmers.

In the present study, adopters refer to farmers who bought the APRON STAR 42 WS dressed bean seeds in the 2018/19 main bean season from any dealer and/or stakeholder in the study area. Farmers were exposed to the technology (the APRON STAR 42 WS chemical) in 2015/16 during the demonstration farms ran by the project, thus the present study assumes that the period between 2015/16 and 2018/19 is long enough for farmers to have evaluated the technology and make decision to either adopt or not to adopt.

### 2.1.3 Livelihood Impacts

Livelihood is defined differently by different authors (Sccones, 2009; De Haan, 2016) but the current study adopts the commonly used definition by Chambers and Conway (1991) which is: “a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: livelihood is sustainable which can cope with or recover from stress and shocks, maintain or enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation; and which contribute to net benefits to other livelihood at the local and global levels and in the short and long term”.

On the other hand, an impact assessment refers to the evaluation of changes in outcome indicators attributable to the particular intervention, and in the context of agriculture, the common impact indicators are productivity, income and profit (Independent Evaluation

Group (IEG), 2011). It is an estimate of causal effectiveness on an outcome. The livelihood impact in this context therefore, refers to the changes in means of living in terms of mainly income and food security and nutrition status that are attributable to the adoption of APRON STAR 42 – WS dressed bean seeds in the study area. A change in farm income is as the key indicator of farm livelihood impact as it influences other aspects of livelihood impacts such as assets, education level, capacities and other resources (Garai *et al*., 2017; Makate *et al.*, 2017; Scoones, 2009). Generally, the livelihood impact shows if adoption of the seeds had any change on farmers' lives.

### 2.1.4 Commercialization

There is no one common definition of smallholder commercialization because of different angles to which authors look at the concept. Literature diversion on whether a household is commercial oriented or not, is based on three main issues namely; production of cash crops, resource allocation on marketable goods, and proportional sales of agricultural produce (Jaleta *et al*., 2009). For example, Govereh *et al*. (1999) defines agricultural commercialization as the share of agricultural produce that is sold, and it ranges from zero, which is subsistence agriculture to 100%, which is full commercialization. However, according to Von Braun (1995), commercialization is more than just surplus sales, it should consider both the input and the output sides.

Therefore, this study takes the concept of commercialization from the perspectives of both input and output sides, and the farm household decision–making behaviour in the production process. According to Jaleta *et al.* (199) decision – making of a commercial farm household is driven by the market indicators whereas the subsistence based farm households' decision – making are based on self–consumption and they only sell the left over from the consumption. The present study however argues that, smallholder farmers have simultaneous objectives, they produce for both own consumption and for sale, hence arguably, the surplus sales should not be underestimated in conceptualizing the smallholder commercial – orientation.

According to Von Braun (1995), technology and commercialization play a complimentary role in stimulating the rural economy – a reason for the present study to go beyond technology adoption impact, to analyzing commercialization. In the context of the present study, commercialization of APRON STAR 42 WS – dressed bean seeds considers both the output and input sides. On the output side, it considers the proportion of total harvest sent to the market assuming that the increased sales of produce attracts increased productivity, which triggers input use. On the input side, the consideration is made on the demand for the APRON STAR 42 WS – dressed bean seeds itself.

### 2.1.5 Food Security and Nutrition

The currently known "food security and nutrition" (FSN) concept has evolved for more than six decades facing acute discussions and disagreements about its meaning among development practitioners globally (Gross *et al.*, 2000; Hendriks, 2015). Along that period, there has been lack of consensus on right terms and concept regarding food and/or nutrition security problem, for example, whether it should be "food security", "food and nutrition security", "nutrition security" or " food security and nutrition", and off course some people have been using the terms interchangeably (Hendriks, 2015). Hitherto, there is a global consensus on the use of the term "food security and nutrition" to refer various food and nutrition related crises such as malnutrition, famine, hunger and undernourishment (FAO, 1996).

Today, the widely accepted definition of the food security and nutrition concept, which guides the present study, is the one developed by FAO (1996) which states, “when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life”. In other words, “a person is considered nutrition secure when she or he has a nutritionally adequate diet and the food consumed is biologically utilized such that adequate performance is maintained in growth, resisting or recovering from disease, pregnancy, lactation and physical work”. The definition has four pillars, which are availability, accessibility, utilization and stability.

According to Hendriks (2015) food security and nutrition is a continuum of experiences of food (in) security situations, which ranges from food security and food insecurity as two extreme ends. In a chronological order from the extreme food insecurity to food security, there are starvation, acute hunger, chronic hunger, hidden hunger, vulnerability to food insecurity and food security. Hendricks proposes that coping strategies and all interventions to solve the food insecurity problems that understands such a continuum ensure that all aspects of food security and nutrition problem are captured.

## 2.2 Theoretical and Conceptual Framework

### 2.2.1 Theoretical Framework

Adopting decision is the process that involves a time lag between awareness and adoption of the new technology. Awareness about the APRON STAR 42 WS – dressed bean seeds in the study area was done through farmers’ participation to demonstrations farms where the technology was showcased. Various authors define adoption differently. This study is guided by Feder *et al.* (1985) definition of adoption, which is, “the integration of an innovation into farmers’ normal farming activities over an extended period of time”. It is a combination of profitability, riskiness, divisibility, initial capital, complexity and availability (Byerlee and Hasse de Polanco, 1986).

The just mentioned six factors are very important regarding farmers' adoption decision. The current study's emphasis however, is on profitability. Adoption is considered to be a discrete binary variable (Wooldridge, 2005). In a binary dependent variable there are only two options such as "Yes" or "No", and adopter or non – adopter. In this study a farmer can be either an adopter on a non – adopter. An adopter in the context of the current study is the one who happened to buy the APRON STAR 42 WS – dressed seeds during the 2018/19 main season, three years after the introduction of the seeds in the study area, while the one who did not buy is a non – adopter. Thus, like in many other adoption studies, this study uses a simple binary dependent variable approach that assigns one and zero values to adopters and non-adopters, respectively.

Theories guiding this study include the theory of the firm, the consumer behavior theory, and the bounded rationality theory. Recall, smallholder farmers produce for both own consumption and for sale, and according to the classical theories of the firm (Debertin, 1986) and consumer behavior (Nicholson and Snyder, 2008), if behaving rationally, these farmers will always aim to maximize profit and utility respectively. However, the bounded rationality theory guides that; farmers are intendedly rational but are limited to be so (Ankarloo, 2002) due to uncertainties. In agriculture, the uncertainties are such as weather changes, and market prices. Thus, farmers decide to adopt new technologies if they perceive that the adoption benefits exceed the adoption costs.

The bases of analysis for this study are livelihood perspectives and farmers commercial orientation. Livelihood perspectives is now days considered to be an appropriate people-centered approach for studying rural development. Chambers and Conway (1991) defines livelihood as a means of securing a living resulting from an interaction between capabilities, tangible assets and intangible assets, and Scoones (2009) puts it simpler as "the means of gaining a living". In other words, it is a combination of resources used and the activities undertaken in order to live. These resources are social capital, natural capital, economic/financial capital and human capital. All people aim to achieve livelihood outcomes, which are more income, increased wellbeing, improved food security and reduced vulnerability (DfID, 1999). This study analyzes two aspects, income (as a function of price and yield sold), and food security and nutrition status.

On the other side, crops commercialization has primary two sides – the demand and supply sides. On the demand side the questions of utility and/or profit maximization sets in whereas on the supply side, profit maximization is the key driving force. The current study is on the light of thinking that commercialization of the APRON STAR 42 WS – dressed bean seeds must take into consideration the demand side (smallholder farmers) who are basically consumers of the technology, and the supply side (proportion of total bean output which is sold to the market). The percentage of beans sold acts as a proxy of response from the market signals. For the business to occur the two sides must come together. Therefore, an adequate assessment of the commercialization must consider both sides.

This study adopts the livelihood approach (the farm livelihood outcomes: farm income and food security and nutrition status) to understand how smallholder farmers organize their livings. The approach enable to explore the farmers demand regarding the use of improved bean seeds hoping that it will enable researchers, producers and policy makers to get it right in the whole process of promoting productivity enhancing technologies. Therefore, the analysis starting from the market back to the producer can help to tell whether the business viability of the seeds exists or otherwise. Generally, for commercialization to be viable, the objective functions of both parts must be attainable.

### 2.1.2 Conceptual Framework

The livelihood of the bean farmers in the study area depend on agriculture. Although to some farmers, bean is not the main crop but at least they grow beans. For years now, these farmers have been using local seeds to grow beans, a practice that the literature identifies it as one of the reasons for low productivity.

Therefore, as Fig. 1 shows, adoption of the APRON STAR 42 WS-dressed bean seeds is expected to improve the farmers’ livelihood outcomes. The livelihood outcomes in this context include farm yield level, income/profitability, and food security and nutrition status. Farmers are assumed to be rational economic agents, hence they are expected to always choose to adopt a technology which they perceive will improve/improves their livelihood through two key indicators, yield and farm income. High yield is expected to increase household bean consumption and bean for sale.

In fact, net farm income is a function of both yield, prevailing market price and production cost. Since individual farmers have no influence on market price, holding the prevailing market price unchanged, associated cost of production can play a big role in influencing farmers’ decision to adopt. Bean consumption and income from bean sales can both lead to an improved household food security and nutrition.

Household income is considered as a key determinant of other livelihood indicators such as farm assets, land, and education level of household members (Sccones, 2009; De Haan, 2016). A positive relationship exists between income and these indicators. A household with reliable income has high probability of financing its members’ education, and can acquire valuable assets and land. Moreover, a change of status of these indicators, which are attributable to new the technology, is assumed to influence adoption decision, just like other socio-economic characteristics of farmers.

Finally, realization of livelihood outcomes among farmers through increased productivity and income will trigger demand of the APRON STAR 42 WS – treated bean seeds thus more adoption. The increased purchase of the seeds implies commercialization of the same. Similarly, the increased purchase of the seeds will lead to high productivity that leads to production of surplus for sale hence increased income and commercialization.

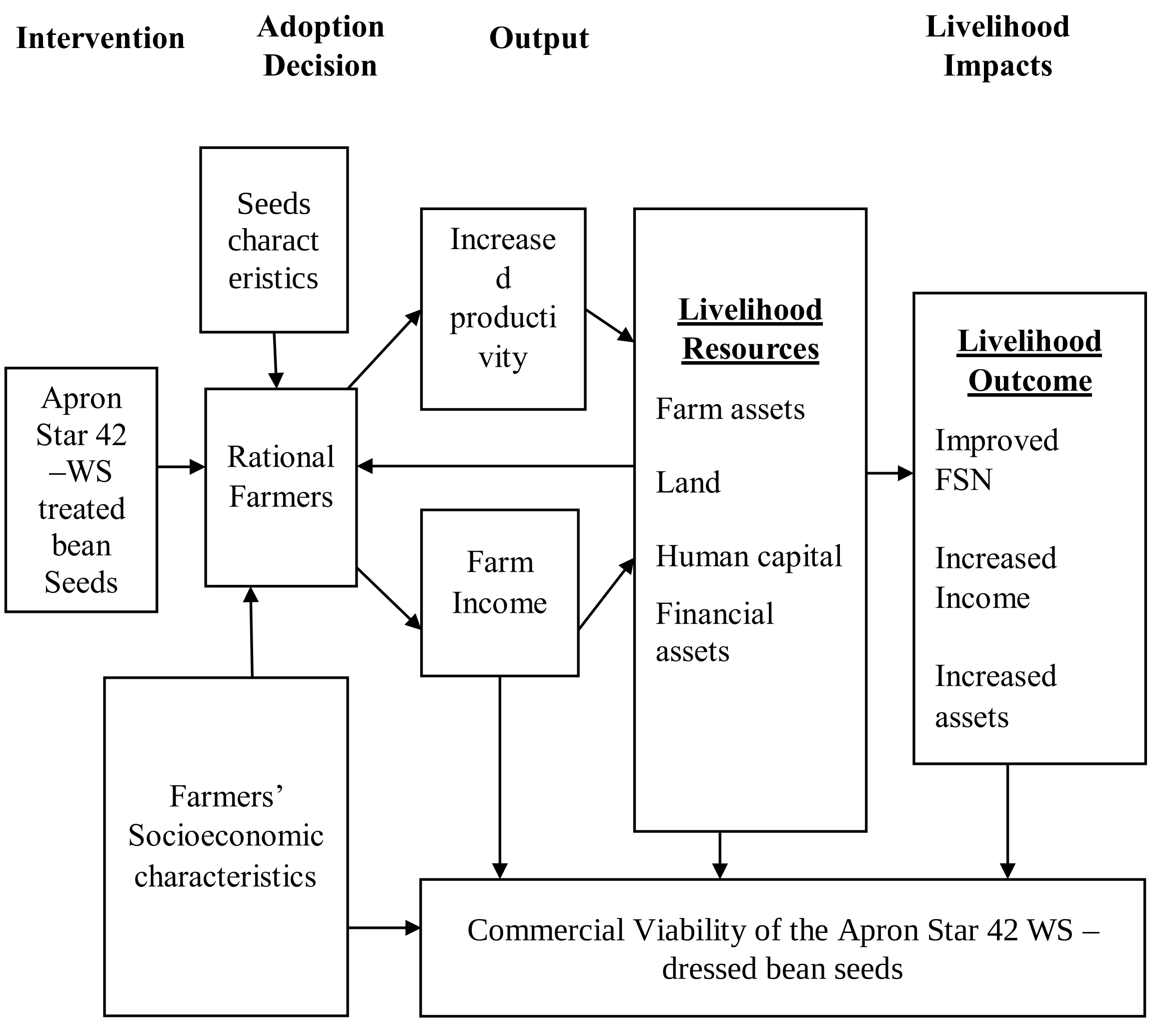


**Figure 1: Conceptual Framework**

**Source: The DfID Sustainable Livelihood Framework (1999).**

## 2.3 The Seed Sector in Tanzania

Development of the seed sector in Tanzania can be mapped out from the 1960's when the country got its independence. Soon after its independence in 1967, Tanzania officially adopted the socialization policy through the Arusha Declaration. During that socialism era, in 1973 the Tanzania Seed Company Limited (TANSEED), the solely government parastatal with mandate to production, importation, distribution, and sale of certified seeds was formed. However, the poor performance of TANSEED plus the global wind of change to liberalization during the 1980s, made the government to officially liberalize the sector in 1989. With the liberalized environment, TANSEED faced stiff competition from the private companies that joined in the business (Mtenga *et al.*, 2001; Minot *et al.*, 2007).

The Tanzanian seed sector comprises a various actors/stakeholders including public, private sector and civil society actors. Hitherto, there are more than 54 registered seed companies in the country, which produce and certify seeds, majority of them focusing on maize (ASARECA/KIT, 2014). The public sector is mainly involved in primary chain activities such as genetic resource management (NPGRI), variety development – Division of Research and Development (DRD) under the Ministry of Agriculture, Food and Cooperatives (MAFC), basic seed and certified seed production and distribution by the Agricultural Seed Agency (ASA), and quality control by Tanzania Official Seed Certification Institute (TOSCI) (Patrick, 2017).

The private sector organized by the Tanzania Seed Trade Association (TASTA) on the other hand produces and markets certified seeds and some basic seed. Agro-dealers are involved in the retail of certified seeds produced by various seed companies. Individual farmers or farmer organizations such as the Community Based Organizations (CBOs) or the "groups network of smallholder farmers", commonly known as *"Mtandao wa Vikundi vya Wakulima Tanzania"* (MVIWATA), and Tanganyika Farmers Association (TFA) platforms are both on the end-user side of the seed chains. The aforementioned platforms are also involved in on-contract certified seed production, Quality Declared Seeds (QDS) production, and the informal seed production (ASARECA/KIT, 2014).

Seed value chain supporting services are provided by the public sector (80 per cent of extension services), TOSCI (quality inspection and certification services), complementary to private sector extension, and seed use promotion services (agro-dealers and seed companies). Non – Government Organizations (NGOs) and farmer organizations are also involved in seed extension, largely as facilitators for the informal sector and QDS seed production (Eastern and Southern Africa Farmers Forum (ESSAF), 2013).

The government of Tanzania recognizes that one of the key factors for increasing agricultural productivity is farmers' access to inputs specifically quality seeds of improved varieties. With this regards, various agricultural policies, legal frameworks and programmes have been formulated and implemented in order to promote development of the seed sector in the country.

The policy and legal frameworks which support the development and support of the seed sector in Tanzania emanate from the Seed Act Number 29 of 1973 which led to the formation of TANSEED and TOSCA, and the Seed Act Number 18 of 2003 (Revised in 2007) which regulates all issues relating to the seed industry (ASARECA/KIT, 2014). Under this Act, TOSCI was established to deal with certification and quality control. There is also the National Seed Committee acting as the stakeholders' forum with the role to advice the government on all issues concerning the development of the seed industry in the country. On the other hand, there is TASTA, which represents the private sector.

Moreover, the country has also a legal regime that regulates seed variety release, seed certification, and quarantine and phytosanitary measures. These include the Seeds Act of 2003, read together with the Seeds Regulations of 2007; the Plant Protection Act of 1997, read together with the Plant Protection Regulations of 1998; and the Plant Breeders Right No. 222 of 2002. The Tanzania Ministry of Agriculture is responsible for overseeing all these policies and regulatory frameworks. According to ASARECA/KIT (2014), the seed systems available in Tanzania are the closed seed chain system, the farm-saved system, the farmer-to-famer system, the community based system, the open market system, the relief system, and the public seed system (ASARECA/KIT, 2014).

Common beans is among the crops categorized by the Agricultural Sector Development Programme Phase II (URT, 2017) as the priority crop due to its economic and food security and nutrition importance. This programme is the roadmap of the agricultural sector in the country. Therefore, beans being recognized as a priority crop implies that the crop is of paramount importance to the country, hence it is not a resource wastage doing as study on it, in particular this study.

According to ASARECA/KIT (2014), opportunities exist for intervention in the bean seed sector. These opportunities include improving local seed quality control by district level inspectors; improving the availability of basic seed; developing technical and business training for seed multipliers; introducing farmer field schools for beans, which, amongst others, show the benefits of the use of clean seed.

Apart from the opportunities, there are also challenges facing the bean seed sub-sector. The challenges include the difficult regulations to access TOSCI services, absence of projects/programmes with a seed multiplication component, inadequate extension services, poorly resourced bean research, access to financial services for bean seed production and marketing, limited capacity in bean seed production, and insufficient knowledge to differentiate between seed and grain (ASARECA/KIT, 2014).

## 2.3 Empirical Review

### 2.3.1 Livelihood Perspectives

The livelihood approach emerged as the centre to developmental studies during the end of 1990s following the introduction of the Sustainable Livelihood Framework that was highly promoted by DfID (De Haan, 2012). The approach was also very much promoted by the British new Labour Government and later it was not only considered as the pro-active and self-help image of the poor but also became the core of the DfID policies of poverty alleviation (De Haan, 2017).

Robert Chambers is considered the founder of livelihood approach due to his contribution to the “Sustainable Livelihood Framework” (De Haan, 2017). According to Chambers and Conway (1991), “a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: livelihood is sustainable which can cope with or recover from stress and shocks, maintain or enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation; and which contribute to net benefits to other livelihood at the local and global levels and in the short and long term”.

Livelihood comprises people, their capabilities and their means of living including food, income and assets. Later on, some other development practitioners and researchers have come up with simpler definitions of livelihood. For example, De Haan (2017) defines livelihood as a means of securing a living resulting from an interaction between capabilities, tangible assets and intangible assets, and Scoones (2009) puts it further simpler as "the means of gaining a living" or a combination of resources used and the activities undertaken in order to live.

From these definitions, three main aspects of livelihoods namely; capabilities, tangible assets and intangible assets which Scoones (1998) calls them the livelihood resources can be derived. Some recent livelihood studies disaggregate them into social capital, natural capital, economic/financial capital and human capital (Xiao *et al*., 2018; Nabahungu and Visser, 2011).

The livelihood approach focus much on how people organize their lives and is considered to be a bottom-up and participatory method of studying rural development as it emphasizes on poor peoples' lives and their daily needs (De Haan, 2012). Apart from the DfID, many other international development organizations such as CARE International, United Nations Development Programme (UNDP), OXFAM, Society for International Development (SID), and other NGOs later on adopted the approach in their development projects.

A multitude of studies using the livelihood approach has been done in different disciplines from the global perspective, but a limited number exists in Tanzania particularly regarding assessing the agricultural technologies impact on farm households' livelihoods. For example, Adebayo *et al*. (2015) and Makate *et al*. (2017) used income as a proxy of financial capital to study impacts of agricultural innovations and technologies on livelihood of farm households in Nigeria and Zimbabwe respectively. Garai *et al.* (2017) used knowledge, attitude, yield and income as components of livelihood improvement attributable to agricultural technology intervention among the dairy farmers in India.

The current study compares productivity (yield), profitability (income/financial), and food security and nutrition status between adopters and non-adopters of the APRON STAR 42 WS – dressed bean seeds (a new agricultural technology) as the pathway to understanding the commercialization viability of the technology. Among the assumptions made is that land (natural capital), household members' education level (human capital) and farm assets are highly determined by income. In this study, it is argued that, it is equally important to understand the way smallholder farmers organize their living in their contexts before introducing and recommending new agricultural productivity-enhancing technologies as it is important for the technologies to be commercialized.

### 2. 3.2 Impact of Agricultural Innovations and Technologies on Livelihoods of Farm Households

The term impact as was defined by Prennushi *et al*. (2000), in this context refers to the extent to which agricultural interventions cause changes in the wellbeing of target populations, such as individuals, households, organizations, and communities. Given the fact that it is difficult to assess the impact for general objectives such as poverty elimination, FAO (2000) as cited by Prenushi *et al.* (2000) suggested the use of medium – term goals such as improved productivity and increased income, which have actually been used in this study.

In the present study an assessment is made on the changes in yield, income and food security and nutrition status attributable to use of the APRON STAR 42 WS – dressed bean seeds. APRON STAR 42 WS – seed dressing chemical is the new technology to bean farmers in the study area and the country at large. However, the technology has been used in some other African countries such as Ethiopia. To the knowledge of this study, there is no any other study regarding the impact of APRON STAR WS 42 in the country. Therefore, a review of studies on the impact of various agricultural technologies on farmers' livelihood was made across Africa.

Generally, the reviewed studies on impact of agricultural technologies to farmers through the livelihood approach have primarily been using farm income and productivity indicators as livelihood outcomes. Others but in limited number have extended the analysis to include household assets and food security status effects attributable to the agricultural technologies adoption. For example, the study conducted by Adebayo *et al.* (2015) to assess the impact of agricultural innovations on improved livelihood and productivity outcomes among smallholder farmers in rural Nigeria, used the household income, per capita expenditure, income diversification and productivity as proxies of the livelihood effects of the agricultural innovations.

Results showed that, the use of innovation systems approach have a strong impact on some aspects of rural livelihoods. Participants of the agricultural innovations programmes had their per capita expenditure increased by N 12 411.95 compared to the non-participants. This strong positive impact is obvious because the average productivity and income effects were also positive. The study however says nothing about the assets, and food security and nutrition status, which are important aspects of livelihood outcomes.

Similar results of farm livelihood effects attributable to agricultural technologies using household income have been reported by Mendola (2006) in Bangladesh; Katungi *et al.* (2017) in Malawi; Mengistie and Kidane (2016) in Ethipia; Mohanty *et al.* (2016) in India, and Makate *et al.* (2016) in Zimbabwe. Mofya-Mukuka and Hichaambwa (2018) used household income and food security indicators to measure livelihood effects of crop diversification to rural farm household in Zambia. Food security and nutrition was measured using the household dietary diversity score (HDDS) and food consumption score (FCS). Results showed a positive and significant effect to all indicators. However, both the HDDS and FCS were weak indicators. On the other hand, HDDS indicated a strong positive effect of improved bean varieties on food security in the study conducted in Malawi by Katungi *et al.* (2017).

Furthermore, in the study on the food security effects of drought tolerant maize adoption in Zimbabwe, Makate *et al.* (2016) used the consumption approach and found that because of adopting the drought-tolerant bean seeds, the household food consumption increased significantly due to increased productivity and income. Other studies with similar results on food security effects of improved seeds include that of Larochelle and Alwang (2014) and Nwachukwu (2017).

In terms of adoption effects on farm household assets, the empirical study conducted in Nigeria by Awotide *et al.* (2015) suggests that that improved agricultural technologies can play a key role in strengthening asset ownership of smallholder farmers for increased agricultural productivity and income generation. Results of the study showed that improved cassava varieties increased assets ownership among adopters. Household assets are considered as the more stable indicators of farm households' livelihood compared to income.

The key livelihood outcomes include income, food security and household assets. However, impact studies on household food security and assets are very limited. Existing studies focus much on productivity and income but in fact, the two are inadequate to explain the livelihood outcomes. This study analyzes households' farm income and food security affects attributable to adopting the APRON STAR 42 WS – dressed bean seeds. Household assets are also analyzed to complement the income analysis, as the former is a more stable indicator of household wellbeing than income (Awotide *et al*., 2015).

In terms of productivity effects resulting from agricultural technologies adoption, there is consensus in the literature about the role agricultural technologies play in increasing productivity. A trial conducted by Agegnehu and Medhin (2014) to evaluate and determine the efficacy of APRON STAR 42 WS seed dressing chemical against cutworms revealed that plots received seeds treated with APRON STAR 42 WS chemical showed early seedlings emergence and higher yield compared to the plots which did not received seeds treated by the chemical.

Makate *et al.* (2016) found that the adoption of draught tolerant maize in rural Zimbabwe has significant influence in increasing the overall maize productivity. The mean yield for the drought tolerant maize was 330.9 kg/ha higher than that of the non-draught tolerant maize. Similar results are reported by the study of Adebayo *et al.* (2015) in Nigeria. In the context of Tanzania, Bucheyeki and Mmbaga (2013) found that Lyamungo 90 and Jesca, which are improved bean varieties ranked higher in terms of yield with an average of 1 430.00 kg and 1 325.67 kg/ha compared to other varieties in Kigoma region.

Similar results were reported by Shenkalwa *et al*. (2013) in the study conducted to test performance of improved bean seeds in Kasulu and Kibondo districts. Other studies on productivity effect of improved seeds with similar results in terms of yield include Beyene and Kassie (2015) and Katungi *et al*. (2016) in Tanzania; Katungi *et al.* (2017) in Rwanda; Adeoti *et al*. (2017) in Nigeria, and that of Nwachukwu (2017) done in the whole SSA.

From the reviewed studies above, it comes out clear that the focus of majority of studies have been on investigating the impact of agricultural technologies specifically improved seeds on either productivity and/or income, or some on assets and/or food security, but not on combination of all the three aspects. The present study evaluates all; income, yield, and food security and nutrition status effects resulting from adopting APRON STAR 42 WS – dressed bean seeds. Basically, yield and income are related, as the farm income depends on yield level and the prevailing market price.

Moreover, yield, income and assets have direct implication on availability, accessibility, and resilience aspects of food security and nutrition (Hendriks, 2015; Jones *et al*., 2013). High yield ensures food availability to the household while income enables food accessibility and diversity. Assets determine the household's resilience to food security shocks. Therefore, a keen analysis of these variables in one study provides a robust analysis of livelihood impacts of adopting the APRON STAR 42 WS – dressed bean seeds.

### 2.3.3 Determinants of Adopting Agricultural Technologies among Smallholder Farmers

In the past two decades, a large number of adoption studies have been conducted in order to explore factors determining adoption of agricultural technologies in particular improved seeds. The literature show various factors that empirically have influence on farmers' decision-making regarding to use or not to use a particular technology. A review by

Mwangi and Kariuki (2015) on factors determining adoption of new agricultural technologies by smallholder farmers in developing countries identified broad categories of factors influencing adoption of agricultural technologies. The categorization is made in terms of the technology itself, economic, institutional and household specific factors. Findings of most studies on factors influencing adoption of agricultural technologies fall into these four categories: technological factors, economic factors, institutional factors, and household specific factors.

In Tanzania, research concentration has been on the improved seeds of cereal crops including beans. For example, the study by Letaa *et al*. (2015) to assess the adoption and spatial distribution of improved common bean varieties in Southern Highland Tanzania, found that there are household level, village level, farm level and market level factors significantly influencing adoption of crop seeds of improved varieties. The farm level factors are such as distance from the farm to the residence while the household level factors are such as the experience of bean farming, access to farm income and household size. Village level factors include the distance to the main road and the access to credit, where as the market attributes of beans make farmers continue to grow the old varieties.

Using the case of improved pigeon pea to study the determinants of agricultural technology adoption in Tanzania, Simtowe (2012) found that ownership of livestock, distance to the agricultural office, access to pigeon pea seeds, and land size have significant effect on influencing adoption of improved pigeon pea. Furthermore, Bayene and Kassie (2015) found that social capital and networks, and information from the extension workers are important in speeding up the adoption of improved maize varieties in Tanzania.

Studies in other countries with similar results include the one done by Nwachukwu (2017) in Nigeria that strongly suggests that the main factors significantly affecting adoption of technology include cultural values, institutionalized land tenures, cropland size, poverty, literacy level, technology complexity, agricultural extension services, age and sex. On the other hand, the study of Katungi *et al*. (2016) suggests that adoption of climbing beans in Rwanda depends on elevation, rainfall, and cropping systems.

Another study done in Nigeria by Fadare *et al*. (2015) reports that farm size, access to extension services, education level, marital status, access of the household head influence adoption decision of maize farmers in the country. Other adoption studies with results in line with those reviewed in this study include the one done by Mlenga and Maseko (2015) in Swaziland, Beshir (2014) in Ethiopia, Wossen *et al*. (2017) in Nigeria, Mwangi and Kariuki (2015), and Abebe and Bekele (2015) in Ethiopia.

Generally, factors such as education level, age, years of experience in farming, access to extension services, and access to credit have been recorded to have a positive relationship with adoption. Educated farmers are said to be knowledgeable enough to understand the importance of adopting improved technologies. The influence of age has been controversial. Age can be related with experience and record a positive influence, while on the other hand, the higher the age the higher can be the reluctance to accept change.

The current study suggests that there are some missing information in the literature regarding the factors influencing adoption of improved agricultural technologies, and argues that probably these might account for the persisted low adoption rate among farmers. The economic and perceived impact of the technology are important to be taken into consideration. The perceived effects of the technology on yield, income, assets and food security may influence the adoption decisions. This study' analysis tries to establish the causality between perceived economic impacts of technology adoption and farmers' decisions to adoption, expecting to provide a light to another line of thinking about smallholder farmers and adoption of agricultural technologies.

## 2.4 Review of Empirical Methods

### 2.4.1 Impact Assessment

There are various techniques of analysis in impact assessment studies each being specific to specific nature of the study and data available. The major problem with impact evaluation studies is that individuals have only one presence, therefore, it is necessary to create the counterfactual: what would happen had the individuals of interest not participated in the intervention or programme. With experimental designs, the counterfactual is constructed through randomization while in the quasi-experimental designs several methods exists including propensity score matching (PSM), instrumental variable method, regression discontinuity design and the difference in difference method.

The major challenge of non-experimental designs however, is establishment of counterfactual to control for the self-selection biasness (Mendola, 2006). Some studies use more than one model to overcome the problem of counterfactual (Kuboja *et al*., 2018; Wossen *et al*., 2017; Awotide *et al*., 2015), however, PSM remains to be the most convincing method of impact assessment studies in many ways.

For example, Montalbano *et al*. (2015) argues that PSM is the strongest method because it takes into account the presence of non-linearity in the relationship; it can incorporate time varying confounders; and it is easy to construct a counterfactual. In situations of absence of baseline like the case of the present study, many studies have been employing the PSM method (Mendola, 2005; Davis *et al*., 2010; Makate *et al*., 2016; Katungi *et al*., 2017) and the current study employs PSM for the first two objectives.

PSM helps to construct a control group of non-adopters by using the propensity scores and estimate differences in yield, income and food security between adopters and non – adopters that are attributable to new technology so that the farm livelihoods situation that would have been if there was no introduction of the APRON STAR 42 WS – dressed bean seeds is determined. The comparison is done using the average treatment effects (on livelihood outcomes) of the treated abbreviated as ATT, which is said to be a better indicator for measuring impact by PSM.

### 2.4.2 Profitability Analysis

According to Mpogole and Kadigi (2012) many studies employ gross margin to analyze profitability of enterprises. Gross margin however is not a profit because it does not include the depreciation costs, fixed costs, and management costs in its cost outlay (equation 1); rather it is a proxy for profit. Gross margin only helps to show the financial direction of the enterprise.

$$GM_i = \sum_{i=1}^{n}(\mathrm{TR} - \mathrm{TVC}) = \sum P_y Y - \sum P_x X_i \quad \text{....................} \quad (1)$$

Where GM is the gross margin – a proxy for bean profit, TR is the total revenue of selling beans, TVC is the total variable costs of producing beans and $P_q$ and $P_x$ are prices of beans and inputs while $Y$ and $X_i$ are quantities of beans sold and inputs used respectively. An example of studies that have used gross margin as a proxy for profit to analyze profitability of agricultural enterprises include Muhammad-Lawal *et al.* (2012); Mpogole and Kadigi (2012); Song *et al*. (2006); Onu (2009); Abdullahi (2012) and Tshering (2002). This study uses a combination of both gross margin and benefit cost analysis.

### 2.4.3 Factors Influencing Adoption

Adoption is a binary variable where by the farmer chooses to either adopt on not adopt. A farmer can not be in both situations at the same time, hence must choose one. Therefore, studies on factors determining adoption use logit or probit models. The logit model uses logistic distribution function (equation 2), whereas the probit model uses the standard normal distribution function (Wooldridge, 2005).

$$P_i = f(Z_i) = \frac{1}{1+e^{-Z}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where $Z_i = x_i\beta + \varepsilon_i$. Interpretation of the logit model can use either marginal effect or logs of odds ratio, where as the probit model uses only logs of odds ratio. For binary dependent variable one can use any of the two models. This study chooses the logit model whose specification is given in equation 3 because of its two options of interpretation that allows flexibility.

$$Z_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where $\varepsilon_i$ is the error term, $P_i$ is the probability of adopting APRON STAR 42 WS dressed bean seeds, and $1 - P_i$ is the probability of the farmer not to adopt the seeds. Empirical studies that have used the logit model to study factors determining adoption of agricultural technologies are such as Mlenga and Maseko (2015) in Swaziland and Simtowe (2012) in Tanzania.

### 2.4.4 Food Security and Nutrition

"There is no perfect single measure that captures all aspects of food insecurity and that food insecurity is not a homogeneous condition easily measured in economic, energy-availability or anthropometric terms" (Webb *et al*., 2006 in Hendriks, 2015). According to Jones *et al*. (2013), food security metrics may focus on availability, accessibility, stability and utilization of food security over time or some combination of them, and they may be drawn from the national, regional, household or even at individual level. Currently, there is diversity in the measurement tools of food security and nutrition, and it is the intended purpose for the particular measurement tool that determines its validity.

Such metrics as grouped by Jones *et al*. (2013) in terms of their level of measurements, purpose, source of data and scale include prevalence of undernourishment, global hunger index, food consumption score, household diversity score, household hunger scale and anthropometric indices. For the purpose of this study which is basically to indicate the impact on household dietary diversity and measure the changes in food security status due to adoption of the APRON STAR 42 WS – dressed bean seeds, two metrics have been chosen; the FCS and the HDDS.

The FCS is an indicator of food security and nutrition, and is widely used by the World Food Programme (WFP). It uses the frequency weighted diet diversity score, which is calculated using the frequency of consumption of different food groups consumed by a household during the seven days recall before the survey (Maxwell, 2013). It measures caloric intake and diet quality at household level.

$$FCS = a_1x_1 + a_2x_2 + \cdots \ldots\ldots + a_8x_8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where 1…….8 = food groups; a = frequency (7 – day recall), and x = weight. The cut-off values are poor (FCS = 0 – 21); borderline (FCS = 21.5 – 35); and acceptable (FCS >35).

The HDDS is an indicator that is widely promoted by the Food and Agriculture Organization (FAO) of the United Nations (UN). It represents the number of different kinds of food groups consumed by the household over a given period of time usually a 24 – hours recall period, without considering the frequency of which the particular food group is consumed. This indicator is a proxy measure of food access.

The calculation of HDDS does not consider the weight of a particular food group or item in a food group in such a way that it only adds the consumption frequencies. The 16 food groups are re-grouped into seven groups and for each group there is a binary response value: ‘zero’ if the food was not consumed and ‘one’ if was consumed in the past 24 hours recall, hence making a maximum value of HDDS be ‘seven’.

According to the International Food Policy and Research Institute (IFPRI) (2006), as cited by Jones *et al.* (2013), the HDDS of six and above implies good dietary diversity while below 4.5 implies low dietary diversity. The medium dietary diversity ranges from 4.5 – 6. The Spearman’s rho correlations between food security measures is used to compare FCS and HDDS. From Table 1, there should be a strong correlation between the averages FCS and HDDS.

**Table 1: Spearman’s rho correlations between food security measures**

| | CSI | rCSI | HFIAS | HHS | FCS | HDDS | SAFS |
|---|---|---|---|---|---|---|---|
| **CSI** | 1 | 0.95 | 0.85 | 0.44 | -0.51 | -0.56 | 0.45 |
| **rCSI** | 0.95 | 1 | 0.84 | 0.42 | -0.48 | -0.53 | 0.46 |
| **HFIAS** | 0.85 | 0.84 | 1 | 0.48 | -0.57 | -0.63 | 0.46 |
| **HHS** | 0.44 | 0.42 | 0.48 | 1 | -0.34 | -0.34 | 0.23 |
| **FCS** | -0.51 | -0.48 | -0.57 | -0.34 | 1 | 0.92 | -0.24 |
| **HDDS** | -0.56 | -0.53 | -0.63 | -0.34 | 0.92 | 1 | -0.29 |
| **SAFS** | 0.45 | 0.46 | 0.46 | 0.23 | -0.24 | -0.29 | 1 |

*** All correlations significant at the p<0.01 level**

**Source: Vhurumuku (2014).**

Empirical studies, which have used FCS and HDDS to measure food security in Tanzania include that of Wenban-Smith *et al.* (2016) which used FCS in combination with other indicators to identify challenges posed by rapid urbanization on food security in Tanzania. Another study by Duda *et al.* (2018) on drivers of rural-urban migration and impact on food security in rural Tanzania also used FCS and HDDS among other indicators to measure food security. Generally, in order to be able to measure food security in a way that the metric captures all aspects Hendriks (2015) and Maxwell (2013) suggests that more than one indicator should be used.

### 2.4.5 Commercialization of APRON STAR 42 WS - Dressed Bean Seeds

#### 2.4.5.1 Crop Commercialization Level

According to Von Braun (1995), commercializing subsistence agriculture can be on the output side through production by increasing market surplus or on the input side by increasing the use of purchased inputs. Research emphasis however has been much on the supply side than the demand. For example, the adoption study by Asfaw *et al*. (2010) in Ethiopia found that adoption of agricultural technology on pigeon pea has significant impact on commercializing the crop.

The current study extends the analysis by bringing in the demand side into the equation using the commercialization index and estimating the actual input demand and its influencing factors in order to understand the whole picture of bean smallholder commercial orientation in the study area. Assessment of the extent/level of bean commercialization employs the commercialization index as given in equation 5 (Jaleta *et al*., 2009; Von Braun and Kennedy, 1994; Mpogole and Kadigi, 2012).

$$\text{Commercialization Index (CI)} = \frac{\text{Value of Bean Sales in Markets}}{\text{Bean Productivity Value}} * 100\% \ldots\ldots\ldots\ldots (5)$$

It is important to note that, in our case CI measures the extent to which a bean farmer is oriented toward the market considering bean production only. A value of zero implies a completely subsistence-oriented farmer while the closer to 100% the index is, the higher the degree of market orientation. Therefore, the commercialization of APRON STAR 42 WS – dressed bean seeds is implied from the crop commercialization. As the farmer becomes more commercial oriented on a particular crop, he/she is more likely to purchase improved or productivity enhancing technologies in order to meet the market demand and maximize profit. Thus, arguably, crop commercialization and its associated inputs commercialization are complimentary.

#### 2.4.5.2 Driving Forces for Crop Commercialization

The present study determined not only the level/intensity of commercialization, but also the forces that drive the extent of that bean commercialization of farmers in the study area. The farm households' bean commercialization level was estimated by using the household crop commercialization index (equation 5), which is the ratio of monetary value of the beans sold out of the total bean harvest in a season to the monetary value of the total quantity of beans produced in the same season.

In determining the extent and direction of forces driving crop (in this case bean) commercialization, the dependent variable is the CI. The fact that the CI contains zero values (in the present study about 18%), implying completely absence of crop commercialization – and the fact that the interest of analysis is on observations with non-zero values, econometric estimation becomes a bit tricky. In other words, the variable CI as a dependent variable is constrained or has a corner solution hence requiring truncating the observations at the constraint (Wooldridge, 2005).

The 18% observations with zero values of CI makes the use of Ordinary Least Square (OLS) application unfitting, hence the available options are Tobit, Heckman and Cragg's double hurdle models (Mutabazi *et al*., 2013; Jaleta *et al*., 2009). The Tobit model estimates both the magnitude and direction of factors influencing a certain constrained dependent variable without separating the zero and non-zero values (Mertey *et al*., 2012; Tufa *et al*., 2013; Mutabazi *et al*., 2013). The Tobit model assumes that factors influencing participation to the market (decision of commercialize or otherwise) are the same as those influencing the extent/level of commercialization. According to Mutabazi *et al.* (2013), it is not always the case that the explanatory variable explains both the intensity and direction of commercialization level, hence better to adopt the Cragg's double hurdle or Heckman models. The present study choses to firstly apply the Tobit model, and to check robustness of the results, the double hurdle models are also used.

#### 2.4.5.3 Factors Influencing Demand for the APRON STAR 42 WS – Dressed Bean Seeds.

Unlike some other studies such as Von Braun and Kennedy (1994), and Mpogole and Kadigi (2012), this study goes beyond the CI assessment by trying to estimate the input (APRON STAR 42 WS – dressed bean seeds) demand so as to be able to determine factors influencing the technology demand. The demand estimation model is given in equation 6.

$$Q = f(P, r_1, r_2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where, Q is the quantity of APRON STAR 42 WS – Dressed bean seed demanded, P is the price of bean produced using the seeds dressed by APRON STAR 42 WS chemical, $r_1$ is the average prices of other bean seeds, and $r_2$are other costs.

# CHAPTER THREE

## 3.0 METHODOLOGY

### 3.1 Study Areas

The International Center for Tropical Agriculture (CIAT) implemented the Sustainable Intensification Innovation Lab project in Southern highlands of Tanzania. The project aimed to improve productivity of beans through introduction of new technologies because of the existing challenges such as low productivity, diseases and pests, poor quality, lack of access to quality seed and market for the produced grains.

The new technology referred to is the package of quality seed of improved beans varieties, seed dressing chemical (APRON STAR 42 WS), and good agronomic practices. In collaboration with other partners, the project began with establishment of demonstration farms within the selected villages of Mbeya, Songwe, Njombe, and Ruvuma to showcase the two technologies followed by field days to share the results. In the followed season, after the farmers were exposed to the technology and participated in demo farms, the seeds were distributed to agro-dealers for farmers to buy.

This study was carried out in Mbozi and Mbeya districts of Songwe and Mbeya regions, respectively where the seeds were tested for commercialization through distributing them to agro-dealers. These regions are among the major beans producing areas in the country. The regions are characterized by high altitude (>1 000 m above the sea level), adequate precipitation, fertile soil and moderate temperature which favor beans production (Ronner and Giller, 2013; Katungi *et al.*, 2009; Hillocks *et al.*, 2006). Apart from beans, other crops grown in the area include coffee, maize, banana and groundnuts.

## 3.2 Sampling Design and Sample Size

This study used a two-stage with stratification probability design to select the sample (Yansaneh, 2005). Stratification was done at district level where strata were the two districts; Mbozi and Mbeya. In the first stage, primary sampling units which are villages were randomly sampled in each strata from a list of 60 villages. The project was implemented in the 60 villages (Appendix 2) from both regions. Therefore, the intention of going back to the study areas was to assess the extent to which farmers decided to buy the seeds and the livelihood differences among them (buyers and non – buyers).

In the second stage, sampling units, which are farm household's heads were selected proportional to size from each village sampled in the first stage. The list of sampling units were available to the Village Based Agricultural Advisors (VBAA) who were the leaders of groups that were formulated during the demonstration. The list of sampled villages with the number of households sampled from each village is presented in Appendix 3.

In determining the sample size, according to Magnani (1997), the required sample size for impact assessment studies depends on two main issues namely the population characteristics, and the researcher or survey designer. The researcher has control over the level of statistical significance, the statistical power, and the magnitude of change or the comparison group differences that were to be measured. The statistical significance is the level of confidence with which it is preferred to be sure that the observed change would not have occurred by chance.

The statistical power on the other hand refers to the level of confidence with which it is desired to be sure that an actual change will be detected. The population characteristics are number of measurement units in the target population, and the baseline level of the indicator. Therefore, the proposed formula is given as:

$$n = D[(Z_{\alpha} + Z_{\beta})^2 * (sd_1^2 + sd_2^2)/(X_2 - X_1)^2] \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. \ldots \ldots (7)$$

Where; n is the minimum sample size required; D is the design effect (assumed to be a default of 0.5).

The design effect provides a correction for the loss of sampling efficiency resulting from the use of stratification sampling instead of simple random sampling (Magnani, 1997). $X_1$ is the estimated level of an indicator (yield) of the control group; $X_2$ is the expected level of the indicator after the intervention; $sd_1$ and $sd_2$ (obtained from similar studies in similar localities) are expected standard deviations for the groups to be compared; $Z_{\alpha}$is the statistical significance; and $Z_{\beta}$ is the statistical power. The average beans production level among smallholder farmers in in the study area is 400 kg/acre while their potential production if improved seeds and fertilizer and all other good farming practices are adhered is an average of 1 tonne per acre (Kasubiri *et al.*, 2016; BMGF, 2012).

The study by Katungi *et al.* (2016) on impact of climbing bean adoption in productivity in Rwanda reports that standard deviations of traditional ($Sd_1$) and improved ($Sd_2$ ) seeds to be 1230.15 kg/ha and 1323.42 kg/ha respectively. In addition, the average yield for traditional ($X_1$) and improved ($X_2$) varieties were 1095.81 kg/ha and 1323.42 kg/ha respectively. Thus, using the standard parameters of 95% level of significance and 80% power, where $Z_{\alpha} = 1.645$ and $Z_{\beta} = 0.840$ respectively, the sample size is:

$$n = 0.5(1.645 + 0.84)^2 * \frac{1230.15^2 + 1547.57^2}{(1323.42 - 1095.81)^2} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$

$n = 203$

### 3.3 Methods of Data Collection

This study uses the cross-sectional data collected from the study area. Farm household level data such as yield, prices, production cost, assets and other socioeconomic characteristics were collected using a semi-structured questionnaire. A checklist was used to gather detailed information from key informants including one extension officer available in each district, seed companies (distributed dressed seed), agro – dealers (distributed dressed seed), distributors of APRON STAR 42 WS 42 WS. About eight agro-dealers are available in the study area and two seed companies who were the key informants in this study. Some sources of secondary data were used such as be journal articles, reports, books and authorized internet materials.

### 3.4 Techniques of Data Analysis

#### 3.4.1 Propensity Score Matching (PSM)

PSM has been used to address the first and second objectives of this study. PSM helps to construct a control group of non – adopters by using the propensity scores and estimate differences in yield, income and food security status between adopters and non – adopters that are attributable to adoption of APRON STAR 42 WS dressed seeds so that the farm livelihoods situation that would have been if there was no introduction of the seeds is determined.

The comparison is done using the average treatment effects (on livelihood outcomes/indicators) on the treated (ATT) which is said to be a better indicator for measuring impact by PSM (Makate *et al.*, 2017). Generally, if yield of technology adopters is $Y_1$ and that of non-adopters is $Y_0$, then the impact of intervention ($\Delta$) is given as $\Delta = Y_1 - Y_0$. Implementation of PSM usually involves five steps namely: propensity score estimation, checking overlap, selection of matching algorithm, estimating ATT and sensitivity analysis.

**3.4.1.1 Estimating Propensity Scores**

These are conditional probabilities of each bean farmer to adopt the APRON STAR 42 WS treated seeds given their observed characteristics in order to create a counterfactual group, while assuming that a farmer belongs to either adopters group of the new technology or non-adopters group but not both (equation 9).

$$p(X) = p(Z = 1 \mid X) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots \ldots \ldots (9)$$

Where $p(x)$ is the propensity score, Z is the binary dependent variable for adoption decision (Z=1 if a farmer adopts and Z=0 if otherwise), and $X$ are the observable socio-economic characteristics of farmers that may influence adoption decision. The binary logit model as a function of observable characteristics influencing adoption was used to estimate the propensity scores as specified by equations 10.

$$\mathrm{p(X) = Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n + \varepsilon_i} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots (10)$$

$$\begin{aligned}\mathrm{SAdoption} = {} & \beta_0 + \beta_1 \mathrm{Age} + \beta_2 \mathrm{Sex} + \beta_3 \mathrm{MStatus} + \beta_4 \mathrm{Edu} + \beta_5 \mathrm{OOcc} + \beta_6 \mathrm{HHSize} \\ & + \beta_7 \mathrm{FSizeM} + \beta_8 \mathrm{FSizeO} + \beta_9 \mathrm{ExPercep.} + \beta_{10} \mathrm{LOwn} \\ & + \beta_{11} \mathrm{FoodShort.} + \beta_{12} \mathrm{Meals} + \beta_{13} \mathrm{AccessES} + \varepsilon_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . (11)\end{aligned}$$

**Table 2: Description of variables used in estimation of propensity scores**

| Variable | Description | Measurement |
|---|---|---|
| Adoption | Household's adoption status of the APRON STAR 42 WS – dressed bean seeds | D=1 if purchased seeds<br>D=0 if otherwise |
| Age | Age of the household head | Number of years |
| Sex | Sex of the household head | D=1 if male<br>D=0 if female |
| Marital status | Marital status of the household head | D=1 if married<br>D=0 if otherwise |
| Education level | The education level of the household head based on the formal educations system | Number of years spent in schooling |
| Other occupation | Whether the household has economic activities other than farming | D=1 if Yes<br>D=0 if No |
| Household size | Number of households in a family | Number of household members |
| Farm size for the main crop | Size of land allocated for the household's main crop | Number of acres |
| Farm size for other crops | Size of land allocated to crops other than the main crop | Number of acres |
| Perception on seed expensiveness | What the household head think of the price of improved bean seeds | D=1 if too expensive<br>D=0 if not too expensive |
| Land ownership | The household's ownership status for the land used or farming | D=1 if owned by household<br>D=0 if rented |
| Experience of food shortage | Whether the household members have ever experienced situations of food inadequacy in the past 12 months before the day of survey | D=1 if Yes<br>D=0 if no |
| HH daily number of meals | Number of times members of the household take food (including the breakfast) | Number of meals/day |
| Access to extension services | Whether the household has access to extension services or not. | D=1 if Yes<br>D=0 if No |

#### 3.4.1.2 Checking Overlap/Balance

The balancing property states that, the conditional distribution of observable characteristics $(X)$ given the propensity score $p(X)$ is the same in both; the new technology adopters group and non – adopters group (Awotide *et al*., 2015; Makate *et al*., 2015; Montalbano *et al.*, 2015). The aim of checking balance is to avoid comparing the incomparable groups. Therefore, balance was checked using histograms approach implemented in STATA.

#### 3.4.1.3 Choosing the Matching Algorithm

Two matching algorithms were used in order to check the robustness of matching. The algorithms are Nearest Neighbor Matching (NNM) and Kernel Matching (KM). The difference between the two is that NNM is based on the nearest propensity scores between treated and non-treated groups, while the KM matches by subtracting from each outcome observation in the treatment group a weighted average of outcomes in the comparison group (Awotide *et al*., 2015).

#### 3.4.1.4 Estimating the Average Treatment Effects on the Treated (ATT)

##### 3.4.1.4.1 Yield Effect

To estimate the productivity effect resulting from adopting the APRON STAR 42 WS treated bean seeds in terms of yield, the bean production function was specified as indicated by equation 12.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 D_1 + \dots + \beta_n X_n + \varepsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (12)$$

Where $Y_i$ in this case is the productivity impact (yield in kg/acre), $X_i$ are the determinants of yield, $D_1$ is the dummy variable for adoption of improved seeds ($D_1 = 1$ if the farmer adopted, $D_1 = 0$ if otherwise with their yields denoted as $Y_1$ and $Y_0$ respectively. The variables used are indicated by equation 13

$$Bean\,Yield = \beta_0 + \beta_1 Farm\,size + \beta_2 HHSize + \beta_3 D_1 + \beta_4 Ext.ServAccess + \varepsilon_i \ldots\ldots (13)$$

The adoption effect on yield is given by equations 14 and 15.

$$Y = ZY_1 + (1 - Z)Y_0 \ldots\ldots (14)$$

$$ATT = E(Y_1 \mid Z = 1) - E(Y_0 \mid Z = 0) \ldots\ldots (15)$$

Where $Y_1$ denotes the production level of a bean farmer who adopts the technology $(Z = 1)$; and $Y_0$ is the production level of a bean farmer who do not adopt the technology. In other words, if the farmer adopts the technology, the productivity impact will be $Y = Y_1$ and if otherwise, the impact will be $Y = Y_0$ and $Y$ is given by equation 13.

**3.4.1.4.2 Income Effect**

The gross margin is used as a proxy for profit or income attributable to the adoption of APRON STAR 42 WS dressed bean seeds. Gross margin is given by equation 14.

$$GM_i = \sum_{i=1}^{n} (\mathrm{TR} - \mathrm{TVC}) = \sum P_y Y - \sum P_x X_i \ldots\ldots (14)$$

Where TR is the total revenue of selling beans, TVC is the total variable costs of producing beans and $P_q$ and $P_x$ are prices of beans and inputs while $Y$and $X_i$ are quantities of beans sold and inputs used respectively. Recall, Y is derived from equations 13 and 14. Thus, ATT on profit is given by equation 15:

$$ATT = (E((P_1Y_1 \mid Z = 1) - P_xX)) - (E((P_0Y_0 \mid Z = 1) - P_xX)))$$
$$= E(GM_1) - E(GM_0) \ldots\ldots (15)$$

Where $GM_1$ and $GM_0$ are the gross margins for adopters and non-adopters respectively.

Moreover, the benefit – cost analysis has also been used to analyze profitability. The benefit-cost ratio is given as:

$$B - C\ Ratio = \frac{\text{Bean Sales per acre}}{\text{Cost incured per acre}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Where the ratio value of 1 implies that the farmer is breaking even, greater than 1 implies profit and less than one implies that the farmers is getting loss.

### 3.4.1.4.3 Food Security and Nutrition Effect

The Food Security and Nutrition (FSN) effect attributable to adoption of improved bean seeds was also captured through the ATT. The measurement of the FSN used Food Consumption Score (FCS) and Household Dietary Diversity Scale (HDDS) to indicate the food security status among adopters and non-adopters smallholder farmers in the study area. Calculation FCS is given by equation 17.

$$FCS = a_1x_1 + a_2x_2 + \cdots \ldots\ldots + a_8x_8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Where 1…….8 = food group; a = frequency (7-day recall), and x = weight. The cut-off values are poor (FCS = 0–21); borderline (FCS = 21.5–35); and acceptable (FCS >35). The food groups used to calculate both FCS and HDDS are provided in Appendix 1.

HDDS indicator is a proxy measure of food access. The calculation of HDDS does not consider the weight of a particular food group or item in a food group in such a way that it only adds the consumption frequencies. The 16 food groups are re-grouped into seven groups and for each group there is a binary response value; 0 if the food was not consumes and 1 if was consumed, hence making a maximum value of HDDS be 7.

According to IFPRI (2006) as cited by Jones *et al*. (2013), the HDDS of six and above implies good dietary diversity while below 4.5 implies low dietary diversity. The medium dietary diversity ranges from 4.5–6. Therefore, after the FCS and HDDS indicators have been calculated for each individual in both groups; the adopters and then non-adopters, the Average Treatment Effect on the Treated (ATT) are respectively given by equations 19 and 20.

$$\mathrm{ATT} = (\,\mathrm{E}(\,a_1x_1 + a_2x_2 + \cdots + a_8x_8 \mid Z = 1\,)) - (\mathrm{E}(a_1x_1 + a_2x_2 + \cdots . + a_8x_8 \mid Z = 0\,)$$

$$\mathrm{ATT_{FCS}} = (\mathrm{E}(\,\mathrm{FCS} \mid Z = 1\,) - \mathrm{E}(\,\mathrm{FCS} \mid Z = 0\,) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (19)$$

$$\mathrm{ATT_{HDDS}} = (\mathrm{E}(\,\mathrm{HDDS} \mid Z = 1\,) - \mathrm{E}(\,\mathrm{HDDS} \mid Z = 0\,) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

### 3.4.2 Binary Logistic Regression

To address the third objective, a binary logistic regression model was used because the dependent variable, adoption decision is binary. The explanatory variables of interest in this study, which are livelihood outcomes are yield, farm income and food security status whose expected signs are positive.

Other variables which have commonly been addressed in the literature such as farmers awareness of the APRON STAR 42 WS – dressed seeds, age of the household head, marital status, experience of bean farming (in years), years of formal education of the household head, access to extension services, and sex of the household head are also included in the current model whose specification is indicated from equations 21 to 24.

The logistic regression model is based on the logistic probability function given as:

$$P_i = f(Z_i) = \frac{1}{1+e^{-Z}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

Where $P_i$ is the probability of success, the probability that a farmer adopts the new technology, and $Z_i$ represents exposure to factors that may influence adoption, $Z_i = \alpha + \beta X_i$ and its probability is expressed as:

$$Z_i = \ln\left(\frac{P_i}{1 - P_i}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

Thus;

$$Z_i = \ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

$$Z_i = \text{New Technology} = \beta_0 + \beta_1 \text{Age} + \beta_2 \text{Sex} + \beta_3 \text{Education} + \beta_4 \text{Farm Size} + \beta_5 \text{Marital Status} + \beta_6 \text{Extension Serivices} + \beta_7 \text{Household Size} + \beta_8 \text{HHIncome} + \beta_9 \text{Yield} + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

Where $\varepsilon_i$ is the error term, $P_i$ is the probability of adopting the new technology, and $1 - P_i$ is the probability of the farmer not to adopt the new technology.

**Table 3: Description of variables used in the logit regression model**

| Variable | Description | Measurement |
|---|---|---|
| Age | The age of the household head | Number of years |
| Sex | The sex of the household head | D=1 if male<br>D=0 if female |
| Marital Status | Marital status of the household head | D=1 if married<br>D=0 if otherwise |
| Education level | The length of time the household head spent in formal schooling | Number of years |
| Household Size | Size of members in the household | Number of members |
| Bean Yield | Average quantity of beans produced | Kg/acre |
| Extension Service | Household access to extension services | D=1 if access<br>D=0 if no access |
| Farm Size | Size of land allocated for bean production | |
| HH Income | Average annual income of a household collected from farming activities | TZS |

### 3.4.3 APRON STAR 42 WS – Dressed Bean Seeds Demand Analysis and Business Viability

In order to determine the factors influencing demand, this study estimates the demand function of bean seed dressed by the APRON STAR 42 WS chemical. The estimated input demand function enables to do an assessment of the factors determining the demand for the seeds, which this study finds them important in investigation commercialization viability. Estimation of the magnitude of which the factors influence demand was done using a multiple regression as explained in the subsequent paragraphs.

The bean (output) production function (equation 25) is used to derive the APRON STAR 42 WS – dressed bean seed demand function.

$$Y_i = \mathrm{f}\,( X_1, X_2, \ldots .. X_n) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (25)$$

Where, $Y_i$ is the quantity (in Kilograms) of bean produced per acre and the $X_i$s are major factors of production. The current study assumes a Cobb Douglas bean production function with APRON STAR 42 WS dressed seed being one of the input (equation 26).

$$f(X) = Y_i = \mathrm{AX}^{\boldsymbol{\alpha}} X^{\boldsymbol{\beta}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (26)$$

Since the bean farmers are assumed to aim at maximizing profit, a profit function will be obtained by taking the difference between the product of equation 26 and price of bean, and the cost of inputs (equation 27).

$$Profit\ (\pi) = ((f(X) * P) - (\sum(r * X_i\ )) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (27)$$

Where, r is the price of inputs and $X_i$ are inputs including seeds. From the profit function, the APRON STAR 42 WS – dressed bean seed demand function is derived by taking the first order condition with respect to the APRON STAR 42 WS dressed seed input. Solving for X will result to equation 32 which is the APRON STAR 42 WS – dressed bean seed demand as a function of its own price, price of its output, farm income, and the price of other bean seeds (local seeds).

$$\frac{d\pi}{dX_i} = ((f(X) * P) - \left(\sum(r * X_i)\right) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (28)$$

$$\frac{d\pi}{dX_1} = \left(\left(AX_1^{\boldsymbol{\alpha}}X_2^{\boldsymbol{\beta}}\right) * P\right) - \left(\sum(r * X_i)\right) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (29)$$

$$\frac{d\pi}{dX_1} = \left(\alpha\left(AX_1^{\boldsymbol{\alpha-1}}X_2^{\boldsymbol{\beta}}\right) * P\right) - \left(\sum(r * X_i)\right) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

$$\frac{d\pi}{dX_1} = \alpha P\left(AX_1^{\boldsymbol{\alpha-1}}X_2^{\boldsymbol{\beta}}\right) - r = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$$

$$X_1 = f(P, r_1, r_2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (32)$$

Where, $X_1$ is the quantity of APRON STAR 42 WS dressed bean seed demanded, P is the output price produced from APRON STAR 42 WS dressed bean, $r_1$ is the own prices of APRON STAR 42 WS - dressed seeds, and $r_2$ is the price of other seeds (local seeds).

The demand analysis is important in assessing the business viability of the seeds on the demand side because it can be used to check for the degree of responsiveness of the quantity demanded of the seeds when for example the prices are changed. Knowing how farmers demand for seeds responds to changes of various factors enables all seeds producers, traders and policy makers to include farmers into their planning equations.

**Table 4: Description of variables used in demand estimation**

| Variable | Description | Measurement |
|---|---|---|
| Farm Income | Estimate total income of the household from bean sales per season. | TZS/season |
| Bean Price | Average market price of beans in the previous season | TZS/kg |
| Own Seed Price | Average price of APRON STAR 42 WS – dressed bean seeds | TZS/kg |
| Local Bean Seed Price | Average price of seeds for other local varieties | TZS/kg |
| Bean Consumption | Average quantity of beans used for household consumption from the total quantity produced in a season | Kg/season |

### 3.4.4 Tobit and Double Hurdle Regression Models

The purpose is to determine the forces driving the farm household's level/intensity of commercialization. As was argued earlier, for the sake of checking the results' robustness, both the Tobit model, and the double hurdle models were applied. In the Tobit model, it is assumed that both the level of commercialization and the decision to commercialization are driven by the same factors.

Using a limit of zero, the Tobit model is generally expressed in equation 33.

$$Y_i^* = \beta X_i + \varepsilon_i \qquad i = 1, 2, 3, \dots, N \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (33)$$

$$Y_i = Y_i^* \qquad \text{if} \quad Y_i^* > 0$$

$$= 0 \qquad \text{if} \quad Y_i^* \leq 0$$

Where: N is the number of observations; $Y_i$ is the dependent variable; $X_i$ is a vector of independent variables; $\beta$ is a vector of parameters to be estimated; and $\varepsilon_i$ is normally and independently distributed error term with zero mean and constant variance. It is assumed that there is an implicit, stochastic index (latent variable) equal to $Y_i^*$ which is observed only when $> 0$ (Wooldridge, 2005). The specified Tobit model used in this study is given by equation 34. Description of the variables used is provided in Table 5.

$$\mathrm{CI} = \beta_0 + \beta_1\mathrm{Age} + \beta_2\mathrm{Sex} + \beta_3\mathrm{Edu} + \beta_4\mathrm{HHSize} + \beta_5\mathrm{FSize} + \beta_6\mathrm{OFSize} + \beta_7\mathrm{LOwnership} + \beta_8\mathrm{OPrice} + \beta_9\mathrm{AccessES} + \beta_{10}\mathrm{Output} \ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots\ldots\ldots. (34)$$

**Table 5: Description of the variables used in the Tobit, Logit and Truncated Regression Models**

| Variable | Description | Measurement |
|---|---|---|
| CI and Z (Commercialization Index) | The level of commercialization | The ratio of the value of beans sold to the value of total beans produced in a season |
| Y (Commercialization decision) | The dependent variable indicating the farm household's probability of participating to the bean market, taking the value of 1 if a farmer recorded bean sales and 0 if otherwise. | D=1 if Yes; D=0 if No |
| Age | Age of the household head | Number of years |
| Sex | Gender of the household head | D=1 if Male; D=0 if Female |
| Edu (Education) | Education level of the household head | Number of years spent in the formal education system |
| HHsize (Household Size) | Size of the household | Total number of members available in the household |
| FSize (Farm Size) | Size of the land allocated for beans production | Number of acres |
| LOwnership | Household ownership for the land used in beans production | D=1 if owned by household; D=0 if otherwise (eg. Rented) |
| OFSize | Total farm size allocated by the household to crops other than beans | Number of acres |
| OPrice (Output Price) | The price of beans based on the previous season's price | TZS/kg |
| AccessES (Extension Services Access) | The household access to extension services | D=1 if Yes; D=0 if No |
| Output | Total quantity of beans harvested by the household | Kg/acre |

Since the Tobit model does not isolate the intensity and direction effect of driving forces of farmers' commercialization, and the fact that the forces do not always exert such a character, double hurdle models are adopted. Another justification for adopting the Cragg's double hurdle models is that the variable CI has got many values of zero (Fig. 2), implying that some households did not participate to the market at all, and there are no values below zero, hence the Cragg's double hurdle models are recommended.

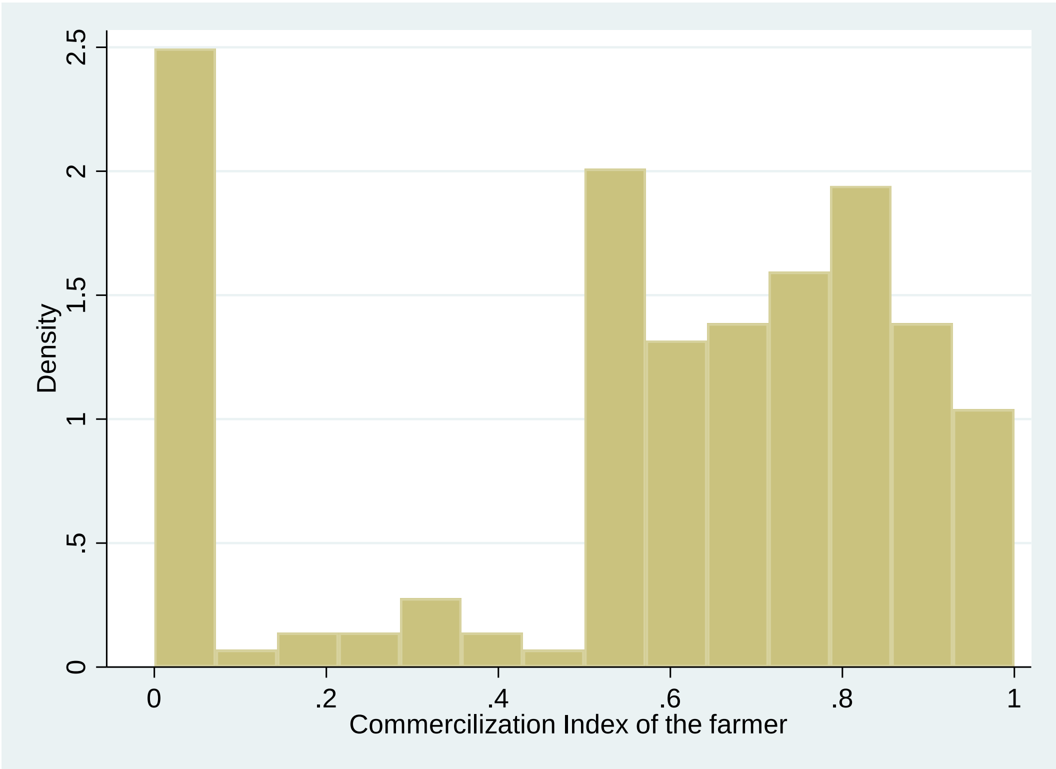


**Figure 2: Density of the CI**

From Fig. 2, it is clear that there is high density of zero values of the dependent variable CI, but in assessing the driving forces of commercialization, the observations of interest are the ones with CI greater than zero, hence all zero values are to be truncated. Double hurdle models are preferred because they isolate the factors influence on commercialization level and that on decision to commercialize.

Implementation of the double hurdle models involves two steps. In the first step (first hurdle), factors determining the farmers' decision to commercialize (market participation) are determined. Since the dependent variable – decision to participate in the market is binary, logit or probit models are used, and in the present study, a logit model safely is chosen with a general expression indicated in equation 35.

$$Y_i^* = \beta X_i + \varepsilon_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (35)$$

$$Y_i = 1 \qquad \text{if} \quad Y_i^* > \tau$$

$$Y_i = 0 \qquad \text{if} \quad Y_i^* \leq \tau$$

Where: $Y_i^*$ is unobservable variable representing a farm household's decision to either participate or not participate in the market; $X_i$ is a vector of independent variables assumed to influence the farmers' decision to participate in the market; $\beta$ is a vector of parameters to be estimated; and $Y_i$ is the binary response for the farm household's status of market participation – assigned a value of 1 if a famer sent beans to the market, and 0 if did not. $\tau$ is the threshold value, which in this case is 0.

Specification of the logit regression model for the first model is given in equation 36

$$Y_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 Age + \beta_2 Sex + \beta_3 Edu + \beta_4 HHSize + \beta_5 FSize + \beta_6 OFSize + \beta_7 LOwnership + \beta_8 OPrice + \beta_9 AccessES + \beta_{10} Output + \varepsilon_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (36)$$

Where: $Y_i$ represents the farm household's decision to either participate or not participate in the bean market and takes the value of 1 if the farmer recorded maize sales and 0 if there was not bean sales record. $P_i$ is the probability of participating in the market, and $1 - P_i$ is the probability of the farmer not to participate in the market. Description of the variables used is also provided in Table 5.

In the second stage (second hurdle), farm level drivers of the intensity to commercialize are determined. A regression model is fitted with data truncated at zero; hence, all values of CI that are equal to or below zero are excluded from the analysis. This procedure results to a truncated model, and it assumes the normality assumption of the population (Tufa *et al*., 2014; Mutabazi *et al*. 2013). Therefore, the truncated regression model is generally expressed as given in equation 37.

$$Z_i^* = \beta X_i + \mu_I \qquad \mu_i \sim N(0, \delta^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (37)$$

$$Z_i = Z_i^* \qquad \text{if} \qquad Z_i^* > 0 \text{ and } Y_i = 1$$

Where: $Z_i$ is the intensity or level of commercialization, which depends on the unobservable variable $Z_i^* > 0$ and conditional to the farm household's decision to commercialize, that is $Y_i = 1$. $\beta$ is the parameter to be estimated, and $\mu_i$ is the error term in the truncated regression which assumes a normal distribution.

The truncated model specified for the present study is given in equation 38.

$$Z_i = \beta_0 + \beta_1 Age + \beta_2 Sex + \beta_3 Edu + \beta_4 HHSize + \beta_5 FSize + \beta_6 OFSize + \beta_7 LOwnership + \beta_8 OPrice + \beta_9 AccessES + \beta_{10} Output + \mu_i \ldots\ldots (38)$$

Where: $Z_i$ is the intensity or level of commercialization that depends conditional to the farm household's decision to commercialize, that is $Y_i = 1$, and consider only the CI values greater than 1, that is $CI_i > 0$. Description of the variables used in the truncated regression model is provided in Table 5.

### 3.4.5 Descriptive Analysis

Descriptive statistics such as frequency, mean, standard deviation and percentages were also used to analyze socio-economic characteristics of farmers in order to compliment on results of the three objectives.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 Farmers' Socio-economic Characteristics

Of the sample size used for the current study, males are 60%, and females are 40%. As Table 6 shows, the average age of the bean farmers is 46 years with minimum and maximum ages being 21 and 76 years respectively. This implies that majority of bean farmers in the study area fall under the age group of working population, hence sufficient labour force exists in the study area. Average years of schooling in the formal education is seven years, which in the country's formal education system it is primary education. That means in average farmers in the study area at least can write, read and count hence if they are educated on the importance of adopting new technologies, they are likely to adopt it.

The average number of members in the household is six people whereby the largest household has 18 members as opposed to the smallest one with three people. There is a big income gap in terms of average annual farm income among bean farmers in the study area. The highest is 70 000 ("000" TZS) whereas the minimum is about 1 911 ("000" TZS). The average annual income is about 1 912 ("000" TZS).

The average farm size for beans production is 1.1 acres whereas that for other crops grown in the study area is 2.44 acres. In other words, famers allocate relatively larger land to other crops compared to beans. This may be translated that bean is not the main crop in the study area. The farmers' average bean production is 370.22 kg/acre. Furthermore, in average, farmers in the study area take three meals per day a number that suggests that food supply and/or accessibility is not a challenge.

**Table 6: Farmers socio-economic characteristics in the study area**

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Age | 45.96 | 11.54 | 21.00 | 76.00 |
| Education level (Years) | 7.29 | 3.35 | 0.00 | 16.00 |
| HH Size (No. HH members) | 5.35 | 2.33 | 1.00 | 18.00 |
| Annual farm Income ("000" TZS) | 1 912.00 | 5 553.00 | 1 911.00 | 70 000.00 |
| Farm Size (Other crops) (Acres) | 2.44 | 2.03 | 0.00 | 18.00 |
| Farm Size (Beans) (Acres) | 1.10 | 1.93 | 0.25 | 25.00 |
| Bean harvest sold (kg) | 233.63 | 397.73 | 1.00 | 2840.00 |
| No. Meals a day | 2.67 | 0.53 | 0.00 | 4.00 |
| Bean Yield (kg/acre) | 370.22 | 518.45 | 7.20 | 4500.00 |

## 4.2 Farmers' Awareness and Adoption Status of APRON STAR 42 WS-dressed Bean Seeds

In studies concerning adoption and impact of agricultural technologies, awareness is an important factor to be considered and off course, the first stage in the adoption process. Results of the current study show that majority of farmers in the study area are aware of the APRON STAR 42 WS – dressed bean seeds. Of the 203 sampled farmers, when asked of whether they are aware of the seeds or not, about 92% responded that, they are aware and 8% were not aware. About 37% of the 92% who were aware adopted the new seeds as opposed to 63% of the same who did not.

All adopters were aware of the new beans, in other words all farmers who were not aware of the new seeds are non - adopters. Moreover, of the 8% of farmers who were not aware, 55.5% are female and the 44.5% are male, whereas among those who are aware, 38.5% are males and 61.5% are females implying that information about the seeds spread wider among women than men. Therefore, it is sufficient to say that, the study was done in an area whose farmers are aware of the APRON STAR 42 WS – dressed bean seeds.

Results further indicate that the major source of information regarding the APRON STAR 42 WS – dressed bean seeds to both adopters and non – adopters in the study area is through VBAA. Fig. 3 indicates that: about 67% of non – adopters obtained information from their VBAAs, 12% from friends, 17% from extension officers and four percent form CIAT. On the other hand, about 37% of adopters obtained information about the APRON STAR 42 WS – bean seeds from their VBAAs, nine percent from friends, 19% from extension officers, one percent from CIAT, 5% from Beula Seed Company, and 25% from the One Acre Fund programme.

These results (Fig. 3) suggest that VBAAs and extension officers are relatively effective means for information dissemination of agricultural information because they are sources from which majority of farmers in the study area obtained their information. More interesting however, is the 25% of the adopters who obtained information from an existing agricultural programme in the study area namely One Acre Fund. Through this programme, farmers were able to acquire the bean seeds in credit through an arrangement that enables them to repay after crop harvest, and off course, this could be the reason that all farmers who obtained information through this source adopted the seeds. Therefore, it is important for different agricultural intervention programmes operating in the same locality to look for the common interests and join forces in order to bring about the big results with the same resources.

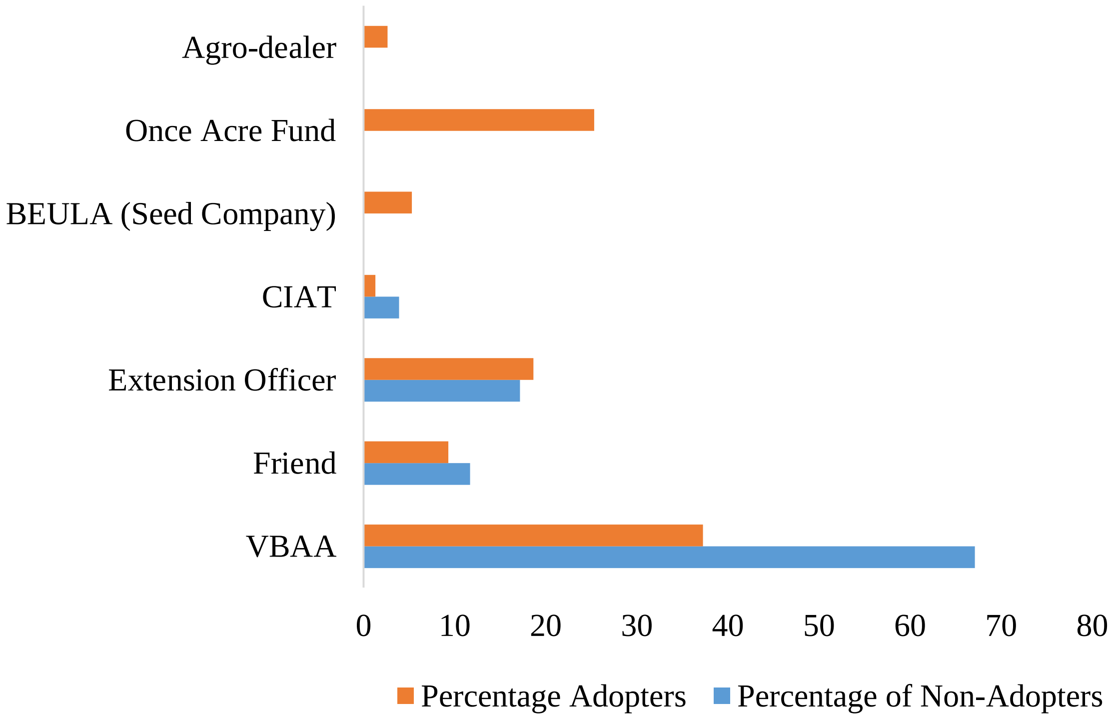


**Figure 3: Sources of information by adoption status about the existence of the APRON STAR 42 WS – dressed bean seeds in the study area**

## 4.3 Factors Influencing Adoption of APRON STAR 42 WS – Dressed Bean Seeds

There is wide knowledge in the literature regarding the determinants of adopting agricultural technologies including improved seeds. This study tries to explore factors beyond the households' socio-economic characteristics, which have been addressed by previous studies (Mlenga and Maseko, 2015; Beshir, 2014; Wossen *et al.*, 2017; Mwangi and Kariuki, 2015; Abebe and Bekele, 2015). The motive is trying to understand the reasons behind the persistence of low adoption of agricultural technologies despite the importance it plays in improving productivity.

The present study therefore provides a supplementary understanding in the existing body of knowledge about the driving forces of adoption. As shown in Table 7, regression results indicate that four variables; farm size, access to extension services, household size and bean yield are significant in influencing farmers' decision to adopt the APRON STAR 42 WS – dressed bean seeds in Mbeya rural and Mbozi districts.

**Table 7: Factors influencing adoption of APRON STAR 42 WS – dressed bean seeds**

| Variable | Coefficient | Standard Error | Z | P>z | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Age | -0.003 | 0.016 | -0.16 | 0.872 | -0.034 | 0.029 |
| Sex | 0.229 | 0.369 | 0.62 | 0.535 | -0.494 | 0.953 |
| Marital Status | 0.452 | 0.804 | 0.56 | 0.574 | -1.124 | 2.028 |
| Education | 0.070 | 0.056 | 1.25 | 0.212 | -0.040 | 0.179 |
| Household size | 0.222 | 0.088 | 2.53 | 0.011** | 0.050 | 0.394 |
| Bean Yield (Kg/Acre) | 0.004 | 0.001 | 4.94 | 00.00*** | 0.003 | 0.006 |
| Access to Ext. Services | 1.094 | 0.385 | 2.84 | 0.004*** | 0.340 | 1.848 |
| Farm Size | 0.360 | 0.217 | 1.66 | 0.097* | -0.065 | 0.786 |
| HH Income | 0.000 | 0.000 | -0.58 | 0.562 | 0.000 | 0.000 |
| Constant | -4.748 | 1.088 | -4.36 | 00.00 | -6.881 | -2.616 |

**Note:** ***, **, * implies significance at $p < 0.01$, $p < 0.05$ and $p < 0.1$ probability levels, respectively

The variable farm size is significant at $p < 0.1$ and is positive implying that the larger the farm size the higher the probability of adopting the APRON STAR 42 WS – dressed seeds. The average farm size of the farmers in the study area is 1.1 acres, therefore according to the current results; farmers with larger farm size are likely to purchase the seeds. Household size is also significant at $p < 0.05$ and its coefficient is also positive implying that households with larger number of members have higher probability of adopting the APRON STAR 42 WS – dressed bean seeds, and vice versa.

This relationship is similar to the study of Simtowe (2012) who found that large farm households have higher probability of adopting improved pigeon pea varieties in Tanzania. In many communities in SSA countries family members are considered as the family labour force therefore it is logic for the results showing a positive relationship between family size and likelihood of adopting agricultural technologies as the family members are sources of labor supply in the household.

Farmers access to extension services and bean yield significantly influence farmers decision to adoption at $p<0.05$ and $p<0.01$ respectively. Farmers with access to extension services have an advantage of obtaining knowledge about good farming practices and the importance of adopting the use of improved seeds. Therefore, access the access to extension services the farmer has, the higher the probability that he/she will adopt the APRON STAR 42 WS – dressed bean seeds.

In terms of the variable yield, the positive sign implies that seeds whose productivity in terms of yield are perceived to be high, have higher probability of being adopted. This was one of the variables of interest for this study as it is the result of famers experience to the technology. Studies that found similar relationship of these variables to probability of adoption include Mlenga and Maseko (2015) in Swaziland, Beshir (2014) in Ethiopia, Wossen *et al*. (2017) in Nigeria, Mwangi and Kariuki (2015), and Abebe and Bekele (2015).

In addition, when the 92% of farmers with an awareness were asked as to whether they have ever used the APRON STAR 42 WS – dressed bean seeds, the response was that 100% of them had ever used the seeds, however 37% of them bought while 63% were given freely during the demonstration farms. When asked as to why did they use such seeds at whatever time they ever used, about 41% responded that they wanted to test the seeds productivity, 11% for consumption and productivity test, 1% used the seeds hoping to secure market for the produce, and about 15% wanted to both test productivity and perceived that the beans have good market (Fig. 4). On the other hand, about 32% used the seeds because they were freely provided. These farmers' responses are important in understanding factors influencing adoption. The 32% of farmers who used the seeds simply because they were free has several implications.

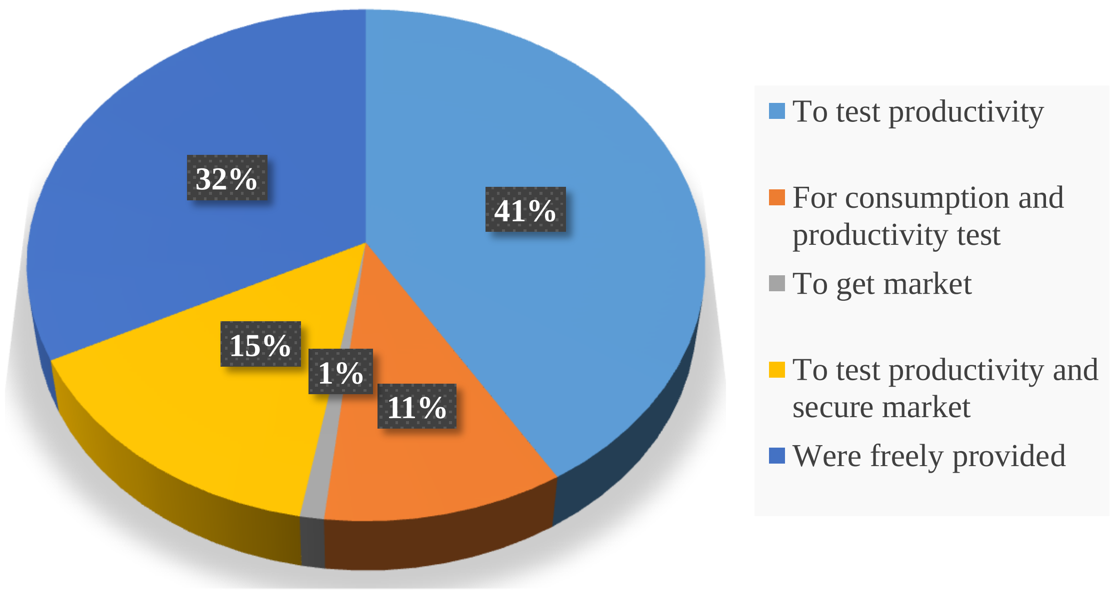


**Figure 4: Farmers' reasons for using the APRON STAR 42 WS – treated bean seeds**

The first implication is that, some farmers are not well informed about the importance of using quality seeds of improved varieties, hence agricultural education is a challenge among farmers in the study area. Secondly, it implies that that 32% of farmers are less commercial oriented, and thirdly, the farmers are poor to afford costs for the seeds because majority of them are poor. Therefore, these factors should be taken into account during interventions.

Additionally, when asked about what factors they consider the most in selecting a particular kind of bean seeds, about 55% of farmers mentioned seed productivity and market for the produce as their main criteria, 36% consider only the productivity, seven percent consider only the market preference, one percent consider yield and the associated costs of production, while about 1% consider the associated costs of production of the seeds (Fig. 5). The implication of the results may imply that research on high yield varieties should go hand in hand with the market research in order to bring about high yield crop varieties which are also preferred by the market.

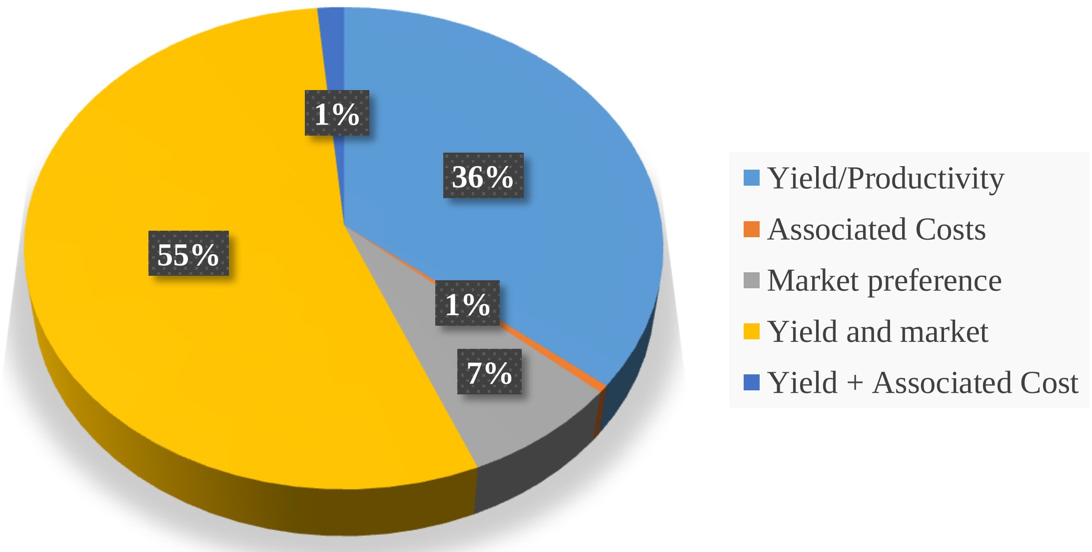


**Figure 5: Farmers' criteria in selecting bean seeds**

### 4.4 Impact of Adopting APRON STAR 42 WS – Dressed Bean Seeds

The current study estimates the impact of adopting improved bean seeds dressed by APRON STAR 42 WS chemical on farmers' livelihood. Specifically, the study estimates productivity effects in terms of bean yield per acre, gross margin effect as a proxy of profitability, and effects on farm households' food security and nutrition status. This study therefore, compares yield, gross margin and food security status between adopters and non

– adopters of the APRON STAR 42 WS – dressed bean seeds to establish the farmers situation on the three variables had the seeds not been introduced in the study area.

The comparison employed the Nearest Neighbor Matching (NNM) and Kernel Matching (KM) algorithms of which the treated unit is matched with the unit in the comparison group that is the closest in terms of propensity scores. The strength of kernel matching is that it used weighted averages of all individuals in the control group to control the counterfactual outcome. It assigns high weight to close observations in terms of propensity score to a treated individual and lower weights to relatively more distant observations. There are off course, other matching algorithms such as caliper/radius matching, stratification matching, and Mahalanobis matching. Each algorithm has its strengths and weaknesses but the two chosen by the present study are commonly used and are considered the strong estimators of the ATT (Adebayo *et al*., 2015; Awotide *et al*., 2015; Makate *et al*., 2017).

The first step was establishing a counterfactual, the comparison group. This was done by estimating the probability of farmers to adopt the APRON STAR 42 WS – dressed bean seeds using similar observable socio-economics characteristics between the adopters and non-adopters. Estimation of farmers' probability to adopt the new bean seeds used the logit model whose regression results are presented in Table 8.

**Table 8: Farmers' probabilities of adopting APRON STAR 42 WS –dressed bean seeds**

| HH characteristics | Coefficient | Standard Error | Z | P>z |
|---|---|---|---|---|
| Age | 0.003 | 0.017 | 0.160 | 0.873 |
| Sex | 0.370 | 0.372 | 1.000 | 0.319 |
| Marital Status | -0.266 | 0.862 | -0.310 | 0.758 |
| Education level | 0.060 | 0.057 | 1.060 | 0.291 |
| Other occupation | 0.094 | 0.518 | 0.180 | 0.856 |
| Household Size | 0.160 | 0.092 | 1.740 | 0.082 |
| Farm Size for main crop | 0.261 | 0.230 | 1.140 | 0.256 |
| Farm size for other crops | 0.129 | 0.108 | 1.190 | 0.233 |
| Seeds | 0.621 | 0.403 | 1.540 | 0.123 |
| Perception on Seed Expensiveness | -1.621 | 0.391 | -4.150 | 0.000 |
| Land Ownership | 0.191 | 0.585 | 0.330 | 0.744 |
| Experience of food shortage | -1.143 | 0.700 | -1.630 | 0.102 |
| HH Number of meals per day | 1.073 | 0.422 | 2.540 | 0.011 |
| Access to extension services | 0.966 | 0.395 | 2.450 | 0.014 |
| Constant | -3.432 | 1.749 | -1.960 | 0.050 |

According to Rosenbaum and Rubin (1983) if two individuals have similar propensity scores, then they are also similar with respect to a set of covariates used for its estimation. In this study, the covariate used to compare farmers are the variables in Table 8. The summary of probabilities indicate that the average probability is 0.375 and the minimum and maximum are 0.003 and 0.993 respectively with standard deviation of 0.259.

In order to avoid comparing the incomparable groups, an overlap check was done firstly by visual inspection of the distribution of propensity score between adopters and non-adopters using the histogram. This procedure enables to check if there is at least one treated unit and one non – treated unit for each value of the propensity score. The histogram suggests a similar distribution of propensity scores between the treated and non-treated group, in other words, between adopters and non-adopters respectively (Fig. 6). From Fig. 6, it is seen in the group of adopters that a small group appears isolated in the very left side. That group however does not affect the estimation because what is looked for is the probability density, the histogram shows the probability densities between the two groups lie within the similar region of common support.

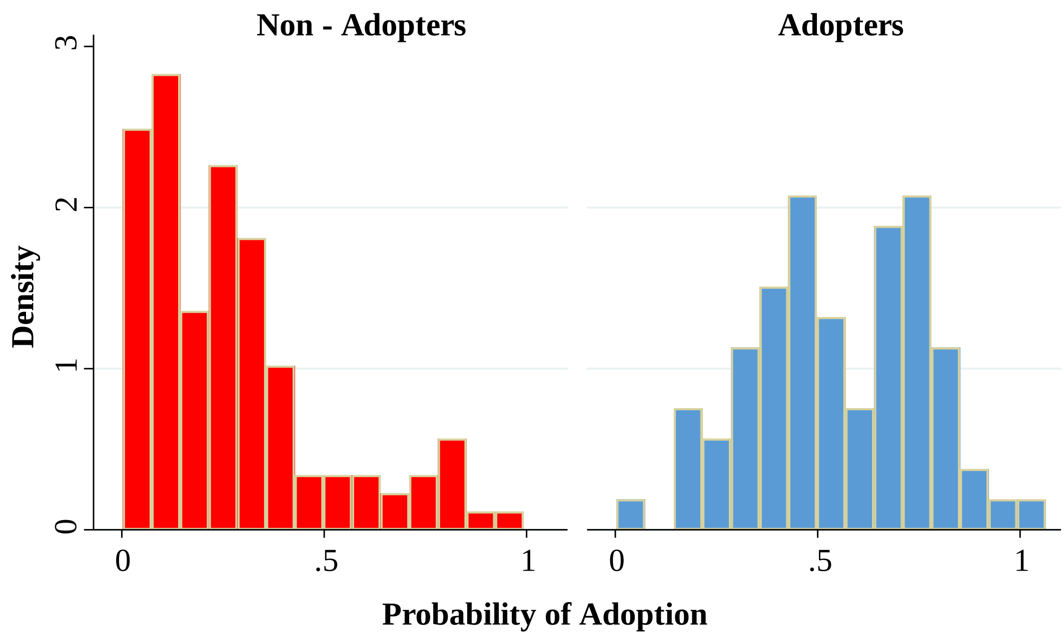


**Figure 2: Distribution of propensity scores among adopter and non-adopters**

Secondly, to ensure that there is a propensity score balance between the two groups, a test to each variable in logit model used to estimate probabilities was done to see if their means are comparable. Results showed that the region of common support is (0.028, 0.993), and test of balancing property of propensity score showed that the balancing property is satisfied. After the balancing property being satisfied, it provided the legitimacy of computing the average output differences between adopters and non – adopters.

### 4.4.1 Yield Impact of Using APRON STAR 42 WS – Dressed Bean Seeds

Both the NNM and KM results show that farmers who adopted the improved bean seeds dressed by APRON STAR 42 WS chemical realized higher harvests than those who did not. The NNM results show that adopters harvested an average of 551.2 kg/acre of beans compared to 211.6 kg/acre of non – adopters, with a difference of 339.7 kg/acre (Table 9). Similar results are observed to the unmatched group of farmers whose difference between adopters and non – adopters is 368.5 kg/acre. The t-statistic for unmatched and matched groups is 5.1 and 4.4 respectively, implying the estimated yield differences between adopters and non-adopters are statistically significant at 1%. These results suggest that APRON STAR 42 WS – treated bean seeds are more productive in terms of kg/acre than non – treated ones.

**Table 9: NNM results of the impact of APRON STAR 42 WS – dressed bean seeds adoption on yield**

| Variable | Sample | Treated | Controls | Diff. | Std. Error | t-stat. |
|---|---|---|---|---|---|---|
| Yield (kg/acre) | Unmatched | 603.9 | 235.4 | 368.5 | 71.7 | 5.1 |
| | ATT | 551.2 | 211.6 | 339.6 | 76.9 | 4.4 |

Similarly, the KM results also indicate that adopters of the APRON STAR 42 WS – dressed bean seeds in the study area experienced higher yield by 385.594 kg/acre compared to the non – adopters (Table 10). The t-statistic is 3.9 implying that the estimated ATT is statistically significant at 1%. KM however, shows a slightly higher difference than that of the NNM though generally both matching indicate that had the new bean seeds were not introduced in the study area; farmers would produce less by about 300 kg/acre.

**Table 10: KM results of the impact of APRON STAR 42 WS – dressed bean seeds adoption on yield**

| No. Treat. | No. Contr. | ATT | Std. Err. | T |
|---|---|---|---|---|
| 75 | 115 | 385.6 | 100.7 | 3.9 |

Results of this study are in line with that of Agegnehu and Medhin (2014) who evaluated and determined the efficacy of APRON STAR 42 WS seed dressing chemical and found that plots received seeds treated with Apron Star chemical had higher yield than the other. Other studies of yield impact of improved seeds with results similar to this study include Bayene and Kassie (2015), Adeoti *et al*. (2017), Katungi *et al*. (2016), Shenkalwa *et al.* (2013), and Bucheyeki and Mmbaga (2013).

### 4.4.2 Impact on Income / Profitability

The ATT on farmers' gross margin indicates that the income effect of adopting APRON STAR 42 WS – dressed bean seeds is positive and statistically significant at 5% (t-statistic=3.9>1.96) hence suggesting that the treated seeds are more profitable compared to non – treated seeds. NNM results shows the ATT in terms of gross margin is 74 493.9 TZS/acre, similar to that of the unmatched individuals whose differences between adopters and non – adopters is also positive amounting to 147 814.1 TZS/acre (Table 11).

**Table 11: NNM results of the effect of adopting APRON STAR 42 WS – dressed bean seeds on farm profitability**

| Variable | Sample | Treated | Controls | Difference | S.E. | t-stat |
|---|---|---|---|---|---|---|
| GM | Unmatched | 259 361.7 | 111 547.5 | 147 814.1 | 36 996.1 | 4 |
| | ATT | 257 596.3 | 183 102.3 | 74 493.9 | 55 598.2 | 3.9 |
| B-C Ratio | Unmatched | 4.7 | 4.6 | 0.1 | 0.9 | 0.1 |
| | ATT | 5.4 | 4.3 | 1.1 | 2.07 | 0.6 |

As indicated in Tables 11, the benefit – cost ratio analysis also shows similar results on both ATT and unmatched individuals, though there is no statistically significant difference between adoptees and non-adopters. Other studies such as Muhammad-Lawal *et al.* (2012); Mpogole and Kadigi (2012); Song *et al*. (2006); Onu (2009); Abdullahi (2012) and Tshering (2002) found that improved seeds had a positive impact on farm profitability. Even though profitability relates to yield, it was worthy to go beyond the yield analysis because of production cost differences among the two groups. The NNM results (Table 11) are similar to that of the KM results (Table 12) which indicates the a statistically significant (t-statistic=2.4>1.96) ATT amounting to 97 524.8 TZS/acre

**Table 12: KM results of the effect of adopting APRON STAR 42 WS – dressed bean seeds on farm profitability (TZS/acre)**

| No. Treat. | No. Contr. | ATT | Std. Err. | t-stat |
|---|---|---|---|---|
| 75 | 115 | 97524.8 | 40923.3 | 2.4 |

### 4.4.3 Impact on Food Security and Nutrition

Measuring food security and nutrition is challenging because of the existence of many metrics, and the complexity of the term itself. The current study used the HDDS and FCS to measure the ATT on food security and nutrition situations among the adopters and non – adopters (Table 13). Results indicate that both adopters and non – adopters have acceptable FCSs whose averages are above 35 implying that they have a good dietary diversity and hence food secure. However, the treated group (adopters) has higher FCS by 3.4 compared to the control group. This suggests that the APRON STAR 42 WS dressed bean seeds improve the food security of farmers in terms of FCS.

In terms of HDDS, both groups had medium dietary diversity score at the time of survey based on the past 24 hours recall. This implies that both groups had a medium access to various groups of food. In both the matched and non-matched farmers, results were the same except that there was a slight difference of scores (1.9) among the unmatched farmers. Statistically, the values of the t-statistic for both indicators of FSN suggest no significant difference of FSN status between the adopters and non-adopters.

**Table 13: Impact of adopting APRON STAR 42 WS dressed – bean seeds on household's food security and nutrition status**

| Variable | Sample | Treated | Controls | Difference | S.E. | t-Statistic |
|---|---|---|---|---|---|---|
| HDDS | Unmatched | 4.6 | 4.7 | -0.05 | 0.2 | 0.3 |
| | ATT | 4.7 | 4.8 | -0.1 | 0.2 | 0.5 |
| FCS | Unmatched | 61.5 | 59.6 | 1.9 | 1.9 | 0.9 |
| | ATT | 61.7 | 58.3 | 3.4 | 3.6 | 0.9 |

The HDDS however indicates results different from that of FCS. Although both groups have a medium dietary diversity, the non – adopters have slightly better scores than the adopters, suggesting that with HDDS adoption of the APRON STAR 42 WS bean seeds does not improve food security. Because HDDS results differ from that of FCS, it suggest that in 24 hours before the day of survey adopters had less food dietary diversity compared to non – adopters. This difference from the FCS results may be attributed by the fact that HDDS does not take into consideration the weight of the particular food in terms of diet, hence high consumption might have been done to foods with low weight to diet diversity.

A similar study by Katungi *et al*. (2017) in Malawi, found that the average effect of adopting improved bean seeds on the household dietary diversity score was about 0.765 implying that the household dietary diversity would have been lower by 0.765 scores had the farmers not adopted the improved beans. Therefore, adoption of APRON STAR 42 WS – dressed bean seeds is important for the improvement of food security and nutrition among farmers in the study area.

Furthermore, descriptive results indicates that generally farmers (of both groups) in the study area have no shortage of food. About 95% of non – adopters households had no worry of not having enough food based on the seven days recall before the day of survey, whereas it is about 97% of their counterpart adopters who did not worry about not having enough food. This implies that food is available and accessible to households in the study area.

Moreover, Table 14 indicates that adopter are better off in term of other selected characteristics of food security and nutrition. Based on the past seven days recall before the day of survey, results indicate that households of adopters have less number of days which: they borrowed food or depended food from friends, restricted adult consumption in order for small children to eat, limited portion size at meal size, and in reducing number of meals per day.

**Table 14: Further household FSN characteristics based on number of days for each variable for the 7 days recall before the day of survey**

| | Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Adopters | Rely on less preferred food | 0.4 | 0.6 | 0 | 2 |
| | Limit portion size at meal | 0.5 | 1.1 | 0 | 7 |
| | Reduce No. meals per day | 0.4 | 0.7 | 0 | 3 |
| | Restrict adult consumption | 0.1 | 0.3 | 0 | 2 |
| | Borrow food | 0.0 | 0.1 | 0 | 1 |
| | No. of meals per day | 2.8 | 0.4 | 2 | 3 |
| Non - Adopters | Rely on less preferred food | 0.5 | 1.0 | 0 | 6 |
| | Limit portion size at meal | 0.6 | 1.2 | 0 | 7 |
| | Reduce No. meals per day | 0.5 | 1.2 | 0 | 7 |
| | Restrict adult consumption | 0.2 | 0.8 | 0 | 7 |
| | Borrow food | 0.1 | 0.5 | 0 | 5 |
| | No. of meals per day | 2.6 | 0.6 | 0 | 4 |

Further descriptive analysis indicates that only 3% of adopters experienced shortage of food during the period of the past 12 months before the survey as opposed to 13% of the non – adopters group. Farmers mentioned that the incidence of shortage of food in the study area occurred during the period between October 2018 and March 2019. About 35% experienced food shortage in January 2019.

When asked about what strategy did the household use to ensure adequate food during the situation of inadequate, all adopters who experienced the incidence used own savings, as compared to 38% of the non – adopters who used the same strategy (Fig. 7). Majority (about 56%) of non – adopters employed a strategy of selling their labour to earn cash while 6% sold livestock (Fig. 7). In other words, results indicate that non – adopters' farm households in the study area are more vulnerable to shock because they do not have sufficient savings and assets, so as an alternative they depend on labour sale different from their adopters counterpart who are resistant to food shortage because of their savings.

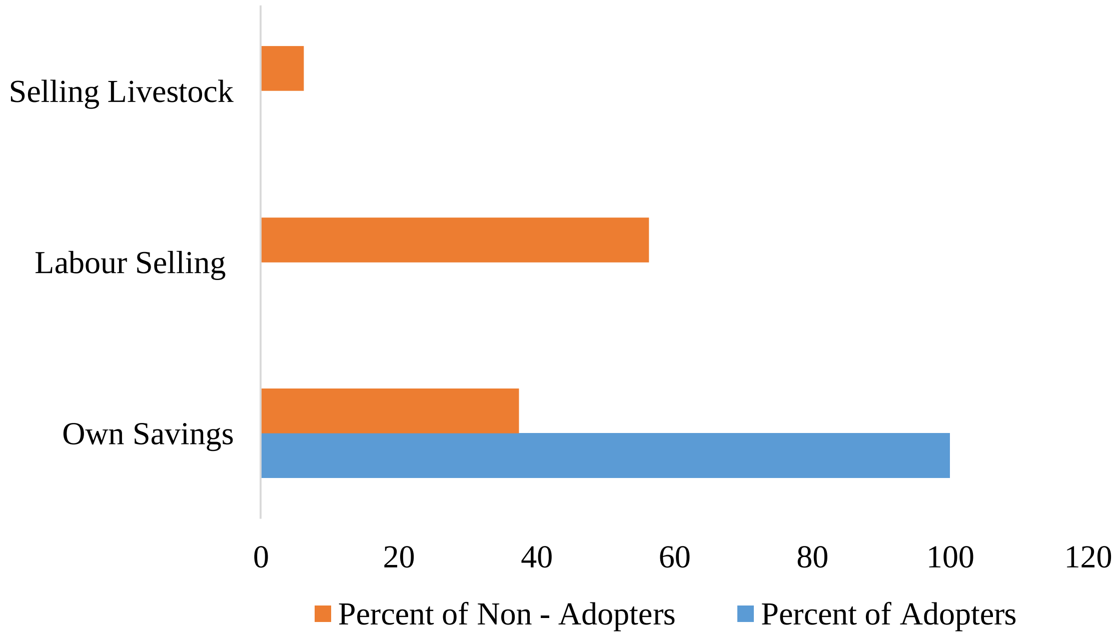


**Figure 7: Farmers' strategies (by adoption status) used to ensure adequate food during the situations of food inadequate.**

## 4.5 Bean Famers' Commercialization and Implied Commercialization of APRION STAR 42 WS – Dressed Bean Seeds in the Study Area

### 4.5.1 Farmers' Commercialization Level

Commercialization of APRON STARS 42 WS – dressed bean seeds depends on the nature of farmers' orientation regarding commercial or production for subsistence (Jaleta *et al.*, 2009; Mutabazi *et al*., 2013; Pingali and Rosegrant, 1995). According to Mpogole and Kadigi (2012), decisions of commercial oriented farmers are based on the market opportunities such as price, place and time; as opposed to the production (subsistence) - oriented farmers whose decisions are driven by the available materials of production of which in many cases are freely provided or obtained.

The literature shows that traditionally, smallholder farmers in rural areas of Africa are subsistence oriented (Jaleta *et al.*, 2009; Mpogole and Kadigi, 2012; Mutabazi *et al*., 2013). The commercialization index for the current study indicates that among the matched farmers, adopters are more commercial oriented than the non – adopters (Table 15). Adopters sold an average of 70% of their yield per acre as opposed to non – adopters whose commercialization index is 0.5 implying that the orientation of both groups is towards commercialization except that adopters are relatively more commercial oriented than the non – adopters.

Alternatively, results of Table 15 indicate that non – adopters do sell half of the total bean produced and consumes the remaining half, thus arguably, with increased production this group is likely to send larger proportion of produce to the market. This implies that there exists an opportunity to commercialize the APRON STAR 42 WS – dressed bean seeds in the study area as both groups' farming orientation is relatively commercial based.

**Table 15: Commercialization level of Bean Farmers in the study area by adoption status**

| Variable | Adoption Status | Mean | Std. Err. | [95% Conf. | Interval] |
|---|---|---|---|---|---|
| **C.I** | Non-Adopters | 0.5 | 0.0 | 0.4 | 0.5 |
| | Adopters | 0.7 | 0.0 | 0.7 | 0.8 |

These findings (Table 15) suggest that, from the output side, the business viability of APRON STAR 42 WS – dressed bean seeds exists. Recalling the yield and gross margin effects, results indicated that adopters harvested higher yield and had gross margin higher than the non – adopters, and the CI indicates that adopters are more commercial - oriented than the non – adopters irrespective of the output price of which this study found no significant difference between the two seeds type. The implication is that the seeds can be commercialized in the study area because in average, farmers in both groups are commercial – oriented with the CI >= 50%, thus as farmers' dependence on the market signals increases, the use of purchased productivity enhancing technologies gets accounted in their equation.

### 4.5.2 Driving Forces for Famers' Commercialization of Beans in the Study Area

#### 4.5.2.1 Factors determining farm household's decision and extent of bean commercialization: The Tobit results

The Tobit regression results indicate that household size, bean farm size, size of land allocated for other crops and access to extension services significantly influence the bean farmers' decision and the extent of commercialization (Table 16). The household size has a significant ($P<0.05$) negative influence on the extent and decision of commercialization because the household's demand for food tend to increase with the size of the household leading to less food be sent to the market as opposed as if the household size was small, holding the production level the same.

The farm size allocated for bean production has a positive influence and statistically significant ($P<0.01$) on the decision and extent of commercialization. It is logically clear and correct that as the land size allocated for bean production increases, the expectation is that the production level will also increase and so does the quantity sold to the marker hence market participation. Likewise, when the land size allocated to production of other crops increases, holding that of bean production constant, the participation and extent of bean commercialization declines because of resource competitiveness. The Tobit results confirms this concept as the variable farm size allocated to production of other crops statistically significant (P<0.1) in negatively influencing the decision and extent of bean commercialization among smallholder farmers in the study area (Table 16).

**Table 16: Tobit regression results on driving forces for bean farmers' decision and extent of commercialization**

| Variables | Coefficients | Std. Err. | t | P>\|t\| | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| Age | 0.000316 | 0.0019 | 0.16 | 0.870 | -0.0035 | 0.0041 |
| Sex | 0.034730 | 0.0447 | 0.78 | 0.438 | -0.0534 | 0.1229 |
| Edu | -0.008098 | 0.0066 | -1.23 | 0.219 | -0.0210 | 0.0048 |
| HHSize | -0.022100 | 0.0099 | -2.23 | 0.027** | -0.0416 | -0.0026 |
| FSize | 0.078838 | 0.0268 | 2.94 | 0.004*** | 0.0260 | 0.1317 |
| Oland | -0.022008 | 0.0129 | -1.71 | 0.089* | -0.0474 | 0.0034 |
| LOwnership | 0.004961 | 0.0674 | 0.07 | 0.941 | -0.1280 | 0.1379 |
| Price | 0.000004 | 0.0001 | 0.04 | 0.968 | -0.0002 | 0.0002 |
| AccessES | 0.123495 | 0.0435 | 2.84 | 0.005** | 0.0377 | 0.2093 |
| Output | 0.000030 | 0.0005 | 0.67 | 0.502 | -0.0001 | 0.0001 |
| Constant | 0.594350 | 0.1636 | 3.63 | 0.000*** | 0.2717 | 0.9170 |
| LR chi2(10) | 22.01 | | | | | |
| Prob > chi2 | 0.0151 | | | | | |
| Pseudo R2 | 0.2024 | | | | | |
| Log likelihood | -43.367029 | | | | | |

**Note:** ***, **, * implies significance at 0.01, 0.05 and 0.1 probability levels, respectively.

Access to extension services has a positive influence on the household's decision and extent of bean commercialization and is statistically significant at P<0.01. This relationship implies that the bean farm household's access to extension services promotes farm productivity and hence leads to production of high yield that could lead to surplus for sale. However, as the Tobit regression results do not draw a boundary between the driving forces for market participation and that for commercialization level, further analysis was done using models that separate the two because they are not the same and hence their influencing factors may differ either.

#### 4.5.2.2 Factors determining farmers' decision to bean commercialization: First hurdle results (Logit)

The logit regression results indicate four variables – education, farm size, household's access to extension services, and output to be statistically significant at determining farmers' decision either to commercialize or not to commercialize beans (Table 17), and hence the inputs (in this case the APRON STAR 42 WS – dressed bean seeds). Farm size for beans production is positive and statistically significant ($P<0.01$) implying that the larger the bean farm, the higher the probability for a farmer to participate in the bean market. This result is consistent with the Tobit results.

Education level however showed a negative influence of determining the farmers decision to participate in bean sales, and was statistically significant at $P<0.01$ (Table 17) This implies that every additional year of schooling of the household head, reduces his probability of participating in the bean market and vice versa. The expectation however was that the educated farmer is likely to participate in the market because of being more knowledgeable about the market information than the less educated ones.

**Table 17: Cragg's First Hurdle Model –The logit regression results for farm level driving forces for commercialization decision (market participation).**

| Variables | Coefficients | Std. Err. | Z | P>\|z\| | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| Age | -0.002 | 0.011 | -0.18 | 0.858 | -0.023 | 0.020 |
| Sex | -0.142 | 0.250 | -0.57 | 0.569 | -0.631 | 0.347 |
| Edu | -0.125 | 0.043 | -2.91 | 0.004*** | -0.209 | -0.041 |
| HHSize | -0.014 | 0.057 | -0.25 | 0.803 | -0.125 | 0.097 |
| FSize | 0.991 | 0.272 | 3.64 | 0.000*** | 0.458 | 1.525 |
| Oland | -0.114 | 0.073 | -1.55 | 0.120 | -0.257 | 0.030 |
| LOwnership | -0.140 | 0.403 | -0.35 | 0.729 | -0.930 | 0.650 |
| Price | 0.000 | 0.001 | -0.96 | 0.339 | -0.001 | 0.001 |
| AccessES | 0.460 | 0.244 | 1.89 | 0.059** | -0.018 | 0.938 |
| Output | 0.003 | 0.001 | 3.37 | 0.001*** | 0.001 | 0.004 |
| Constant | 1.414 | 0.963 | 1.47 | 0.142 | -0.473 | 3.301 |

**Note:** ***, **, * implies significance at 0.01, 0.05 and 0.1 probability levels, respectively.

Both the access to extension services and bean output showed a positive influence in determining farmers decision to commercialize at P<0.05 and P<0.01, respectively. Access to extension services enhances bean productivity as farmers learn on good farming practices. In terms of the yield influence, it is obvious that as the output increases, the farmer is likely to participate in the market because there will be sufficient surplus for sales.

#### 4.5.2.3 Factors determining farmers' extent/level of commercialization: Second hurdle results (Truncated)

After knowing the factors that influence the farm household's decision to commercialize, it is important to assess the factors that determine the level of commercialization. It is important to note that decision to commercialize is not the same as the level of extent of commercialize, so does the forces behind them may differ. All farmers may make a decision to commercialize but each farmers' extent of commercialization will be different from one another, hence necessitating an isolation of the factors behind them.

Results of the truncated regression model (Table 18) indicate that education, household size, access to extension services, and output, significantly influence the farm household's extent of bean commercialization. Every one additional year of schooling increases the about 0.008 proportion of farmers' extent of bean commercialization. A similar role of education on the extent of farmers' commercialization was also found in Martey *et al.* (2012).

**Table 18: Cragg's Second Hurdle Model –The truncated regression results for farm level factors determining the extent/intensity of commercialization**

| Variables | Coefficients | Std. Err. | z | P>\|z\| | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| Age | -0.0009 | 0.00129 | -0.69 | 0.489 | -0.0034 | 0.001642 |
| Sex | 0.0246 | 0.03056 | 0.81 | 0.42 | -0.0353 | 0.084517 |
| Edu | 0.0075 | 0.00429 | 1.75 | 0.079* | -0.0009 | 0.015925 |
| HHSize | -0.0200 | 0.00712 | -2.81 | 0.005*** | -0.0340 | -0.006059 |
| FSize | 0.0045 | 0.01781 | 0.25 | 0.800 | -0.0304 | 0.039422 |
| Oland | 0.0008 | 0.00941 | 0.08 | 0.933 | -0.0177 | 0.019229 |
| LOwnership | -0.0309 | 0.04448 | -0.69 | 0.488 | -0.1181 | 0.056309 |
| OPrice | 0.0001 | 0.00006 | 1.34 | 0.179 | 0.0000 | 0.000202 |
| AccessES | 0.0697 | 0.02966 | 2.35 | 0.019** | 0.0116 | 0.127813 |
| Output | -0.0001 | 0.00003 | -1.81 | 0.071** | -0.0001 | 0.000004 |
| Constant | 0.6747 | 0.10984 | 6.14 | 0.000*** | 0.4594 | 0.889937 |

**Note:** ***, **, * implies significance at 0.01, 0.05 and 0.1 probability levels, respectively.

The household size is has shown a negative influence on determining the farmers extent of bean commercialization at $p < 0.01$ significance level. Large sized households tend to have the high demand for food especially when there is high rate of dependency in the household because few have to produce for many. As a result, less amount of produce will be sold in older to ensure food adequacy in the household. The household size results confirms that of the Tobit regression. Truncated regression results (Table 18) further indicates that access to extension services and the output level both enhances the farmers extent of commercialization at $p < 0.05$ significance level.

#### 4.5.2.4 Matching the Tobit, Logit, and Truncated Regression results and implication to commercial viability of the APRON STAR 42 – dressed bean seeds

Results of the Tobit regression model indicate that household size, farm size for bean, farm size for other crops, and access to extension services as factors determining both decision and extent of commercialization (Table 16). The logit regression results yields education, farm size, access to extension services and bean output as factor' determining farmers' decision to commercialize (Table 17), whereas the truncated regression results (Table 18) found education, household size, access to extension services and output as significant factors influencing the extent of bean commercialization.

In Table 18, while the Tobit results indicate no significant influence of farmers' education level on participation and extent of commercialization, both the logit and truncated regression results show that farmers' education level has a significant influence on participation and extent of commercialization, respectively. The same applies to the variable output, which is not significant in Tobit but significant in both logit and truncated regression results.

Other studies such as Mutabazi *et al*. (2013) in Tanzania, Tufa *et al*. (2013), Berhanu and Jaleta (2010), Asfaw *et al*. (2010) in Ethiopia, Martey *et al*. (2012) in Ghana; and Awotide *et al*. (2016) in Nigeria. Therefore, if the Tobit model alone was considered, farmers' education level and bean output would have been ignored the variable education while it is actually significant. Generally, factors determining the participation and extent of crop commercialization do differ with locations thus it is important to study specific factors to specific localities because generalization will lead to wrong conclusions.

**Table 19: Comparing the Tobit, and the Hurdle regression results regarding the farm level driving forces for bean commercialization.**

| | Tobit regression | | | Logit regression | | | Truncated regression | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **Coefficients** | **Std. Err.** | **P>t** | **Coefficien** | **Std. Err.** | **P>z** | **Coefficient** | **Std. Err.** | **P>z** |
| Age | 0.000316 | 0.00194 | 0.870 | -0.002 | 0.011 | 0.858 | -0.0009 | 0.00129 | 0.489 |
| Sex | 0.034730 | 0.04468 | 0.438 | -0.142 | 0.250 | 0.569 | 0.0246 | 0.03056 | 0.420 |
| Edu | -0.008098 | 0.00656 | 0.219 | -0.125 | 0.043 | 0.004*** | 0.0075 | 0.00429 | 0.079* |
| HHSize | -0.022100 | 0.00989 | 0.027** | -0.014 | 0.057 | 0.803 | -0.0200 | 0.00712 | 0.005*** |
| FSize | 0.078838 | 0.02680 | 0.004*** | 0.991 | 0.272 | 0.000*** | 0.0045 | 0.01781 | 0.800 |
| Oland | -0.022008 | 0.01286 | 0.089* | -0.114 | 0.073 | 0.120 | 0.0008 | 0.00941 | 0.933 |
| LOwnershi | 0.004961 | 0.06740 | 0.941 | -0.140 | 0.403 | 0.729 | -0.0309 | 0.04448 | 0.488 |
| Price | 0.000004 | 0.00010 | 0.968 | 0.000 | 0.001 | 0.339 | 0.0001 | 0.00006 | 0.179 |
| AccessES | 0.123495 | 0.04350 | 0.005*** | 0.460 | 0.244 | 0.059* | 0.0697 | 0.02966 | 0.019** |
| Output | 0.000030 | 0.00005 | 0.502 | 0.003 | 0.001 | 0.001*** | -0.0001 | 0.00003 | 0.071* |
| Constant | 0.594350 | 0.16357 | 0.000*** | 1.414 | 0.963 | 0.142 | 0.6747 | 0.10984 | 0.000*** |

**Note:** ***, **, * implies significance at 0.01, 0.05 and 0.1 probability levels, respectively.

The Tobit regression results also shows that household size has a negative significant influence on farmers’ participation and extent of commercialization while the logit shows no significant influence on participation. The truncated regression model shows the negative influence of household size on extent of commercialization, hence suggesting that the Tobit model wrongly assumed that household size influence the farmers’ decisions to whether to participate or not participate in the bean market. In addition, it is logically true for the household size to reduce the extent of commercialization because the larger the household the higher the demand for food, hence a reducing the proportion that could be sent to the market.

Similarly, the farm size exerts a significant positive influence in both participation and extent of commercialization as per the Tobit regression results. In terms of participation the logit model confirms the significance the variable farm size whilst the truncated regression model shows that farm size has no significant influence of the extent of commercialization. This is another oversight of the Tobit model's assumption that factors determining decision and extent of commercialization are the same.

Only the Tobit regression results indicate that the farm size located into production of crops other than beans is significant at influencing both participation and extent of commercialization. The logit and truncated results indicate that the variable is not significant. Land size of other crops was used as proxy for diversification, therefore crop diversification do not influence of farmers' decision and extent of commercialization.

The implication of these results on the commercialization of the APRON STAR 42 WS – dressed bean seeds emanate from the conceptualization of bean commercialization from the supply (output side). That is, crops commercialization triggers the use of productivity enhancing technologies in order to increase production to meet the market demand. Thus, in this context the input of interest is the bean seeds treated by the APRON STAR 42 WS dressing chemical. Therefore, commercialization of these seeds is implied from commercialization of the crop (beans), of which its driving forces has been determined.

Therefore, the variables education level, household size, farm size located for bean production, farm size located for other crops, access to extension services, and bean output are factors to be taken into consideration in promoting bean commercialization and so its associated inputs. For example, the average education level of farmers in the study area is seven years that is standard seven, which means these farmers can at least read and count. This implies that given that the variable has positive and significance on influencing bean commercialization, there is a viability of commercialization seeds because farmers can be taught and understand the importance of using improved seeds. Similarly, the access to extension service, once improved will indirectly trigger the use of productivity enhancing technologies.

### 4.5.3 Demand Estimate of APRON STAR 42 WS – Dressed Bean Seeds

The APRON STAR 42 WS – dressed bean seed demand model was set as a function of its own price (in TZS/kg, the price of local bean seeds (in TZS/kg), farm income (in TZS from bean sales per season) and quantity of bean consumed out of the total quantity harvested in a season (in kg). All these data were collected in the study area. Initially, the linear regression results of the model showed only the bean consumption variable significant at p<0.01 with positive relationship with quantity demanded.

The model transformation into natural logarithm (equation 39) made all variable but bean price significant in influencing the seed demand (Table 20).

$$\ln Q_d = 8.132 + 0.190\ln(\text{Income}) + 0.101\ln(\text{BeanPrice}) - 0.933\ln(\text{OwnSeedPrice}) + 0.356\ln(\text{LBeanPrice}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (39)$$

The R-square test indicates that 19.55% of the observed variation in the quantity demanded of the seeds is explained by the variables in the model. The Variance Inflation Factor (VIF) test was done and shows no severe collinearity exists among the independent variables in the model (Table 20).

**Table 20: Multiple regression estimates of the factors affecting demand of the APRON STAR 42 WS – dressed bean seeds**

| Variables | Coefficient | Standard Error | t | P>\|t\| | VIF |
|---|---|---|---|---|---|
| Natural Log of Farm Income | 0.190 | 0.059 | 3.230 | 0.001*** | 1.280 |
| Natural Log of Bean Price | 0.101 | 0.271 | 0.370 | 0.709 | 1.270 |
| Natural Log of Own Seed Price | -0.933 | 0.514 | -1.810 | 0.071* | 1.080 |
| Natural Log of Local Bean Seed Prices | 0.356 | 0.190 | 1.870 | 0.063* | 1.070 |
| Natural Log of Bean Consumption | 0.365 | 0.058 | 6.250 | 0.000*** | 1.020 |
| Constant | 8.132 | 4.705 | 1.730 | 0.086 | |

**Note:** ***, **, * implies significance at 0.01, 0.05 and 0.1 probability levels, respectively.

Since the model is in form of natural logarithm, the coefficients are elasticities and are interpreted just as other elasticities. The variables farm income, price of local bean seeds, and consumption have positive relationship with the quantity demanded of the APRON STAR 42 WS – dressed bean seeds at $p<0.001$, $p<0.063$ and $p<0.000$ respectively. The income coefficient implies that, holding constant the bean price, price of local bean seeds, own price and bean consumption, a 1% increase (decrease) of income leads to 0.19% increase (decrease) in quantity demanded of the APRON STAR 42 WS – dressed bean seeds. This is true because ceteris paribus an increase in income increases the purchasing power leading to farmers' demand to increase. This change however is relatively low, implying that farmers are less responsive to income change regarding the purchase of the APRON STAR 42 WS – dressed bean seeds.

There is a positive elasticity between the quantity demanded of APRON STAR 42 WS – dressed bean seed and the price of other local bean seeds. A 1% rise (fall) of the price of local bean seeds will lead to about 0.36% rise (fall) in the quantity demanded of APRON STAR 42 WS – dressed bean seeds holding other variables in the model constant. This indicates that farmers opt for the alternative seeds when the price of the other rises and vice versa, or else remaining constant.

On the other hand, 1% increase (decrease) in bean consumption out of the total quantity harvested in a season leads to 0.37% increase (decrease) in quantity demanded of APRON STAR 42 WS – dressed bean seeds. This farmers' response however was expected to be otherwise, as increased purchase of inputs would mean commercialization, which would signify more output sold than being consumed as results suggests. The implication of this variable therefore is that farmers in the study area are subsistence – oriented, hence contradicting the commercialization index. However, the positive relationship between the seeds quantity demanded and yield consumption could imply that the increased consumption triggers more demand of the inputs in order to increase yield for household consumption.

Moreover, there is a relative strong negative own price elasticity implying that farmers' response to quantity demanded due to change of own price is relatively of large extent compared to the other variables. A 1% increase (decrease) of the own price of APRON STAR 42 WS – dressed bean seeds leads to 0.9% decrease (increase) of its quantity demanded. These results suggest that, to increase farmers' demand of seeds in the study area the optimal area of intervention is on the seed price. These results conform to that of Ogola *et al.* (2012) who found similar response of quantity demanded of potato seeds to its own price in Kenya.

The price of bean output exhibits a positive elasticity on quantity demanded of the APRON STAR 42 WS – dressed bean seeds though not significantly. The nature of relationship however is logical and theoretically correct as when price of output rise keeping other factors constant producers will benefit by securing more revenue from higher price, which is an incentive for more production and hence higher demand for inputs. But the current study finds no significance on output price changes on influencing seed demand, possibly because there is generally no significant difference in market price of beans between those produced by local seeds and that of APRON STAR 42 WS – dressed bean seeds.

Generally, factors affecting the quantity demand of APRON STAR 42 WS – dressed bean seeds in the study area are own seed price, price of local bean seeds, farm income and bean consumption. Own seeds price affects strongly its quantity demanded. This suggests an existence of business viability of the seeds in the study area on the demand side with an adjustment variable being own price. Results further implies that a small change (1%) in price of the seeds leads to relatively higher change (0.9%) in its demand as compared to other variables in the model, hence suggesting that for seed traders and producers to increase the demand of improved seeds in the area, it requires a decrease of the seeds price. However, in terms of types of elasticities, all variables are inelastic implying that a proportional change of the variable results to less than proportional change in the quantity demanded of the seeds.

# CHAPTER FIVE

## 5.0 SUMMARRY, CONCLUSIONS, RECOMMENDATIONS AND POLICY IMPLICATIONS

### 5.1 Summary and Conclusions

The overall objective of the study was to evaluate the impact of adopting agricultural technologies using the case of APRON STAR 42 WS – dressed bean seeds on livelihoods of smallholder farmers in Mbeya and Mbozi districts in Mbeya and Songwe regions, respectively. Specifically, the study analyzed the productivity, profit and food security and nutrition effects attributable to the technology adoption, the actual seed demand and farmers' orientation with regard to commercial or subsistence.

A propensity score matching technique was employed to construct the counterfactual in order to isolate the livelihood impacts attributable to adoption of the technology. Main indicators of livelihoods impact were farm income and food security and nutrition statuses. The food security and nutrition status was mainly measured using the FCS and HDDS with a supplement of other FSN characteristics. The farmers' commercial orientation was assessed using the actual demand analysis of the seeds and the commercialization index. To assess the decision and extent of bean commercialization both the Tobit and Cragg's double hurdle regression models were used and their results compared.

Descriptive results indicated that majority of bean farmers in the study area fall under the working population category with minimum and maximum ages being 21 and 76 years respectively. The average farmers' farm size for bean production is 1.1 acres, implying a typical small-scale production in terms of farm size. In terms of awareness, results indicates that about 92% of farmers are aware of the APRON STAR 42 WS – treated seeds, therefore, it is concluded that farmers in the study area were aware of the existence of the new technology.

Adoption level is 37% among the 203 sampled farmers and of the 16 farmers who were not aware, 63% were female and 38% were male implying that information flow among women is relatively higher compared to men. Regarding the decision to adopt on not adopt the seeds, results suggest that four variables; farm size, access to extension services, household size and bean yield are significant in influencing farmers decision. Coefficients of all the four variables exhibited a positive sign. Therefore, in promoting the seeds in our case a special care should be taken to these variables in order to increase adoption.

The results further indicate that adopting APRON STAR 42 WS – treated bean seeds improves households' farm income, food security and nutrition status, and productivity. Despite the selling price having no significant difference between the two seed types, gross margin per acre for adopters is still above that of non – adopters. During the group discussion with farmers however, the major complains was about the higher price of the improved seeds compared to the local ones. These complains are confirmed by the actual demand analysis that showed that majority of farmers bought local seeds because they are cheap. Own seed price, price of other seeds, beans consumption and income were found to be significant in determining the quantity demanded of the seeds with own price being relatively more responsive than other variables.

Results of the Tobit regression model indicated that household size, farm size for bean, farm size for other crops, and access to extension services as factors determining both decision and extent of commercialization. The logit regression results found education, farm size, access to extension services and bean output as factor' determining farmers' decision to commercialize, whereas the truncated regression results found education, household size, access to extension services and output as significant factors influencing the extent of bean commercialization.

Therefore, recalling the purpose of this study and the acquired findings, a conclusion is made as follows: firstly, there exists a commercialization viability of the APRON STAR 42 WS – dressed bean seeds in the study area. Secondly, using the APRON STAR 42 WS – dressed bean seeds improves the livelihoods of smallholder farmers in the study area in terms of income and food security and nutrition among others, therefore the current study proposes that the seeds can be recommended for use among smallholder farmers in the study area.

## 5.2 Recommendations

Centered on the interpretation and discussion of the findings for each specific objective of this study, the following are being recommended: Firstly, the study recommends that the use and/or adoption of improved agricultural technologies should be promoted because they improve the livelihood of smallholder farmers. Results of the first two objectives of this study indicate that adoption of APRON STAR 42 WS – dressed bean seeds has improved the smallholder farmers' productivity, farm income, and food security and nutrition statuses. From results of the third objective, household size, farm size, access to extension, and output should be taken into consideration in promoting the use of agricultural technologies among smallholder farmers.

Secondly, price reduction of the APRON STARS 42 WS – dressed bean seeds should be made in order to stimulate its demand. From the fourth objective, results indicate that 1% decrease of price leads to 0.9% increase in quantity demanded of the seeds, a change which is nearly unitary. Therefore, given the fact that the use of certified seeds among smallholder farmers in Tanzania is low (about 5%) as reported by ASARECA/KIT (2014), results of the current study indicate that adjustment of the own seed price stimulates its demand at relatively higher rate compared to other stimulants (consumption, price of other bean seeds, and bean yield price).

Thirdly, it is recommended that given the nature of smallholder farmers in the study area, buying seeds in credit arrangements can be established to improve farmers' access to seeds. Even though farmers' credit issues were not part of analysis of this study, results indicated that about 25% of adopters made decisions to adopt the seeds because they were able to buy them in credit arrangements (as a strategy to improve accessibility to improved seeds) through the 'one acre fund programme' available in the study area. However, in implementing this strategy, risks and costs of credits should be thoroughly assessed.

Fourthly, in further increasing the seeds accessibility, the study recommends that the distribution channels of the APRON STAR 42 WS – dressed bean seeds be revisited, in particular the linkage between the seed producers, agro-dealers, VBAAs and farmers – the final consumer of the technology. The study found an information gap along the distribution channels as some farmers and even the VBAAs reported to have no information of where they can buy particular seeds. Since majority of both adopters (about 37%) and non-adopters (about 67%) obtained information about the APRON STAR 42 WS – dressed bean seeds from the VBAAs, it suggests that if seeds producers will deliver seeds to VBAAs, farmers will easily access them.

## 5.2 Policy Implications

Results of the present study have several policy implications. The first policy implication with regard to the seeds' price is that, policy makers can use the own price of seeds as a tool to adjust quantity demand of the seeds because the actual demand analysis has shown a relative highly responsiveness to change in own price of seeds. Results indicated that a

1% increase (decrease) of seed price results to 0.9% decrease (increase) of the quantity demanded of the seeds, therefore, for policy makers, the entry point of intervening demand is own seeds price. However, before implementation of any seeds' price adjustment schemes, it is important that an assessment of actual cost of the seeds production is made along its whole value chain in order enable the policy and decision makers to have the evidence based decision making that considers interests of both seed producers and consumers (farmers).

The second policy implication is that, rural agricultural development interventions should promote adoption of improved agricultural technologies in order to improve the livelihood of smallholder farmers. Results of the current study indicates that adoption of improved bean seeds have improved the farmers' productivity, income and the food security and nutrition statuses, thus, suggesting that in improving the wellbeing of rural people through agriculture, promoting adoption of new agricultural technologies is inevitable.

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# APPENDICES

## Appendix 1: Food Groups and calculation of FCS

| S/N | Food Groups | Number of days eaten in past 7 days (Ranges form (0-7) | Weight for FSC | | FCS |
|---|---|---|---|---|---|
| | | | Food groups | Weight | |
| 1. | **Cereals and grain:** Rice, pasta, bread / cake and / or donuts, sorghum, millet, maize, fonio | | **1. Cereals and Tubers** | 2 | |
| 2. | **Roots and tubers:** potato, yam, cassava, white sweet potato, taro and / or other tubers | | | | |
| 3. | **Legumes / nuts :** beans, cowpeas, peanuts, lentils, nut, soy, pigeon pea and / or other nuts | | **2. Pulses** | 3 | |
| 4. | **Orange vegetables (vegetables rich in Vitamin A):** carrot, red pepper, pumpkin, orange sweet potatoes, | | **3. Vegetables** | 1 | |
| 5. | **Green leafy vegetables:**, spinach, broccoli, amaranth and / or other dark green leaves, cassava leaves | | | | |
| 6. | **Other vegetables:** onion, tomatoes, cucumber, radishes, green beans, peas, lettuce, etc. | | | | |
| 7. | **Orange fruits (Fruits rich in Vitamin A):** mango, papaya, apricot, peach | | **4. Fruits** | 1 | |
| 8. | **Other Fruits:** banana, apple, lemon, tangerine | | | | |
| 9. | **Meat:** goat, beef, chicken, pork, blood (meat in large quantities and not as a condiment) | | **5. Meat and Fish** | 4 | |
| 10. | **Liver, kidney, heart and / or other organ meats** | | | | |
| 11. | **Fish / Shellfish:** fish, including canned tuna, escargot, and / or other seafood | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | (fish in large quantities and not as a condiment) | | | | |
| 12. | **Eggs** | | | | |
| 13. | **Milk and other dairy products**: fresh milk / sour, yogurt, cheese, other dairy products<br>(Exclude margarine / butter or small amounts of milk for tea / coffee) | | **6. Milk** | 4 | |
| 14. | **Oil / fat / butter:** vegetable oil, palm oil, shea butter, margarine, other fats / oil | | **7. Oil** | 0.5 | |
| 15. | **Sugar, or sweet:** sugar, honey, jam, cakes, candy, cookies, pastries, cakes and other sweet (sugary drinks) | | **7. Sugar** | 0.5 | |
| 16. | **Condiments / Spices:** tea, coffee / cocoa, salt, garlic, spices, yeast / baking powder, lanwin, tomato / sauce, meat or fish as a condiment, condiments including small amount of milk / tea coffee. | | | | |

**Appendix 2: A list of villages from which sampled villages were drawn**

| Village Name | District |
|---|---|
| ICHENJEZYA | Mbozi |
| MASANGULA | Mbozi |
| ILEMBO | Mbozi |
| LUNGWA | Mbozi |
| NSENGA | Mbozi |
| ISANDULA | Mbozi |
| NANSAMA | Mbozi |
| CHAPWA | Mbozi |
| LUMBILA | Mbozi |
| IGALE | Mbozi |
| ISINIZYA | Mbozi |
| WERU (II) | Mbozi |
| NYIMBILI | Mbozi |
| CHIMBUYA | Mbozi |
| ISANSA | Mbozi |
| IGUNDA | Mbozi |
| SAKAMWELA | Mbozi |
| HASMBA | Mbozi |
| MAGAMBA | Mbozi |
| MANTENGU (B) | Mbozi |
| LUDEWA | Mbozi |
| IKOMELA | Mbozi |
| IWALANJE | Mbozi |
| KILIMAMPIMBI | Mbozi |
| MBIMBA | Mbozi |
| UKWERE | Mbozi |
| IDIBIRA | Mbozi |
| IPYANA | Mbozi |
| IHOWA | Mbozi |
| HANSEKETWA | Mbozi |
| MALOWE | Mbeya |

| | |
|---|---|
| SHISONTA | Mbeya |
| IDIWILI | Mbeya |
| JOJO | Mbeya |
| NJELENJE | Mbeya |
| LUSUNGO | Mbeya |
| INYALA | Mbeya |
| IWALA | Mbeya |
| MAPOGORO | Mbeya |
| IZUMBWE | Mbeya |
| IDUGUMBI | Mbeya |
| MWASELELA | Mbeya |
| NYALANYALA | Mbeya |
| IDUNDA | Mbeya |
| SHIZINGO | Mbeya |
| IPINDA | Mbeya |
| MAKWENJE | Mbeya |
| IYAWAYA | Mbeya |
| SHIGAMBA | Mbeya |
| ITEWE | Mbeya |
| DARAJANI | Mbeya |
| MUVWA | Mbeya |
| INOLO | Mbeya |
| NSAMBIA | Mbeya |
| GALIJEMBE | Mbeya |
| TEMBELA | Mbeya |
| MSHEWE | Mbeya |
| ISONGWA | Mbeya |
| IWOWO | Mbeya |
| MWASHOMA | Mbeya |

**Appendix 3: A list of sampled villages and number of farm households sampled from each village**

| Village name | Sample (n) | Percentages |
|---|---|---|
| BARA | 1 | .5 |
| DARAJANI | 6 | 3.0 |
| HANGUMBA | 1 | .5 |
| HANSEKET | 11 | 5.4 |
| HASAMBA | 7 | 3.4 |
| HATELELE | 5 | 2.5 |
| IDIWILI | 10 | 4.9 |
| IDUGUMBI | 7 | 3.4 |
| IGANDUKA | 1 | .5 |
| IGUNDA | 3 | 1.5 |
| ILEA | 2 | 1.0 |
| ILEMBO | 5 | 2.5 |
| ISONGWA | 12 | 5.9 |
| ITAKA | 1 | .5 |
| ITAKA B | 7 | 3.4 |
| ITEKA | 2 | 1.0 |
| ITEWE | 9 | 4.4 |
| ITUMPI | 1 | .5 |
| IWALA | 11 | 5.4 |
| KATELELE | 3 | 1.5 |
| LUANDA | 2 | 1.0 |
| LUBILA | 1 | .5 |
| LUMBILA | 8 | 3.9 |
| LUNGWA | 12 | 5.9 |
| LWATI | 3 | 1.5 |
| MAGAMBA | 1 | .5 |
| MAHENJEB | 1 | .5 |
| MANTENGU | 4 | 2.0 |
| MLOWO | 2 | 1.0 |
| MPITO | 1 | .5 |
| MSHEWE | 8 | 3.9 |
| MSIYA | 1 | .5 |
| MUVWA | 10 | 4.9 |
| MYOVIZI | 1 | .5 |
| NANSAMA | 1 | .5 |
| SAKAMWEL | 9 | 4.4 |
| SAMBEWE | 3 | 1.5 |
| SHAJI | 3 | 1.5 |
| SHASYA | 1 | .5 |
| SHUMOLA | 2 | 1.0 |
| SHUMOLWA | 1 | .5 |
| UKWILE | 15 | 7.4 |
| VWAWA | 1 | .5 |
| WASA | 1 | .5 |
| WELU | 1 | .5 |
| ZELEZETA | 5 | 2.5 |
| **Total** | **203** | **100.0** |

**Appendix 4: A household's survey questionnaire on Impact of Improved Bean Seeds Adoption on Livelihood of Farm Households Mbeya rural and Mbozi Districts, Tanzania**

**A. Introduction**

| | |
|---|---|
| **Name of Household Head (Optional)** | |
| **Household Adoption Status**<br>1 = Adopter<br>2 = Non-adopter | |
| **Village** | |
| **Ward** | |
| **District** | |
| **Region** | |
| **Enumerator's name and date** | |
| **Supervisor's name and date** | |

**B. Farmers' socio-economic characteristics**

| Age (Years) | Sex | Marital Status | Education level | Occupation | HH Size (TZS) | Annual Farm Income (TZS) |
|---|---|---|---|---|---|---|
| | 1= M<br>2 = F | 1= Single<br>2=Married<br>3 = Others (Specify) | 1 = Primary education<br>2 = Secondary education<br>3 = Tertiary education (college/university<br>4 = Other (Specify) | 1 = Farmer<br>2 = Employee<br>3 = Entrepreneur<br>4 = Others (Specify | | |
| | | | | | | |

## C. Household Farming Activities and productivity

| QC01 | QC02 | QC03 | QC04 | QC05 | | QC06 | QC07 | QC08 |
|---|---|---|---|---|---|---|---|---|
| Do you grow beans? 1 = Yes 2 = No | In how many acres of land do you grow beans | How much beans did you harvest in the last season? (bags/kgs per acre) | Do/did you use seeds treated by APRON STAR 42WS? 1 = Yes 2 = No | What other crops do you grow 1 = Maize 2 = Potatoes 3 = Rice 4 = Banana 5 = Other (Specify) | | On which crop do you depend for your household income? | How much did you harvest in last season? (bags/kgs per acre) | Do/did you use improved seeds in these crops? 1 = Yes 2 = No |
| | | | | Crop code | Land Size | | | |
| | | | | | | | | |

**QC09:** Have you ever grown beans with local seeds not treated by APRON STAR 42WS?
1 = Yes 2 = No

**QC10:** Which kind of bean seeds is more productive (in terms of yield/acre) than the other?
1 = Local seeds?
2 = Improved seeds treated by APRON STAR 42 WS

## D. Farm income/profit, costs and assets

### i) Household farm costs and income over the last production season

**QD01:** For what purpose do you grow beans?
1 = for own consumption
2 = for sale
3 = for broth (consumption and sale)

**QD02:** Is the land used to grow beans owned by your household or rented?
1 = Owned by household 2 = Rented

**QD03:** If your answer in QD02 above is 2, how much did you pay in the last crop season? (TZS. Per acre) **…………………………..**

| QD04 | QD04 | QD06 | QD07 | QD08 | QD09 | QD10 |
|---|---|---|---|---|---|---|
| How many acres of beans did you grow in the last season? | What was the average cost of production per acre used in the last season? | How much beans did you harvest in the last season? (in Kgs/acre or bags/acre) | How much was consumed and sold from the total yield produced? (In Kgs or bags or tin) | What was the selling price of beans in the last harvesting season? (in TZS. per bag, per kg, or per tin) | How much in total did you earn by selling beans I the last season | Was the household income improved by the beans sales? 1 = Yes 2 = No |
| | | | | | | |

**QD11: What items contributed highly to the total cost of bean production in the last season?**

| S/N | Item | Cost per acre (TZS) | Overall for total planted area (TZS) |
|---|---|---|---|
| | Land | | |
| | Land preparations | | |
| | Seeds | | |
| | Fertilizers | | |
| | Pests and insecticides | | |
| | Weeding | | |
| | Harvesting | | |
| | Others costs (Specify) | | |
| | Total | | |

**QD12:** Do you have other sources of income other than crop production**?** ☐

1 = Yes 2 = No

**QD13:** If your answer in QD12 above is 1, please mention the contribution of each source (s) to your income over the period of the past 12 months (one year)

| S/N | Activity | Amount (TZS.) |
|---|---|---|
| 1 | Formal employment | |
| 2 | Labour selling (day worker) | |
| 3 | Petty business (e.g. kiosk, saloon etc.) | |
| 4 | Livestock keeping | |
| 5 | Fishing | |
| 6 | Others (specify)1 | |

### ii) Farm household assets over the past 12 months (one year)

#### a. Farm assets

| S/N | QD14: | QD15 | QD16 | QD17 | QD18 | QD19 | QD20 |
|---|---|---|---|---|---|---|---|
| | Did your household own any farm implement/equipments, machinery and/or farms structures such as hand hoes, plough, tractor, chicken house etc. in the last 12 months? | Does your household currently own? Yes =1 No = 2 | Did your household buy any of these during the past 12 months? | How many of these did your household buy in the past 12 months? | If you are to sell one of these today, how much would you tag (TZS.) | Did your household rent any of these in the past 12 months? | How much did your household pay to rent or borrow the items (TZS.) |
| 1 | Hand hoe | | | | | | |
| 2 | Slasher | | | | | | |
| 3 | Axe | | | | | | |
| 4 | Watering Can | | | | | | |
| 5 | Pow tiller | | | | | | |
| 6 | Ox plough | | | | | | |
| 7 | Tractor | | | | | | |
| 8 | Generator | | | | | | |
| 9 | Motor pump | | | | | | |
| 10 | Storage house | | | | | | |
| 11 | Poultry/livestock house | | | | | | |
| 12 | Land (ha) | | | | | | |

#### b. Other durable assets

| S/N | QD21 | QD22 | QD23 | QD24 | QD25 | QD26 | QD27 |
|---|---|---|---|---|---|---|---|
| | Did your household own any farm implement/equipments, machinery and/or farms structures such as hand hoes, plough, tractor, chicken house etc. in the last 12 months? | Does your household currently own? Yes =1 No = 2 | Did your household buy any of these during the past 12 months? | How many of these did your household buy in the past 12 months? | If you are to sell one of these today, how much would you tag (TZS.) | Did your household rent any of these in the past 12 months? | How much did your household pay to rent or borrow the items (TZS.) |
| 1 | Television | | | | | | |
| 2 | Motorcycle | | | | | | |
| 3 | Car | | | | | | |
| 4 | Bed | | | | | | |
| 5 | Table | | | | | | |
| 6 | Chair | | | | | | |
| 7 | Radio | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | Solar panel / 1Electricity | | | | | | |
| 9 | Satellite dish | | | | | | |
| 10 | Iron (for pressing clothes) | | | | | | |
| 11 | Computer | | | | | | |
| 12 | Sofa set | | | | | | |
| 13 | House with iron sheet | | | | | | |

## E. Household Food Security and Nutrition aspects

### i) Household food consumption pattern in the past 7 days (one week)

| Food Group | Food Item | QE01 | QE02 | | QE03 | | QE04 | QE05 | |
|---|---|---|---|---|---|---|---|---|---|
| | | In the past 7 days (one week), did member of your household consume any of the following? Yes = 1 No = 2 | How much in total was consumed in the past one week? | | How much of the consumed food came from purchases? | | How much money was spent on the food | How much food came from own production? | |
| | | | Qty | Unit | Qty | Unit | TZS. | Qty | Unit |
| A | **Cereals, Grains and Cereal Products**: (Maize Grain/Flour; Green Maize; Rice; Finger Millet ; Pearl Millet; Sorghum; Wheat Flour; Bread; Other Cereal) | | | | | | | | |
| B | **Roots, Tubers, and Plantains**: (Cassava Tuber/Flour; Sweet Potato; Irish Potato; Other Tubers) | | | | | | | | |
| C | **Nuts and Pulses**: (Bean; Pigeon Pea; Groundnut; Ground Bean; Cow Pea; Other Nut/Pulse) | | | | | | | | |
| D | **Vegetables**: (Onion; Cabbage; Wild Green Leaves; Tomato; Cucumber; Other Vegetables) | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| E | **Meat, Fish and Animal Products:** (Egg; Dried/Fresh Fish (Excluding Fish Sauce/Powder); Beef; Goat Meat; Pork; Poultry; Other Meat) | | | | | | | | | |
| F | **Fruits:** (Mango; Banana; Citrus; Pineapple; Papaya; Guava; Avocado; Apple; Other Fruit) | | | | | | | | | |
| G | **Milk/Milk Products:** (Fresh/Powdered/Soured Milk; Yogurt; Cheese; Other Milk Product - Excluding Margarine/Butter or Small Amounts of Milk for Tea/Coffee) | | | | | | | | | |
| H | **Fats/Oil:** (Cooking Oil; Butter; Margarine; Other Fat/Oil) | | | | | | | | | |
| I | **Sugar/Sugar Products/Honey:** (Sugar; Sugar Cane; Honey; Jam; Jelly; Sweets/Candy/Chocolate; Other Sugar Product) | | | | | | | | | |
| J | **Spices/Condiments:** (Tea; Coffee/Cocoa; Salt; Spices; Yeast/Baking Powder; Tomato/Hot Sauce; Fish Powder/Sauce; Other Condiment - Including Small Amounts of Milk for Tea/Coffee) | | | | | | | | | |

### ii) Other FSN issues

| S/N | Question | Answer |
|---|---|---|
| **QE06** | In the past 7 days, did you worry that your household would not have enough food? 1 = Yes 2 = No | |
| **QE07** | In the past 7 days, how many days did your household rely on less preferred and/or less expensive foods? | |
| **QE08** | In the past 7 days, how many days did your household limit portion size at meal-times? | |
| **QE09** | In the past 7 days, how many days did your household reduce number of meals eaten in a day? | |
| **QE10** | In the past 7 days, how many days did your household restrict consumption by adults in order for small children to eat? | |
| **QE11** | In the past 7 days, how many days did your household borrow food, or rely on help from a friend or relative? | |
| **QE12** | How many meals (including breakfast) are taken per day in your household? | |
| **QE13** | In the last 12 months, have you been faced with a situation when you did not have enough food to feed the household? 1 = Yes 2 = No | |
| **QE14** | When did you experience this incident in the last 12 months? 1=Feb, 2=Mar, 3=Apr, 4=May, 5=Jun, 6=Jul, 7=Aug, 8=Sep, 9=Oct, 10=Nov, 11=Dec (all 2018), and 12=Jan 2019 | |
| **QE15** | What strategy (s) was adopted by your household to ensure adequate food during the situations of inadequate food over the period of the past 12 months?<br>1=Sold household assets<br>2=Used own savings<br>3=Sold livestock<br>4=Others (Specify) | |
| **QE16** | What were the major cause(s) of this situation among the following?<br>1=Inadequate food stock due to crop pest damage<br>2=Food was expensive in the market<br>3=Inadequate household food stock due to lack of farm inputs<br>4=Others (specify) | |

### F. Factors influencing decision to adopt APRON STAR 42WS technology

**QF01:** Are you aware with the APRON STAR 42WS? ☐
1 = Yes 2 = No

**QF02:** If your answer in **QF01** above is 1, how did you know it?
……………………………

**QF03:** If your answer in **QF01**above is 1, have you ever used bean seeds treated by APRON STAR 42WS? ☐
1 = Yes 2 = No

**QF04:** If you have used APRON STAR 42WS, how did you access it? .......................................

1 = Yes 2 = No

**QF05:** Why did you decide to use bean seeds treated by APRON STAR 42WS?

i) ……………………............................................................................................................

ii) ………………………………………………………………………………………

iii) ………………………………………………………………………………………....

**QF06:** If you answer in **QF03** above is 1, for how long have you been using it? ……………

**QF07:** If you answer in **QF03** above is 2, why haven't you been using it?

i) ……………………….

ii) ……………………….

iii) ………………………..

**QF08:** Which factor do you consider the most in selecting a bean variety to grow?

1 = Yield (productivity)

2 = Associated cost of production

3 = Market preference

4 = Others

(Specify)………………………………………………………………………

**QF09:** Do you have access to extension services?

1 = Yes 2 = No

**QF10:** If you have access to extension services, what services do you always obtain?

i) …………………..

ii) …………………….

iii) …………………….

**QF11:** Will you use the same seeds you are currently using in the next seaso

1 = Yes 2 = No

**QF12:** Give Reasons for your answer in the question above

i) ……………………………………………….

ii) ……………………………………………….

iii) ……………………………………………….

## Appendix 5: Checklist for key informants

**A. Introduction**

Name of respondent:
…………………………………………………………………………
Gender of respondent:
………………………………………………………………………..
Village:
……………………………………………………………………………………….
Ward:
…………………………………………………………………………………………
District:
……………………………………………………………………………………….
Region:
……………………………………………………………………………………….

**B. Guiding questions**

1. The story about the APRON STAR 42WS
   - How was it implemented
   - Seeds distribution mechanism
2. Rate and level of adoption of the technology
3. Performance of the technology
4. Reasons for adoption or on adoption (production costs? selling price?)
5. Livelihood differences between adopters and non-adopters (income, food security, assets)
6. Recommendations