ANALYSIS OF QUALITY CONTROL IN THE INFORMAL SEED SECTOR: CASE OF SMALLHOLDER BEAN FARMERS IN BONDO SUB-COUNTY, KENYA

By

WILFRED ODHIAMBO OUKO

A Thesis Submitted to the Graduate School in Partial Fulfillment for the Requirements of the Master of Science Degree in Agricultural and Applied Economics of Egerton University

EGERTON UNIVERSITY

November, 2016

DECLARATION

I declare that this thesis is my original work and has not been presented in this or any other university for the award of any Degree or Diploma.

Sign --------------------------------------- Date ---

Wilfred Odhiambo Ouko

KM17/3590/13

APPROVAL

This thesis has been submitted to the graduate school of Egerton University with our approval as University supervisors.

Sign --------------------------------------- Date ---

Prof. Margaret Ngigi (PhD)

Associate Professor of Agricultural Economics, Egerton University, Njoro

Sign -- Date ---

Prof. Job Lagat (PhD)

Associate Professor of Agricultural Economics, Egerton University, Njoro

DEDICATION

To my dear mother, Susan Osir for her inspirational and tireless support and for encouraging me to work hard at school; my beloved wife, Ann Wilfred for her patience and encouragement; my beloved son, Emmanuel Osir for being tolerant; my sister Monica and my brother Mathew for being resourceful. My heartfelt gratitude to you for your support.

ACKNOWLEDGEMENTS

I would like to express my unreserved gratitude to God for granting me the opportunity to stay and study in South Africa. Thanks to Egerton University for providing the environment and facilities which enhanced the success of my studies.

My thanks to African Economic Research Consortium (AERC) / Collaborative Master of Science in Agricultural and Applied Economics (CMAAE) program for financial support to pursue a Master of Science Degree in Agricultural and Applied Economics at Egerton University.

I would like to sincerely thank Professor Margaret Ngigi and Professor Job Lagat for tirelessly supervising the whole research work; their guidance and support are highly appreciated. I also wish to acknowledge the support from staff members of the Department of Agricultural Economics and Agribusiness Management of Egerton University as well as Professor Hans P. Binswanger-Mkhize of University of Pretoria, Jean Claude Rubyogo of International Center for Tropical Agriculture and Professor Akanni Kunle of Olabisi Onabanjo University Nigeria for their support and various contributions towards the success of this work.

To my friends and course mates, I appreciate the honourable support during this nobble course. God be glorified forever!!

ABSTRACT

The contribution of common bean to nutrition and income has not been fully felt by smallholder farmers in western Kenya due to low yields. Good quality seed, if used with complementary practices can increase bean productivity. This study was conducted in Bondo sub-County to determine the methods used by farmers in seed quality control; factors affecting the choice preferences for informal bean seed sources; the structure and contribution of social networks in seed quality control. Primary data were collected from 100 respondents through scheduled interviews using structured questionnaires. STATA and UCINET computer packages were used to run data. A multinomial logit model was used to analyse the effects of socio-economic characteristics on the choice of seed sources. The nature of social networks was determined using measures of centrality and brokerage and visualized through network graphs. The results showed that smallholder bean farming was male dominated (57%) with average of 1.19 ha landholding and 0.34 ha under beans. Majority (90%) of farmers assessed quality characteristics while sourcing seed, with 46% considering seed free from insect attack as being of good quality. Majority (84%) of farmers never treated seed at planting, but practiced weeding (84%), timely harvesting (87%), cleaning (90%) and proper storage (92%) for quality control. The study revealed that farmer-to-farmer social networks exhibited the highest degree (48), betweenness (2690) and lowest closeness (169) centrality measures. Majority (97%) of farmers relied on informal sources for seed. The preferences for the informal seed sources are influenced by age, family size, area under beans, distance to nearest seed source, nature of land ownership, occupation and group membership; all of which were statistically significant at 0.05 levels. Therefore, the study suggests policy interventions to design locally-based bean seed system which utilizes farmer-to-farmer social networks to enhance supply of quality seed to smallholder farmers. Preference for certain bean varieties should be used for strategic varietal development. Finally, youth groups should be used as springboards for seed related interventions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

AFSTA	African Seed Testing Association
CBOs	Community Based Organizations
CIAT	International Centre for Tropical Agriculture
CRS	Catholic Relief Services
DARTS	Department of Agricultural Research and Technical Services
FAO	Food and Agriculture Organization of the United Nations
FBOs	Faith Based Organizations
IARIs	International Agricultural Research Institutes
KEPHIS	Kenya Plant Health Inspectorate Service
MLRM	Multinomial Logistic Regression Model
NGOs	Non-Governmental Organizations
PABRA	Pan Africa Bean Research Alliance
SCA	Seed Certification Agency
SNA	Social Network Analysis
SPSS	Statistical Package for Social Sciences
SSA	Sub Saharan Africa
WBG	World Bank Group
WMS	Welfare Monitoring Survey

CHAPTER ONE
INTRODUCTION

1.1. Background of the study

Grain legumes play a crucial role in human diet and economy. In many developing countries, grain legumes are relatively cheap and readily available source of nitrogen-rich edible seeds. They are used to develop a wide diversity of high-protein products and thus, constitute the major source of dietary protein in the diets of the poor with numerous nutritional benefits (Rebello *et al.*, 2014; Bouchenak and Lamri-Senhadji, 2013; Shi *et al.*, 2004; Venn, 2004). As major components of various farming systems, legumes provide residual nitrogen through fixation of atmospheric nitrogen and hence, reduce the needs for mineral nitrogen fertilizers (Dong *et al*., 2003).

Common bean (*Phaseolus vulgaris* L.) is the most important grain legume for direct human consumption in the world. It is the most widely grown and consumed grain legume in developing countries. Being a major source of dietary protein, minerals and certain vitamins, this crop plays a significant role in human nutrition (Pflieger *et al*., 2014). Bean per capita consumption in East Africa (50–60kg) (Buruchara *et al*., 2011) is perhaps the highest in the world (Legesse *et al*., 2013). In western Kenya, beans are produced by smallholder farmers mainly for subsistence. These farmers also sell part of their bean produce in the local grain market to meet other household needs. Hence, bean production contributes to economic and food security for these households (PABRA, 2014).

Several nutritional benefits can be attributed to consumption of common bean (PABRA, 2014). For instance, incidents of diseases like cancer, diabetes or coronary heart disease can be reduced through regular consumption of common bean (Leterme, 2002). This is because common bean is low in fat and is cholesterol free. Once eaten, beans digest slowly causing low sustained increase in blood sugar. This slow digestion of common bean can also deter resurgence of hunger, reduce frequency of food intake and enhance weight-loss programs (Katungi *et al*., 2009).

Despite the numerous benefits and high potential demand for beans, low yields have been realized for this crop in western Kenya. The low yields can be attributed to among other reasons: the use of unimproved bean varieties as well as recycled seed accessed through the informal seed system. The seed production in the informal seed system is integrated in farmers' cropping system and local grain market. Both local landrace and improved varieties (if any) are recycled and farmers keep on selecting preferred traits to advance into the subsequent seasons. Farmers also share seed among themselves and offload the surplus into local grain market.

The Crops Act (2013) places beans among schedule one crops. The crops listed under the schedule are presumed to have breeding programs requiring compulsory certification. Therefore, production and commercialization of bean seed is a reserve of legally recognized institutions and seed companies or licensed seed dealers. This implies that legally, bean seed should be accessed by farmers only through the formal seed system.

The formal seed delivery system entails defined model (Rubyogo *et al.*, 2010) that leads to certified seeds of released crop varieties. They include germplasm development or breeding; variety release; bulking; distribution and marketing. The system is made up of public and private organizations with specialized roles in supplying seed of improved varieties. It guarantees clear distinction between seed and grain; maintenance of varietal identity and purity. The system ensures optimal physical, physiological and health quality of seed. In this system, marketing of certified seed is regulated. Formal seed system involves seed legislation and seed development. Seed legislation entails: regulations on variety release; quality standards on seed classes as well as quality control and seed certification. Seed development has to do with varietal breeding, testing and release; seed production, multiplication, processing and marketing.

Notwithstanding the stringent requirement to have bean seed accessed only through the formal seed system, the informal seed system remains the major source of bean seed. The informal system supplies up to 90% of seed requirement by smallholder farmers (Sperling and McGuire, 2010) – which confirms its dominance in bean seed supply, but raises several questions: (1) what informs farmers' selection of seed source; (2) how do the farmers control seed quality both at source and on-farm?; and (3) how successful are the farmers in controlling seed quality?. The study sought to determine the reasons that underlie farmers' preference for bean seed sources; investigate the methods used by the farmers for seed quality control in informal bean seed sources; as well as determine the nature and contribution of social networks in the informal seed sector.

1.2. Statement of the problem

Despite the existence of a formal seed system, the bean seed supply in Bondo Sub County has remained largely informal. The most distinct feature about this system is that it follows several localized pathways including own saved seed, neighboring farmers, local grain market (open-air assembly market) among other sources. Unfortunately, the quality of beans for seed exchanged through this system cannot be ascertained because it is embedded in a complex web of social networks without structures evident in formal system. Since the system has been in existence for a long period of time, it is likely that the nature of its networks contribute in some way to seed quality control. However, the role social networks play in seed quality control has not been assessed. Further, the factors that inform the farmers' choice preferences for particular seed source(s) needed to be clearly understood. This study aimed to fill this knowledge gap.

1.3. Objectives of the study

1.3.1. General objective

The general objective of the study was to contribute to attainment of sustainable integrated bean seed system for enhanced access to quality seed by smallholder farmers and increased bean productivity.

The specific objectives were to:

1. Characterize bean farmers in Bondo sub county
2. Determine the methods used for quality control in informal bean seed sources
3. Determine the nature and contribution of social networks in seed quality control
4. Determine factors influencing farmers' preferences for seed sources

1.4. Research questions

1. What are the socio-economic characteristics of smallholder bean farmers in Bondo sub-County?
2. What methods do farmers use in controlling bean seed quality?
3. What is the nature and contribution of social networks in seed quality control?
4. What factors influence farmers' preferences for bean seed sources?

1.5. Justification of the study

Understanding the choice preference for seed sources is useful in unpacking farmers' perception of seed quality and whether quality matters when choosing seed source. This provides insights into the basis for dominance of the informal seed sector in the supply of bean seed to the smallholder farmers; as well as helps in understanding how this system thrives in a legal setup that expressly upholds the formal seed system. Furthermore, isolating the mechanisms by which farmers control quality in the informal seed sector is useful in several ways: the results help to identify the abilities or otherwise of these farmers to guarantee sustained supply of good quality bean seed. Determining the nature of social networks is useful in making recommendations for possible designing of locally-based bean seed system to utilize farmer-to-farmer linkages within the networks. It is hoped that where applicable, the results of the study will be out scaled to other legumes under schedule one of the Kenya seed act (2013).

1.6. Scope and limitations of the study

The study focused on smallholder farmers engaging in bean production. Large farm holders and were not included in the study.

Due to budgetary and time constraints as well as accessibility concerns, the study was confined to four sub-locations. This left out several smallholder bean farmers who may have had equally useful information.

1.7. Definition of terms

For the purpose of the study, the following terms were used. However, it is worth noting that the terms were used to fit the purpose of the study and may not necessarily adhere to the conventional definitions.

Seed: grains of plants used for sowing, normally capable of germination to produce new plants and provide the means of establishing a new crop by farmers each season.

Seed quality: those characteristics including physical purity, health and size of bean seed perceived by farmers as potentially having influence on germination, growth, yield and marketability of bean produce.

Seed quality control: the process through which farmers ensure that desirable seed attributes or characteristics, as perceived by them, are maintained or enhanced.

Seed system: the entire complex of organizations, individuals and institutions associated with the development, multiplication, processing, storage, distribution and marketing or exchange of seed.

Informal seed system: a seed supply system integrated into the farmers' farming system and where quality control is vested in the farmers.

Formal seed system: a system with well-defined procedures for development, distribution and access to certified seed of distinct varieties and stipulated quality**.**

Integrated seed system: a system that upholds coordinated actions between formal and informal seed sectors.

Smallholder farmers: defined in terms of size of land as those farmers who own less than two (2) hectares of land on which they reside, grow crops and also keep a few heads of livestock.

Bean productivity: a measure of efficiency of production expressed as the ratio of the total bean output (in tons) per unit of land cultivated (in hectares).

Social network: a number of farmers connected by communication ties through which they exchange seed related information.

Household: a number of people living together in the same house under the headship of one person known as the household head

Local grain dealer: a farmer who grows beans in his or her own farm and sells the produce to other farmers as seed

Seed treatment: those activities which are carried out by farmers with the aim of protecting bean seed from being destroyed by pests either after planting or during storage – they include application of chemicals or wood ash.

Cultural practices: those activities carried out in relation to bean production, harvesting and post-harvest management, which do not involve the use of commercial chemicals, but rely on traditional practices adopted from previous generations of farmers.

Harvesting: the act of removing either whole or part of the bean plant from the field after crop maturity.

Threshing: defined as the act of removing bean grain from the pods after harvesting by picking the pods or uprooting the whole bean plant at maturity.

Season: the cycle followed in bean production from planting to harvesting and usually takes 10 to 12 weeks.

CHAPTER TWO
LITERATURE REVIEW

2.1. Importance of seed in agricultural production

The prominence of seed as the bearer of most essential features for crop production remains an uncontested fact. For many centuries, crop domestication has been enhanced through the use of seed – consequently informing present day agriculture (Louwaars and Gam, 2009).Seed is the most important agricultural input as well as the basic unit for distribution and maintenance of plant population. It carries the genetic potential of the crop plant – thus, dictates the ultimate productivity of other input such as fertilizer, pesticide and irrigation water, which build the environments that enable the plant to perform (Mugonozza, 2009). Successful stand establishment requires high quality, genetically pure seed that produces rapid, uniform seedling emergence (McDonald, 1998). This is true more so for the smallholder farmers in Sub Saharan Africa (SSA), where agriculture is characterized by much risk and uncertainty (WBG, 2008). Notwithstanding the vital roles of other components of agriculture including markets, credit supply and support institutions; the use of appropriate seed presents a major starting point in crop production (McGuire, 2010).

The use of good quality seed of adopted and improved varieties is widely recognized as fundamental to ensure increased crop production and productivity. This is even more important in SSA, in the view of increasingly decreasing available land, declining soil fertility, ever growing population and effects of climate change – necessitating promotion and use of good quality seed as a means to intensify food production. The potential benefits from the distribution of good quality seed of improved varieties are enormous. The availability of quality seed of wide range of varieties and crops to the farmers is crucial if food security is to be achieved in SSA. Enhanced productivity, higher harvest index, reduced risks from seed-borne diseases and higher incomes are some of the direct benefits potentially accrued to the farmers (FAO, 2010).

Besides its role in production, food security and rural development, seed is a major element in deliberations concerning technology development and dissemination, biodiversity, globalization and equity. Thus, sustainable availability of good quality seed is an important development issue (Louwaars, 2007).

2.2. Seed quality

Seed quality can be defined in terms of its components including seed health, varietal and physical purity, size, vigor and germination. While the first three components (health, purity and size) may be observed and determined; seed vigor is inherent and has direct influence on germination. Thus, seed vigor constitutes all the intrinsic properties which determine the potential level of activity and performance of seed during germination and seedling emergence (Ellis, 1992). The aspects of performance that may show variations include rate of germination, emergence and seedling growth as well as emergence of seedlings under unfavorable conditions. Hence seed vigor influences crop growth and yield levels.

In the recent past, continued development of seed enhancements has attracted much of research efforts on seed quality. Many of these properties are regularly considered by seed analysts. However, due to advances in computer technology, seed quality tests are now standardized and evaluated (McDonald, 1998). The potential of seed quality to influence crop yield forms the basis of seed certification (Ellis, 1992), especially in the formal seed sector; while informing the efforts by farmers to select appropriate seed based on preferred attributes.

2.3. Seed Certification

Seed certification is a legally sanctioned system for quality control of seed multiplication and production. The purpose of seed certification is to maintain and make available high quality seed and propagating materials of notified plant varieties (AgriInfo, 2011). The Kenya Plant Health Inspectorate Service (KEPHIS) is a regulatory body established under the State Corporations Act. Seed certification was previously undertaken by the National Seed Institute under the then Ministry of Agriculture that later became the National Seed Quality Control Station (AFSTA, 2010).

2.3.1. Seed Certification process and phases

Seed certification consists of a chain of processes including: (1) an administrative check on the origin of propagating material for the purpose of trueness to purity (genetic purity); (2) field inspection at the time of growing a crop for seed production purpose - the data should be obtained on trueness to varietal purity, isolation of seed crop to prevent crops-pollination, mechanical admixtures and diseases dissemination, objectionable weeds and admixtures; (3) supervision on agricultural operations intercultural operations, harvesting, storage, transport and processing etc. for identity and quality of lots; (4) sample inspection for quality and to maintain genetic purity, a lab test of representative samples drawn by the seed certification agency (SCA) for determining germination percentage, moisture content, weed seed content, admixture and purity; (5) bulk inspection for checking homogeneity of the bulk as compared with the sample inspected and (6) control plot testing, samples drawn from the source seed and the final seed produced can be grown in the field along with standard samples of the variety. Seed certification has five phases including: verification of seed source; inspection of seed crop in the field; supervision at post-harvest stages including processing and packing; seed sampling and analysis; grant of certificate, certification tag, tables and sealing (AgriInfo, 2011).

2.4. Seed systems

Seed systems entail a set of dynamic interaction between seed supply and demand, resulting in farm level utilization of seed and thus plant genetic resource. Thus, seed system is the economic and social mechanism by which farmers' demand for seed and other desirable seed traits is met by various sources of supply (FAO, 2010).

A seed system can be described as the entire complex of organizations, individuals and institutions associated with the development, multiplication, processing, storage, distribution and marketing of seed in any geographical setting (Maredia *et al* (1999). The seed system includes informal (traditional) and formal (nontraditional) systems. Legal institutions such as variety release procedures, intellectual property rights, certification programs, seed standards, contract laws, and law enforcement enhance the operations and ideals of both formal and informal seed systems. These institutions help in determining the amount, quality, and cost among other standards of seeds passing through the seed system.

Seed provision to farmers also includes activities undertaken to influence the process, such as: pricing, financial and technical support, provision of inputs, communication, coordination, as well as market research and promotion. Notably, policy formulation underpins seed systems, defining the boundaries and opportunities for the conduct of all seed system activities (WBG, 2009).

Seed systems, formal or informal, fulfill a series of functions that are basic prerequisites for expecting the best possible productivity from a crop in a specific situation. Healthy, viable seed of the preferred variety needs to be available at the right time, under reasonable conditions, so that farmers can use their land and labor resources with the best yield expectations. The wrong variety, sown at the wrong time with infected seed of poor germination potential, will seriously limit a farmer's expectation of production and productivity.

A seed system can be assessed at any time according to how well it fulfills these functions. Conditions, situations, groups of farmers, or crops can be identified under which the specific system works well (Welfzien *et al*., 2010).

2.4.1. Seed system actors

Seed system actors (organizations and individuals) across countries and can be categorized based on the type of seed system they serve. Informal seed system actors are mainly the NGOs, farmer organizations, individual smallholder farmers and local grain dealers. On the other hand the formal system is dominated by the public sector (government research institutions, universities and ministries of agriculture), private sector (seed companies, private research institutes, seed retailers, credit institutions), International Agricultural Research Institutions (IARIs), NGOs, Faith Based Organizations (FBOs), donor agencies, farmer organizations, trade associations, cooperatives and farmers as the end users. These actors may assume multiple roles in the process of seed provision, performing one or several activities (WBG, 1999).

2.4.2. Dimensions of seed system

Patterns of seed access and use emerge as skilling occurs differently for individual farmers across the dimensions illustrated in **Figure 1**. These patterns define both the limits of the modern or formal seed system as well as the characteristics of a range of alternative (informal) systems (Stone, 2004).

Decisions about the type of exchange, the type of good and the value of the good being accessed are all conditioned by individual and social context characteristics, with a range of options along each axis. Three key elements of economic decision-making are the type of exchange used to access a good, the type of good itself and the value of that good to the individual.

Exchanges might occur across a spectrum that includes formal market structures, informal markets and non-formal exchange arrangements or self-provisioning (Hart, 2006). Informal markets directly relate to formal markets, with non-formal traditional economic exchanges existing outside of this direct comparison. The establishment of local seed markets and producers bring these different types of economic arrangements into direct contact with one another, so that all three exist on a continuous spectrum (Hart, 2006 in Jones, 2013).

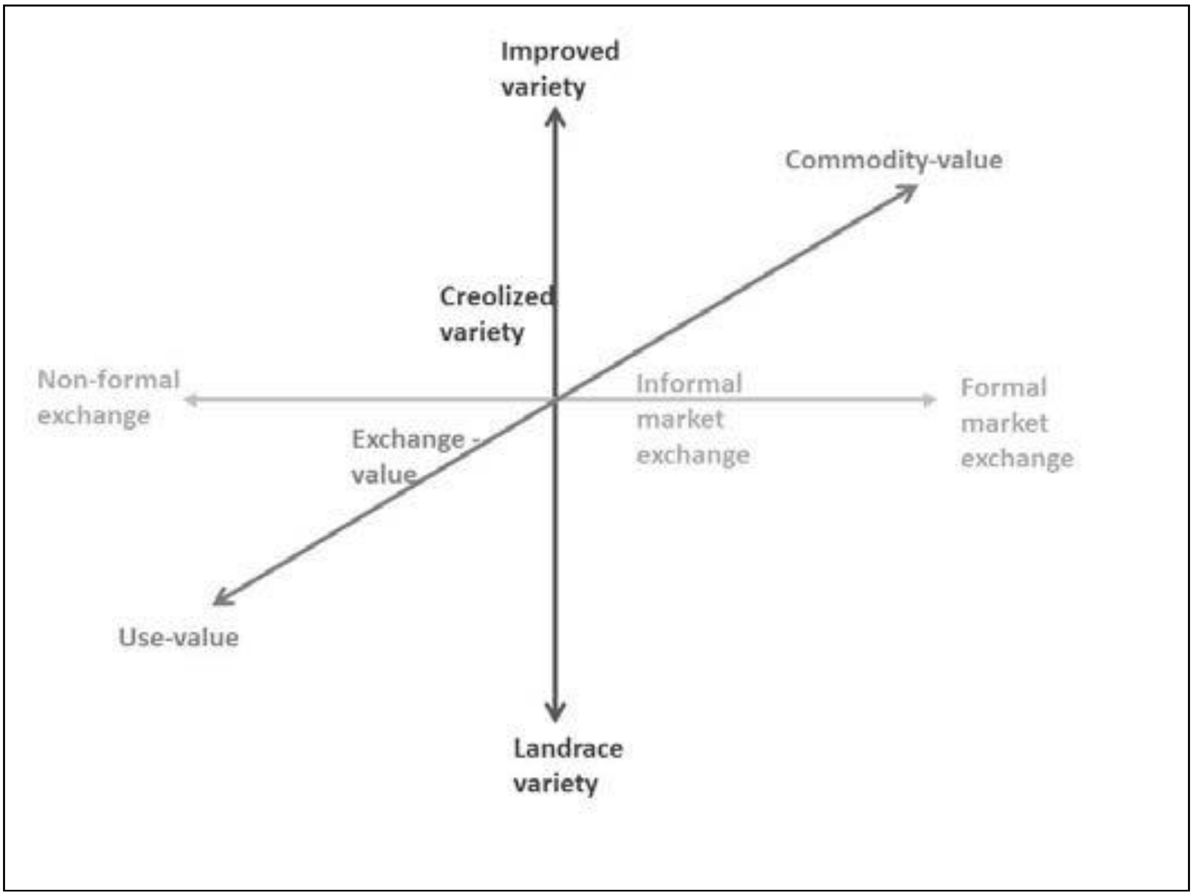

Figure 1: Dimensions of seed access decision making
Source: Jones (2013)

2.5. Formal seed system

The formal seed system, as defined by FAO (1999) comprises all seed program components, namely; plant breeding, seed bulking, processing and marketing. These are facilitated by extension services, quality control and certification. The formal seed sector serves to diffuse quality seed of improved varieties developed by formal breeding programs. The materials for formal breeding programs are obtained from collections of gene banks. The gene banks contain materials originally collected from farmers' systems, that is, developed and maintained by farmers.

Regulations exist in this system to maintain variety identity and purity as well as to guarantee physical, physiological and sanitary quality. Seed marketing takes place through officially recognized seed outlets, and by way of national agricultural research systems. In formal seed production, seed multiplication occurs through several generations rather than continually recycling the seed of one generation, to avoid building up physical or genetic contamination over time in the same lot of seed (Louwaars *et al*., 1999).

The formal system has been relatively successful for well-endowed, high-potential areas, but much less successful in more variable, marginal areas. This can be attributable to the system's inability to produce sufficient seed of preferred varieties, and deliver it to farmers at the right time. Seed production is risky in terms of time, space and financial implications; and returns are determined by multiplication rate (that is, amount of seed yield that can be harvested per unit of seed sown (McGuire, 2005).

The formal seed system focuses more on the interests of the seed company, and has more access to biotechnology and plant breeding techniques (Baniya *et al.*, 2003). Notably, this system neglects the indigenous knowledge as well as seed requirements and varietal preferences by smallholder farmers. However, a key pillar of the formal seed system is seed certification, which underpins seed quality assurance.

2.6. Seed marketing

The challenges faced in marketing of seed imply that it is the most critical component of the seed sector. The make-up of seed is such that its quality wanes away fast – being a living organism. Thus, its shelf life is limited and it must be marketed with in the season. Another peculiar feature of seed is that it requires two to three years lead time to meet the specific requirements that is to meet the demand for particular seed, its production has to be organized at least two years in advance. The changes in the weather, price of crop, and price of competing crop, may change the prospects of demand for seed of particular variety at the commencement of sowing season (Singh, 2004).

The nature of seed demanded by farmers differs. Large and medium scale farmers use markets to purchase uniform genetic materials that are highly responsive to chemical inputs and embody specific characteristics including color and uniformity of grain size rewarded by the market. By contrast, more subsistence-oriented smallholders may value characteristics such as drought tolerance, early maturity or good storage more than fertilizer responsiveness. Because of the small size of their land holdings, mixed cropping practices, and strategy of minimizing production risks by diversifying the variety base, smallholders also demand relatively small quantities of seed but for a number of varieties of the same crop and recycle seed over more seasons than larger commercial farmers (Maredia *et al*., 1999).

Seed demand from different users can be met by promoting a range of seed organizations with comparative cost advantages in supplying seeds of distinct commodities to different groups. For example, multinational seed companies can meet the seed needs of large-scale commercial farmers whose quality requirements and willingness to pay are higher than smallholder farmers. The seed needs of the latter group can be met more effectively by small-scale firms' or Community-based Seed Multiplication and Distribution Schemes such as farmers seed groups and Cooperatives (Maredia *et al*., 1999).

The largest problem faced by seed multiplication program elsewhere in Africa is difficulty of building a sustainable seed market. Small quantities of seed are being profitable sold with in the village community. Sales are strongest for newly introduced varieties. But most small-scale farmers are unwilling to pay premium price to their neighbors for seed they can obtain from their own harvests (Rohbarch *et al*., 2002).

2.7. Informal seed system

According to Walelign (2008), the informal seed sector has been in operation in Kenya particularly for the small scale farmers. The source and quality of most of the planting materials and seed purchased, multiplied and marketed by the informal seed sector may not be known, yet this is the major source of planting material for the farmers. Other informal sources of seed include farm-saved seed, farmer-to-farmer exchange, local markets, Non-Governmental Organizations (NGOs) and Community Based Organizations (CBOs).

Informal or on-farm seed systems vary across countries, regions and crops. The system relies on seed saving practices - keeping parts of the harvest for planting in the next season. The system usually plants local varieties of seed kept from the previous year's harvest, obtained from neighbors and/or the local market. This is the predominant system for food crops in subsistence agriculture. It is estimated that in developing countries, the informal seed system is responsible for more than 80% of the total area planted with subsistence crops. It is very resilient system, which is very active even without the support of public or private institutions. On farm seed system are essential for improving food security for developing countries. They will likely to continue to be the main source of seed for subsistence crops in the world. This system is not market oriented; seeds are usually produced for consumption .Some surplus can be bartered with neighbors or sold to local grain dealers (FAO 2004).

For small-scale farmers in developing countries, management of seed is of crucial importance and forms an integral part of their crop production systems. For many centuries, farmers have developed and maintained their own plant genetic resources, based on local means of seed production, selection and exchange. Introgressions, mutations and introductions from elsewhere are the common sources of new genetic material in a community. Newly introduced varieties are subject to farmers' experimentation, and when adopted they become part of the local gene pool. In many cases, this integration involves physical mixing of seeds and spontaneous crossing with other materials. The informal seed sector has strong local character, without necessarily being confined to a small geographical area (GTZ, 2000).

2.8. Social networks

Nicholas *et al.* (2013) in their study on female social networks and learning about new technology in India demonstrate that men and women in the same households have very different social networks and thus different access to information regarding agricultural technologies. They found that the underlying factors that shape network linkages between male farmers are different than those shaping their wives social networks.

Kyle (2013) argues that relying on social networks for diffusion of information seems desirable in practice because it is an extremely low cost approach in diffusing a new technology. If the allocation achieved by exchange in networks is efficient, then networks could be relied upon as a highly sustainable method of ensuring efficient spread of technologies, particularly in the absence of efficient markets.

Handschuch and Wollni (2013) in their case of finger millet in western Kenya conclude that besides formal extension, farmer-to-farmer networks are found to be an effective trigger for the dissemination of finger millet practices. In rural Kenya, many social groups exist and the majority of farmers participate in at least one group. However, group activities vary widely and can be an influential factor for the diffusion of market information which contributes to a large percentage of transaction cost involved in banana production.

2.9. Theoretical framework and empirical methods

2.9.1. Theory of choice

Bean farmers' decisions on seed source(s) is embedded in the theoretical framework of choice theory, often referred to as the science of choice (Parkin, 1997). Economic theory of choice is central to understanding how and why individuals make certain choices in the context of information available to them. In essence, it is often assumed that such individuals act rationally, hence they seek the most cost effective means to achieve a specific goal without reflecting on the worthiness of that goal.

Many definitions of economics as a science of choice have been documented. Alfred Marshall's definition of economics in the early 1900s as the study of humankind in the ordinary business of life led to the neoclassical definition: the study of choice in the ordinary business of life (McCloskey, 1996). Case and Fair (1992) defined economics as the study of how individuals and societies choose to use the scarce resources that nature and previous generations have provided. Miller (1994) viewed economics as the study of how people make choices to satisfy their wants. Parkin (1997) described it as the study of the choices people make to cope with scarcity

The choice theory is thus instrumental in studying individuals' decisions on how optimal selection can be made when faced with an array of options. The choice maker's aim is to maximize desirable returns from the option selected. Rational choice theory constitutes a dominant paradigm in explaining human behavior and actions; underpinned by neoclassical economic theory and utilitarian theory.

2.9.2. Rational choice theory

Rational choice theory or rational optimization approach has been widely used in social sciences. It uses abstract deductive reasoning by drawing conclusions and predictions from sets of assumptions, and provides critical view of what ought to be. Proponents of the rational choice approach hold that it provides a unified and rigorous framework for understanding human behaviors and actions, an analytical tool for relating aggregate events to micro–worlds of individual decision making, and has a great predictive power not found in other approaches (Friedman and Hechter, 1988; Rule, 1997; Chai, 2001).

However, critics point out that the theory enshrines unrealistic assumptions on preferences and fails to incorporate such factors as altruism and cultural diversity. Such limitations have served to confirm the fact that a tractable representation of the complex world would only capture limited features of such complexity. Therefore, details are stripped away to expose only specific aspects of behavior relevant to the question being analyzed.

Rational choice theory assumes that individuals are purposive and intentional (Friedman and Hechter, 1988). Individual decisions and actions are shaped by subjective tastes as measured by individual's utility and constrained by resource scarcity, opportunity costs, institutional norms as well as availability, timeliness and quality of information.

2.9.3. Rational preferences

The postulate of rationality of preferences constitutes a key assumption in the neoclassical economic analysis of behavior. Individuals are assumed to have explicit, complete, reflexive, and transitive rank ordered preferences over the possible outcomes of their actions (Bicchieri, 2004). Preferences would also assume non–satiation, strict convexity, and continuity properties. In other words, individuals would consistently prefer more of something to less and average outcomes to extremes (Rahelizatovo, 2002).

Preferences are subjective individual tastes measured by the utility derived from the use of a certain commodity or bundles of commodities. Such preferences may be represented graphically using indifference curve. Such a curve consists of a locus of pair–wise combinations of outcomes that would provide the same level of satisfaction to the decision maker. Each indifference curve represents a different level of utility. The continuity and completeness of a preference ranking would lead to a dense map of indifference curves. The further an indifference curve is from the origin, the higher the utility level. In addition, the convexity of preferences ensures that the indifference curve exhibits the diminishing marginal rate of substitution. In other words, the more an individual has of a good, the less satisfaction he perceives from an additional unit of the same good and the more he is willing to exchange it for a given amount of the other good (Case and Fair, 1992; Varian, 1999; Parkin, 1997).

2.9.4. Optimization behavior

The fundamental economic problem has been attributed to the limited resources available to satisfy human beings unlimited wants and needs (Parkin, 1997). Resource scarcity drives individuals to make choices to attain desirable goals consistent with their preferences. Differential access to resources affects the individual's ability to attain the alternative end results, making some easy to achieve, and others more difficult or even impossible to reach (Friedman and Hechter, 1988). However, decision makers are assumed to conduct rational calculation and subsequently select the course of action likely to be associated with the highest outcome values constrained by resources available to them.

Utility theory offers an understanding of individuals' choice through utility maximization behavior (Varian, 1993; Parkin, 1997). Individuals' preferences are associated with a real–value indexed utility. Consequently, individuals choice is assumed to favor the course of action that provides the highest utility, or maximum satisfaction. Yet, individuals choices often fail to agree with such an ideal proposition. There are other factors that affect decisions. One such factor is opportunity costs, which are incurred when the decision maker forgoes the best alternative available to him. Individuals must consider these implicit costs in their pursuit of maximum benefits and satisfaction (Rahelizatovo, 2002). High opportunity costs can affect the attractiveness of the most preferred action and may prompt the choice of a lower level of utility.

Similarly, institutional norms and rules, as well as access to better quality information at the time a choice is made, also influence individual's decision and outcomes. Individuals may also reduce the risk and uncertainty surrounding their choices by acquiring more information. Perception of rewards and costs are shaped by social institution rules (Rahelizatovo, 2002).

2.10. Conceptual framework

It was conceptualized that smallholder farmers are faced with a range of seed sources including own saved seed, neighboring farmers, local grain market (open-air assembly market) among other sources (Figure 2). The choice of a particular seed source is informed by an array of socio-economic characteristics. The seed source chosen influenced the quality of seed.

Quality control methods vary across the seed sources. In the informal seed system, the use a particular method depends on the farmer's socio-economic characteristics. However, the method chosen has direct influence on the resultant seed quality.

The role of social networks in the control of seed quality is two-fold. Through information and knowledge sharing, farmers' capacities on choice of quality control methods are enhanced. This indirectly influences seed quality since farmers adopt better methods from other farmers. On the other hand access to seed through social networks enhances seed quality. As farmers repeatedly exchange seed with neighbors and friends, their ability to identify quality traits is enhanced.

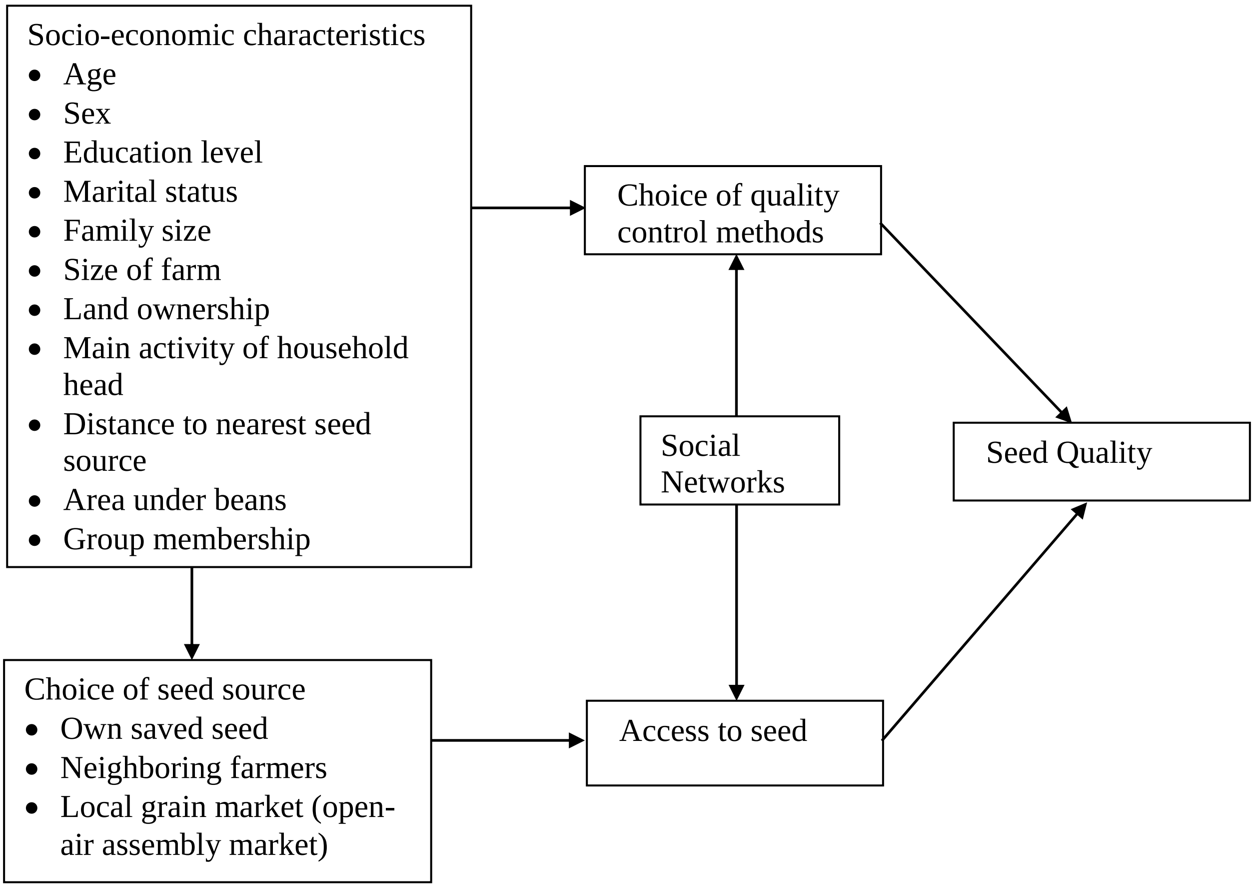

Figure 2: Conceptual framework
Source: Own conceptualization

CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Study area

The study was conducted in Bondo sub county, situated at latitude 0° 14' 19 N, longitude 34° 16' 10 E and elevation of 1,227 meters above the sea level. It borders Siaya Sub-county; Kisumu County to the East; Homa-Bay County to the South and Uganda to the West (Figure 3). Administratively, it is divided into three divisions namely: Maranda, Nyang'oma, and Usigu. The divisions are divided into six wards which are further divided into ten locations and twenty sub-locations.

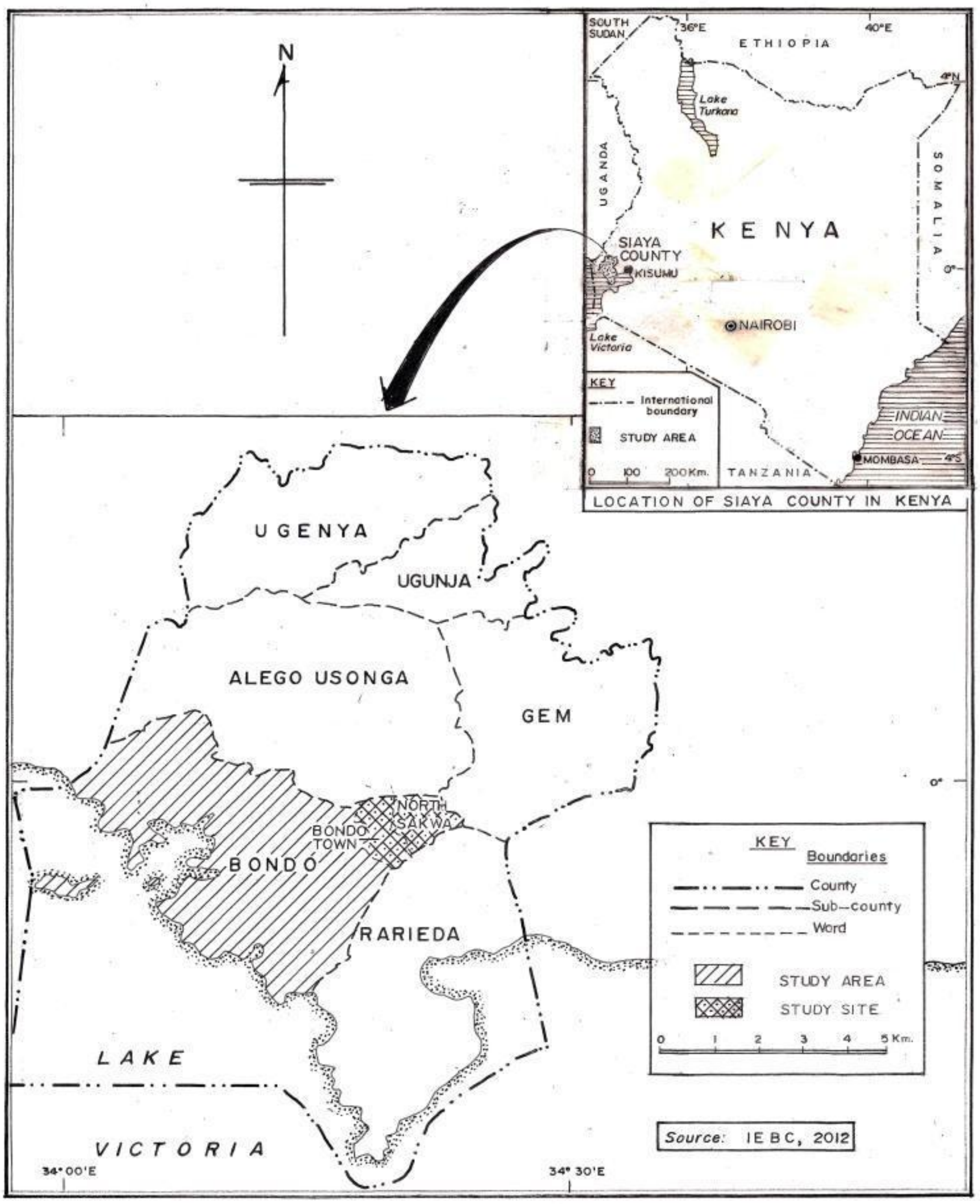

Figure 3: Map of Bondo sub-County, Siaya County, Kenya
Source: Department of Geography, Egerton University, Njoro

According to national housing and population census (2009), Bondo Sub-county has an estimated human population of 157,522. Agriculture is the mainstay of the residents with relatively highly productive soils ranging from black cotton to sandy loam to red loam soils. The major crops grown include maize, beans, sorghum, and several horticultural crops. Crop production is supplemented by livestock keeping and mild fishing along Lake Victoria. It covers an area of 593 Km^2 with an average population density of approximately 266 persons per Km^2 and population growth rate of 3.35%.

3.2. Population of study and sampling unit

The population of the study was the number of smallholder bean farming households. The sampling unit was the head of the household.

3.3. Sampling procedure

Three stage sampling design was used. Bondo Sub-county was purposively selected in Siaya county because it is a major bean growing area. Within Bondo Sub-county, North Sakwa ward was selected purposively due to comparatively larger number of smallholder bean farmers as well as accessability. Likewise, two locations and four sub-locations within North Sakwa ward were selected purposively due to larger number of smallholder bean farmers. The total population was the number of smallholder bean farming households. The numbers sampled were derived as the proportion of population per sub location to the total population (Table 1).

Table 1: Population and sample size, by location and sub-location

Location	Sub location	Total population	Numbers sampled
Bondo township	Ajigo	628	26
	Bar-kowino	740	30
North Sakwa	Abom	477	20
	Bar-chando	575	24

Source: computation data from Crops office, Bondo sub County.

3.4. Sample size

A sample of 100 smallholder bean farmers was selected from the four Sub-locations using simple random sampling method. The randomness of the sampled respondents was cross checked and confirmed through georefrencing the coordinates of their locations. The required sample size was determined using the sampling method by Anderson *et al*. (2007).

$$n = \frac{pqz^2}{E^2}$$

Where n = sample size, p = proportion of the population containing the major interest, q = 1-p, z= 95% confidence level (α = 0.05), E = acceptable/allowable error

z = 95% (standard value of 1.96);

p = 0.5;

q = 1-p = 0.5 and

E = 9.8%

Therefore, the sample size was calculated as;

$$n = \frac{(1.96^2)(0.5^2)}{0.098^2} = 100$$

3.5. Data collection

Primary data were obtained through scheduled interviews using structured questionnaires. Both open ended and closed ended questions were used. Each respondent was interviewed individually in local dialect to fully obtain the relevant information. Types of data included general demographics of the respondents such as age, gender, and education level. Data on socioeconomic characteristics, bean seed sources, seed source preferences, bean production, harvesting and storage practices as well as interactions among bean farmers were collected.

3.6. Data analysis techniques and model specification

Primary data collected were verified, coded and analyzed using descriptive and inferential statistics. STATA computer software package was used for descriptive analyses as well as to run the multinomial regression model. UCINET computer software package was used to analyze the nature of social networks and generate network graphs. The analytical methodologies used are described in the sections that follow.

Objective 1 was analyzed using descriptive statistics

A descriptive analysis of the variables was done using graphs, percentages, means, mode, medians and standard deviations. Statistical significance of differences between farmers from different sub locations was determined using t-tests.

Objective 2 was analyzed using descriptive statistics

A descriptive analysis was done using percentages, means, frequencies and standard deviation. The t-tests were run to determine the statistical significance of differences between farmers in different sub locations.

Objective 3 was analyzed using social Network Analysis technique

Social network analysis (SNA) was used to understand the linkages among farmers. SNA offers a variety of techniques for measuring, visualizing, and simulating relationships and allows for analysis of these relationships in visual as well as mathematical terms. Williams and Hummelbrunner (2011) describe social network as a number of actors connected by some kind of relationship. Actors can be individuals, groups, or organizations. Relationships can take on many meanings, depending on type of network under study (communication ties, informal relations and membership ties). Networks can also include actors' relationships with other kinds of entities, such as events they attend or activities in which they are involved.

To obtain information on individual-specific social networks, each farmer was asked to name two persons to whom he or she talks most frequently about agricultural decisions. This approach is defined as the sociometric method to measure network links (Rogers, 2003). It was pioneered by Coleman *et al.* (1957) and applied in an agricultural context by Conley and Udry (2001) in their study on the adoption of pineapples in Ghana. The advantage of restricting a farmer to name two persons is that he or she will probably name the two strongest network members, which ensures that the analyst gets a close picture of the individual network. The disadvantage, however, is that the farmer might exchange crucial information that leads to adoption with a more distant network partner (Rogers, 2003; Santos and Barrett, 2004). A solution to this problem would be to let the farmer name an unlimited number of network members and then differentiate between strong and weak ties (Matuschke and Qaim, 2009).

SNA systematically analyzes network data and describes the social order contained therein. The basic unit of analysis is the individual with the individual's economic, social, or cultural relationships. Society is not seen as an aggregate of individuals and their attributes, but as a structure of interpersonal ties. Thus, the focus is on both the relationships of actors and their attributes. The aim is to explain the actions of individuals with reference to these social structures (Williams and Hummelbrunner, 2011).

Three SNA tools were employed. Information about specific relationships among farmers were gathered and represented in a relational matrix. The relationships were visualized through network maps. Finally, the structure of the networks were assessed through measures of centrality: betweenness centrality, degree centrality, closeness centrality and brokerage positions. Degree centrality refers to the number of direct links an actor has with others, hence it is a measure of activity. Closeness centrality takes indirect relationships into account and calculates the average distance between an actor and the rest of the network. It gives an idea of an actor's accessibility and relative autonomy. Betweenness centrality measures the degree of control that a particular actor can exert over others (Williams and Hummelbrunner, 2011). The centrlity measures were defined using the Freeman (1979) and adopted by Lada (2013) as indicated in equation 1 to 5.

(i) The degree centrality:

$C_D = \Sigma_{i=1}^{g} \frac{[C_D(n) - C_D(i)]}{[(N-1)(N-2)]}$ 1

Where,

C_D = the degreed centrality;

n = the number of persons with characteristics of interest; and

N = the total number of respondents

C_D *(n)* = the maximum value in the network

(ii) Betweenness centrality:

$C_B(i) = \sum_{j<k} g_{jk}{}^{(i)}/g_{jk}$ 2

normalized as:

$C_B(i) = C_B(i)/[(n-1)(n-2)/2]$ 3

Where,

$C_B(i)$ = the betweenness centrality of the individual actor;

g_{jk} = the number of geodesics connecting *jk;*

$g_{jk}(i)$ = the number of geodesics that actor *i* is on;

[(n-1)(n-2)/2] = number of pairs of vertices including the vertex itself

(iii) Closeness centrality:

$C_C(i) = \left[\sum_{j=i}^{N} d(i,j)\right]^{-1}$ 4

normalized as:

$C_C(i) = \left(C_C(i)\right)/(N-1)$ 5

Where,

$C_C(i)$ = the closeness centrality of individual actor

d = the average shortest path between a vertex and all vertices in the graph

Brokerage positions were used to define the extent to which an actor or actors can influence the flow of information within a network either as cut points (bottlenecks) or mediators (network hubs). The UCINET software was employed in analyzing the data.

Objective 4 was analyzed using both descriptive statistics and the Multinomial Logistic Regression Model (MLRM).

3.6.1. Analytical framework for the econometric model

The study employed consumer theory to understand the factors influencing the choice preferences for bean seed sources by smallholder farmers. In consumer theory, demand functions are derived from considering a model of preference maximizing behavior coupled with underlying socio-economic constraints and or decision making for the set of available options that maximize utility (Dwivedi, 2004; Nicholson, 2002; Varian, 1999). In this study, the smallholder farmers were faced with more than one seed source options. Further, the socio-economic characteristics of the farmers as well as their influence on seed source preference needed to be tracked, thus permitting the use of Multinomial Logistic Regression Model (MLRM).

Multinomial logistic regression (MLRM) model allows for analysis of different individual characteristics confronted with multiple choices (Maddala, 1983; Green, 1993; Hill *et al.,* 2008). It estimates the probability of an individual *i* choosing an activity *j*, seed source in this case given a set of explanatory variables (socio-economic characteristics). MLRM can be used to predict a dependent variable based on continuous and/ categorical independent variables, where the dependent variable takes more than two forms (Kohler and Kreuter, 2005). Moreover, the model is used to determine the percent of variance in the dependent variable explained by the independent variables and to rank the relative importance of independent variables. MLRM does not assume linear relationship between the dependent variable and independent variables, but requires that the independent variables be linearly relaated to the logit of the dependent variable (Gujarati, 1992). Further, the model allows for interpretation of the logit weights for the variables in similar way as in linear regression (Pundo and Fraser, 2006)

To construct the choice preference for seed source by smallholder farmers, this study adopted the utility function formulated by Greene (1993), in adjusted form as shown in equation 6;

$$U_{ij} = \beta z_{i} + \varepsilon_{ij} \quad \text{.......} 6$$

U_{ij} is the satisfaction that the i[th] farmer derives by choosing j[th] seed source

z_i is a vector of individual farmer characteristics

β is the parameter to be estimated and ε_{ij} is the error term.

Given the difficulty in measuring utility directly (Sheffrin *et al.*, 2006), it was assumed that farmers chose seed source from which they derived seed with most satisfactory quality. The general multinomial logistic regression model used was as as specified in equation 7 by Schmidt and Strauss (1975) and used by Kyalo (2009) and Kadigi (2012).

$$Prob\ (Y_i = 1) = \frac{e^{\beta_{j} x_i}}{\sum_{k=0}^{J} e^{\beta_k x_i}}\ , j = 0,1, \dots, J \quad \text{.......} 7$$

With at least three categories of independent variables, equations were estimated to provide probabilities for *J + 1* choice of seed source for a farmer with X_i socio-economic characteristic.

The β_j *and* β_k are the coefficients which wereestimated using the maximum likelihood method. Equation 8 presents simplified empirical specification of the model.

$$\Pi_{ij} = \beta_o + X_i\beta_k + e_{ik} \quad \text{.......} 8$$

Where; Π_{ij} is the probability that bean farmer *i* chooses seed source *j*, β_o is the constant term, X_i are the farmers socio-economic characteristics, β_k are the model coeficients (parameters) to be estimated and e_{ik} is the error term.

To eliminate indeterminancy, the model was normalised by fixing $\beta_o = 0$. The probabilities added up to 1 hence, only J parameter vectors weer required to obtain J+1 probability. The probailities were therefore specified as indicated in equation 9;

$$Prob\ (Y_i = 1) = \frac{e^{\beta_{j} x_i}}{\sum_{k=0}^{J} e^{\beta_k x_i}}\ , for\ j = 0,1, \dots, J, \beta_o = 0 \quad \text{.......} 9$$

In the model, seed source preference with at least three options was set as the dependent variable. The options included own-saved-seed, neighbouring farmers, and local grain market. The variable own-saved-seed took the value 1, neighboring farmers took the value 2, and local grains market took the value 3. The STATA and SPSS computer software packages were used to analyze data.

For the three seed source options, the equations were defined as indicated in equation 10 to 12:

$$
\begin{aligned}
Prob\ (Y=1) = {} & \beta_1 HHAGE + \beta_2 HHSEX + \beta_3 EDLVL + \beta_4 MRTSTAT + \beta_5 FAMSIZE \\
& + \beta_6 OWNSHLAND + \beta_7 FARMSIZE + \beta_8 HHMAINACTVY \\
& + \beta_9 DISTSEEDSRC + \beta_{10} AREABEANS + \beta_{11} GRPMSHP + e_i \dots\dots\dots\dots 10
\end{aligned}
$$

$$
\begin{aligned}
Prob\ (Y=2) = {} & \beta_1 HHAGE + \beta_2 HHSEX + \beta_3 EDLVL + \beta_4 MRTSTAT + \beta_5 FAMSIZE \\
& + \beta_6 OWNSHLAND + \beta_7 FARMSIZE + \beta_8 HHMAINACTVY \\
& + \beta_9 DISTSEEDSRC + \beta_{10} AREABEANS + \beta_{11} GRPMSHP + e_i \dots\dots\dots\dots 11
\end{aligned}
$$

$$
\begin{aligned}
Prob\ (Y=3) = {} & \beta_1 HHAGE + \beta_2 HHSEX + \beta_3 EDLVL + \beta_4 MRTSTAT + \beta_5 FAMSIZE \\
& + \beta_6 OWNSHLAND + \beta_7 FARMSIZE + \beta_8 HHMAINACTVY \\
& + \beta_9 DISTSEEDSRC + \beta_{10} AREABEANS + \beta_{11} GRPMSHP + e_i \dots\dots\dots\dots 12
\end{aligned}
$$

3.6.2. Empirical studies on logistic regression

Several studies which employed Multinomial and logistic regression model in general have been documented. Fertő and Szabó (2002) applied multinomial logistic model to reveal the determinants influencing the choice supply channels in Hungarian fruit and vegetable sector whereby the choice alternatives were wholesalers' chain, marketing cooperative chain, and producer organ. The conditional (fixed effects) logit was employed by Stall *et al.* (2006) in an analysis that evaluated farmers' choice of milk marketing channels in Gujarat among those that were available in the area: direct sales to individual customers, sales to generally in formal private traders/venders and sales to cooperatives/ private dairy processors.

Kumar (2010) used the logit model to study the factors that influence decision of milk traders to participate in the milk value addition activities in Bihar India. In an analysis of dairy farmer participation in cooperatives in the Northeast USA, Bhuyan (2009) adopted a binary logistic regression as an analytical tool whereby dairy farmers as they participate in these cooperatives' marketing functions either as members or as non-member patrons.

Tsourgiannisa *et al.* (2008) in studying factors affecting the marketing channel choice of sheep and goat farmers in the region of east Macedonia in Greece regarding the distribution of their milk production also applied logit model. Additionally, Jari (2009) brought into play the multinomial logistic regression model in an investigation of institutional and technical factors influencing agricultural marketing channel choices amongst smallholder and emerging farmers in the Kat River Valley in South Africa. In the model, farmers were confronted with three possibilities of market participation choices, *viz*. formal markets, informal markets and not participating in markets, which was set as the dependent variable. Sonda (2008) employed the multinomial logistic regression in analysing livestock related factors and farmers choice of maize cultivars in Tanzania. The binary logit model was used by (Mbise, 2007) to determine factors influencing the decision of coffee farmers to adopt either co-operative or non-co-operative market channels in Kilimanjaro Tanzania. Other studies that employed logistic regression are (Karbauskas, 2010; Blandon *et al.,* 2009; Kyeyamwa *et al.,* 2008; Alexander *et al.,* 2007; Park and Lohr, 2006; Bartels *et al.,* 2006; Hall *et al.*, 2006; Onyango and Govindasamy, 2004).

3.6.3. Justification of the Multinomial Logistic Regression Model

Multinomial logistic regression model is useful in analysing data where the study aims to find the likelihood of a certain event occurring. In other words, using data from relevant explanatory variables, multinomial logistic regression is used to predict the probability of occurrence, but not necessarily determining a numerical value for the dependent variable (Gujarati, 1992). This study sought to analyse the probability of choosing three informal seed sources by smallholder bean farmers, with given socioeconomic characteristics. Dougherty (1992) explained that the formulation of the multinomial logistic regression model is similar to a binary logistic regression. Nevertheless, whereas in binary logistic regression, the dependent variable has two categories (dichotomous variable), in multinomial logistic regression, it has more than two categories (polytomous). Thus, multinomial logistic regression is an extension of binary logistic regression. According to Mohammed and Ortmann (2005), several methods can be used to explain the relationship between dependent and independent variables. Such methods include linear regression models, probit analysis, log-linear regression and discriminant analysis. However, multinomial logistic regression was chosen because it has more advantages, especially when dealing with qualitative dependent variables. Linear regression model (also known as Ordinary least squares regression (OLS) is the most widely used modelling method for data analysis and has been successfully applied in most studies (Montshwe, 2006). However, Gujarati (1992) pointed out that the method is useful in analysing data with a quantitative (numerical) dependent variable but has a tendency of creating problems if the dependent variable is qualitative (categorical), as in this study. Amongst other problems, the OLS cannot be used in this study because it can violate the fact that the probability has to lie between 0 and 1, if there are no restrictions on the values of the independent variables. On the other hand, multinomial logistic regression guarantees that probabilities estimated from the logit model will always lie within the logical bounds of 0 and 1 (Gujarati, 1992). In addition, OLS is not practical because it assumes that the rate of change of probability per unit change in the value of the explanatory variable is constant. With logit models, probability does not increase by a constant amount but approaches 0 at a slower rate as the value of an explanatory variable gets smaller. When compared to log-linear regression and discriminant analysis, logistic regression proves to be more useful. Log-linear regression requires that all independent variables be categorical and discriminant analysis requires them all to be numerical, but logistic regression can be used when there is a mixture of numerical and categorical independent variables (Dougherty, 1992). In addition, discriminant analysis assumes multivariate normality, and this limits its usage because the assumption may be violated. According to Gujarati (1992), probit analysis gives the same results as the logistic model. In this study, the logistic model is preferred because of its comparative mathematical simplicity and fewer assumptions in theory. Moreover, logistic regression analysis is more statistically robust in practice, and is easier to use and understand than other methods.

3.6.4. Description of variables

The study was based on the axiom that the choice preference for particular seed source (dependent variable) may be determined by an array of farmer's characteristics (Table 2).

Table 2: Description of variables used in the Multinomial Logistic Regression Model

Variable code	Variable	Measurement	Type	Expected sign
SEEDSRCE (Y)	Seed source preferred	Own-saved-seed=1, neighboring farmers=2, local seed producer=3, local grain market=4, ertified seed stockists=5	Categorical	+/-

Variable code	Variable	Measurement	Type	Expected sign
HHAGE	Age of bean farmer	Age in years	Continuous	+/-
HHSEX	Sex of the farmer	Male=1, Female=0	Dummy	+/-
EDLVL	Educational level	Years of schooling	Continuous	+/-
MRTSTAT	Marital status	Single=1, married=2, divorced=3, separated=4	Categorical	+/-
FAMSIZE	Family size	Number of household members	Continuous	+/-
FARMSIZE	Size of farm	Number of hectares	Continuous	+
OWNSHPLAND	Natrure of ownership of land by the farmer	Owned with title deed=1, owned without title deed=2, lease=3	Categorical	+
HHMAINACTVY	Main activity of the farmer	Farming =1, Civil servant =2, Businessman =3 Retired with pension =4, Retired without pension =5	Categorical	+
DISTSEEDSRC	Distance to nearest seed source in Kilometres	Number of Kilometres	Continuous	+
AREABEANS	Area under beans in hectares	Number of hectares	Continuous	+
GRPMSHP	Group membership	Member=1 Non-member=2	Categorical	+/-

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The first section of this chapter presents the descriptive analysis of the socio-economic characteristics of smallholder bean farmers. In the second section a description of the methods used by smallholder farmers for quality control is presented. Section three presents analysis, description and graphical visualization of the nature and contribution of social networks in seed quality control. The fourth section presents characterization of formal and informal seed sources and role of bean varieties as a pointer to seed source preference. Finally, section five presents econometric logistic analysis of the factors that influence smallholder farmers' preferences for informal seed sources.

4.1. Characterization of bean farmers in Bondo sub County

The socio-economic characteristics of the bean farmers are summarized in Table 3. The mean age of the farmers was 52.4 years. A one sample t-test was run to determine whether the mean age was different from the population mean age. There was no statistical difference t (99) = 0.000, p = 1.000 at 0.05 level. The standard deviation (SD) of the age of household head was 14.33. The ages were dispersed with majority (95%) of ages lying between 23.74 and 81.06.

The mean number of years of schooling was 10.5 years ranging from a minimum of 4 years to a maximum of 18 years. This indicates appreciable levels of literacy and since literacy level in any society is a proxy for ability to embrace change, it is suggestive that the farmers have the potential to learn new ideas and adopt new technologies relating to seed quality control; as supplements to the traditional methods currently used.

The mean household size was 11. This relatively large household size is a reflection of embracement of African culture which upholds extended families (Kadigi, 2012). The number of members in a household has an implication on the disposable income, expenditure levels, and the choice of goods basket. This would then reflect on the type of seed the household would prioritize for planting.

Distance to nearest seed source shows that farmers would have to cover an average of 7.42 km to get bean seed from alternative sources where the seed is not available from own stocks or immediate neighbours (Table 3). Longer distances are associated with higher transaction costs in terms of time and energy losses especially for smallholder bean farmers who require small quantities of seed (Suri, 2006; Farrow *et al.*, 2010). This is a plausible explanation for farmers' inclination towards saving their own seed (Sperling *et al.*, 2013).

The average farm size held was 1.19 ha. The size of land held by a farmer determines the size of land that would be dedicated to bean production given competition among several enterprises on the same land parcel. In this regard, the mean area under beans was 0.34 ha. Due to land scarcity, smallholder farmers sometimes resort to mixed cropping (planting beans alongside other cereals like maize) to increase area under beans.

Forty thee percent of the farmers were females while 57% were males. The increasing interest by men in bean production is attributed to the transformation of beans from traditional subsistence crop where its production was female–dominated (Katungi *et al.* 2009; CIAT, 2004; David *et al.,* 1999) to market–oriented one. This is consistent Birachi *et al.* (2011) that in areas where common bean was a market–oriented crop, its production was male–dominated.

Majority of the farmers (60%) owned land with title deeds while 40% had no title deeds. The nature of land ownership is critical because it provides an incentive or otherwise to the owner to invest in long term productive enterprises (Dube and Guveya, 2013; Sylvester, 2013; Jacoby and Minten, 2005).

While 63% of the households practiced farming as their sole occupation, 15% were civil servants and 22% engaged in non-agriculture businesses besides being farmers. The plausible explanation is that the civil servants and business people have strong linkages with rural areas and would be interested in farming to complement their incomes and also reduce expenditures on agricultural products which can be produced within the farm. They also have a greater potential to invest in agriculture due to enhanced access to credit facilities.

Table 3: Distribution of farmers by socio-economic characteristics, Bondo sub-County, 2015

Variable	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Age of household head	52.40	14.33	22.00	83.00
Education level	10.52	2.90	4.00	18.00
Family size	11.24	2.03	8.00	17.00
Distance to nearest seed source	7.42	1.46	3.00	10.00
Size of farm	1.19	0.49	0.20	2.00
Area under beans	0.34	0.28	0.04	1.20

Variable	Percentage of respondents (%)
Sex of household head	
• Males	57.00
• Females	43.00
Main activity of household head	
• Farming	63.00
• Civil servants	15.00
• Business	22.00
Nature of land ownership	
• Owned with title deed	60.00
• Owned without title deed	40.00

4.2. Methods used for quality control in informal bean seed sources

In order to know how quality of beans could be controlled in informal systems, it was necessary to understand the entire production process from seed sourcing, planting to harvesting as well as post-harvest management.

4.2.1. Assessment of seed quality characteristics at sourcing

The ability of the farmers to select good quality bean seed is critical in ensuring higher yields (CRS, 2014). Good quality seed will result in high germination rate, crop population, uniform stand and consequently uniform maturity (Karrfalt, 2013; Powell, 2009). In Rwanda and Congo, farmers carefully considered seed type and quality when sourcing seed for planting (Trutmann *et al.,* 1996). Farmers in Ethiopia took specific phyto-sanitary measures to enhance bean seed quality through sorting out poor-quality materials, including visibly diseased grains (Rubyogo *et al.,* 2009).

To ensure quality control in informal sources, 90% of households in Bondo assessed the type of bean they would adopt as seed. The characteristics sought during selection are presented in Figure 4. The most outstanding characteristics thought to portray high quality were beans free from insect attack as indicated by 71% of the households. This is plausible because even formal seed companies ensure the beans are free from insect attack by dressing with insecticides (Sridhar and Kumar, 2013).

Twelve percent of the farmers assessed the size of seed. Seed size is critical during planting and marketing. Large seeded bean types have higher seed rates while small seeded types have lower seed rates hence, farmers intending to reduce seed costs would prefer small seeded types. On the other hand, bean grain and seed traders would prefer large seeded types because they use lower quantities to fill the measuring containers and thus make higher profits.

Assessing the proportion of discolored seed was important (9%) because seed discoloration may be an indication of disease infection, premature harvesting or improper drying. Premature harvesting may lead to seed with low viability while disease-infected and improperly dried seed are highly likely to rot when planted. Six percent of the farmers considered the proportion of broken seed. Higher proportion of broken seed increase the cost of seed by reducing the value per unit of seed purchased. Presence of chaff and the color of seed were regarded as least important characteristics while sourcing bean seed. However, seed colour is an indicator of varietal purity and uniformity.

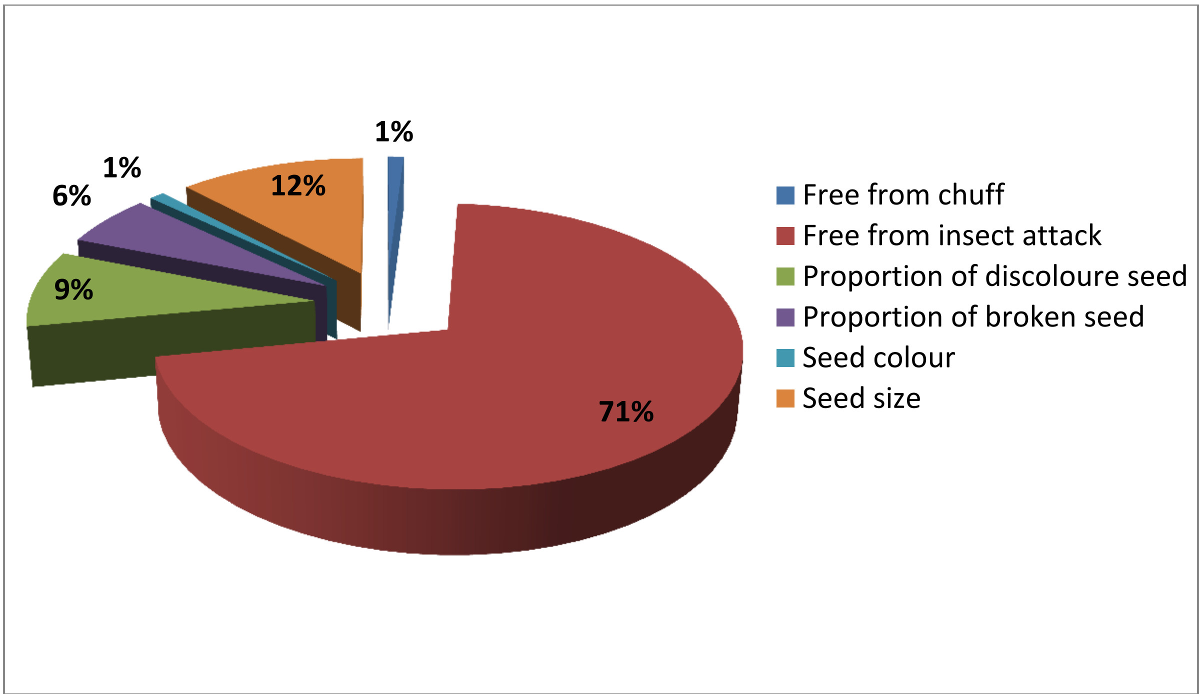

Figure 4: Distribution of farmers by quality characteristics of seed assessed

4.2.2. Planting and post planting management practices

To eventually generate good seed, both planting and post planting management practices are critical. The processes that households use in the first stage of seed preparation and field management of bean crops are presented in Table 4.

Results demonstrate that 16% treated beans before planting. The credible explanation is that farmers use seed from their own stores or other sources they trust – whose quality and management requirements they know well; and may not require additional treatment at planting (CRS, 2013). Farmers carry out functions of multiplication; seed selection and storage in the informal system as in the formal system, but the functions are integrated in their crop production and marketing practices rather than discrete activities (Sperling *et al.*, 2013).

The post planting management practices in informal seed production were basically cultural practices such as weeding (84%), early planting (7%), intercropping (6%), and rouging (3%). It is quite apparent that farmers understand the importance of weeding. Controlling weeds enhances quality of bean grain because many weed plants act as hosts for pests and diseases. Thus, if left unchecked the harvest may be infested in the field and consequently, the pests/diseases may be carried into the stores, predisposing the stored beans seed to early deterioration in quality. The other practices were considered less important although in formal seed production, both early planting and rouging are critical aspects (Kadigi, 2012).

Table 4: Distribution of farmers by planting and post-planting practices used for bean quality control, Bondo sub-County, 2015

Management practice	Farmers practicing (%)
Seed treatment at planting	
Treating	16
Not treating	84
Cultural practices for controlling pests and diseases	
Weeding	84
Early planting	7
Intercropping	6
Rouging	3

4.2.3. Harvesting and post-harvest management practices.

The harvesting and post-harvest management practices are presented in Table 5. There was a variation in the timing of harvest where 87% harvested beans when the pods were completely dry, 8% when leaves had fallen and 5% when the pods turned yellow. The time of harvesting is a proxy for maturity level of beans and consequently determines the quality of bean grain harvested. This has an impact on the farmers' seed especially where a farmer grows own-saved seed (Nasirumbi, 2009).

Farmers harvested beans by uprooting the whole plant (97%), cutting the bean plant at the collar (1%) and collecting the dry pods (2%). While the first two methods are less time consuming, the third method is a preferred where there is less uniform pod maturity; requiring piecemeal harvesting (Khaemba and Akiro, 2008). Majority (95%) of the farmers agreed that during harvesting, some bean grains fell to the ground while 5% indicated that they were able to collect all the bean grains. How farmers handle the fallen grains is critical because often the grains get contaminated with soil and pests which may find their way into the store if unchecked (Malinga and Tenesi, 2010). Majority of the farmers collected and consumed (63%) the fallen grains, 22% left them in the field to germinate while 16% mixed them with other bean grains and sold.

The time lapse between harvesting and threshing has an influence on the quality of bean grains. While extraneous factors such as cold weather conditions may increase the time lapse, the process may also be impeded by the fact that for the smallholder farmers, both harvesting and threshing compete for the same labor (Otieno and Nyabuto, 2001). Similarly, after harvesting, sufficient drying is required to enhance opening of pods during threshing; and reduce grain breakage. Farmers threshed their beans three days after harvesting (75%), seven days after harvesting (13%), one day after harvesting (11%) and fourteen days after harvesting (1%).

The location where threshing is done is critical as the grains may be predisposed to mixing with soil and foreign matter; hence quality compromised. Farmers threshed their beans in the open yard (79%), in the farm house (20%) and in the field (1%). A plausible explanation for preferring open yard and farm house over threshing in the field is that, many farmers use the bean residues to feed their livestock (Grisley and Mwesigwa 1991; Birachi *et al.,* 2011). However, threshing in the field helps to recycle the nutrients held in the bean residues thus, improving soil fertility (Dong *et al.*, 2003).

Majority of (90%) farmers cleaned the beans at threshing stage while 10% kept the threshed beans for later cleaning. There were differences in the methods for cleaning bean seed/ grains where farmers completely removed the chuff and broken seed, sorted the grains by size and sorted out discolored beans (76%); removed the chuff only (22%) and removed broken beans only (2%). This affirms the importance of absence of chuff as the major quality characteristic assessed by farmers while sourcing bean seed from the informal seed sources (Maredia *et al*., 1999).

Farmers stored their beans after threshing, cleaning and drying (92%), after threshing only (3%) and after threshing and cleaning (5%). Storage is not only critical for seed viability and ultimately yields (CRS, 2011), but also promotes food security and resilience (Seyoum and Jonfa 2012). Reduced quality of grain from insect infestation and moisture can have significant implications to both food availability and income. This results from direct loss and poor quality which influence market prices. Cereal prices fluctuate greatly between harvests which can make effective storage profitable (CRS, 2013).

It is important to dry beans after threshing and cleaning to ensure requisite moisture content before storing. High moisture results in lower germination rates, plant vigor and yield. Whereas in the formal sector machines are used to ensure requisite moisture content of beans before storage, such equipment are absent in the informal sector (Sperling *et al.*, 2013). Farmers tested bean dryness by tossing the grains between hands and listening to unique metallic sound (48%), biting the grains with teeth (34%) and pressing the bean grains between fingers (18%). All these methods have no scientific backing, but they have been learnt, practiced over decades, and passed over from one generation to another (Asfaw *et al.*, 2013; Kadigi, 2012).

The length of storage period is a critical aspect of seed quality management. The longer the storage period, the higher are the risks of losing the stored beans to storage pests (CRS, 2014) and therefore extra costs incurred in maintaining bean seed/ grain quality. Farmers stored their beans for 1-5 months (68%), more than 5 months (31%) and less than one month (1%). Those who stored beans for shorter periods were either risk averse or disposed of their beans to meet immediate household needs including paying school fees for their children. These farmers fetched relatively lower prices when they sold immediately after harvest. Conversely, those who stored beans for longer periods did so for speculative purposes, eventually selling as seed at higher prices due to higher demand during planting period (CRS, 2014).

The type of storage structure, location, and material used to construct the storage structure play an important role in enhancing the shelf-life and viability of the stored grain/ seed at the time of disposal. Farmers stored beans in their houses (98%) or used some raised platforms near their houses (2%). Concrete was largely used by farmers for constructing storage structure (37%), while wood (34%) and clay (29%) were also used. The preference for concrete is attributed to its durability and less susceptibility to breakage by termites and rodents unlike wood and clay, thus reducing the likelihood of infestation and costs associated with bean storage. On the other hand, wood and clay were both readily available and affordable.

The period of usage of storage structure is critical in bean quality. Storage pests get recycled into the store if the same structure is used for a long time, more so if the necessary treatments are not adhered to. Ideally, the farmers would have to change the storage structure nearly every season to break the cycle of storage pests' incidences. However, this is untenable given the financial constraints and the minimal scale of bean production by these farmers. Farmers had used their storage structures for at least four seasons (90%), three seasons (7%), two seasons (2%) and 1 season (1%). Majority of the farmers stored beans together with other grains in the same store (98%) while the others used their stores exclusively for beans (2%). Mixing of grains in the same store compromises the quality of stored beans because the other grains may be hosts for certain pests, thereby increasing susceptibility to infestation (Traore and Kone, 2013).

To reduce incidences of pest infestation, farmers undertook sanitary measures before storing beans including: cleaning the store (85%), reinforcing with dung or concrete (11%) and both cleaning and reinforcing (4%). Additionally, 39% applied some treatment to the store. Farmers who applied treatments to the storage structure used commercial insecticides (80%), wood ash (15%) and smoke (5%). Wood ash and smoke are traditional methods which are considered cheap, convenient and safe (Kyemba *et al.*, 2010). However, due to their usage over long periods of time, their effectiveness cannot be guaranteed as many pests tend to develop resistance to them over time (Tuni, 2011). This is a credible explanation for the shift from the use of wood ash and smoke to the use of commercial chemicals. This is also possible because as farmers engage in repeated interactions with the extension service providers there is tendency of transition from traditional practices to conventional modern practices (Kadigi, 2012).

To deal with storage problems, farmers exposed and sundried the stored beans (58%), applied pesticides (41%), or physically killed the insects/pests (1%). Exposing the stored beans in the sun is the most convenient and least costly method of dealing with storage pests (Santra, 2010). The use of pesticides is the most effective but relatively less popular with smallholder farmers due to cost implications (Kangili, 2009), while physically killing the insects may only be applied to large pests like rodents.

Table 5: Distribution of farmers by harvesting and post-harvest management practices used for bean quality control, Bondo sub-County, 2015

Management practice	Farmers practicing (%)
Timing of harvesting	
When pods are completely dry	87
When pods turn yellow	8
When leaves have fallen	5
Method of harvesting	
Uproot whole plant	97
Collect dry pods	2
Cut plant at the collar	1

Management practice	Farmers practicing (%)
Use of bean grains fallen while harvesting	
Collect and consume	63
Leave in the field to germinate	22
Mix with other grains and sell	16
Time between harvesting and threshing	
3 days	75
7 days	13
1 day	11
14 days	1
Where threshing is done	
Open yard	79
Farm house	20
In the field	1
Stage at which cleaning is done	
During threshing	90
After threshing	10
Method of cleaning	
Completely remove chuff, broken seed, discolored seed, sort by size	76
Remove chuff only	22
Remove broken seed only	2
Methods of testing bean dryness	
Toss and listen for metallic sound	48
Bite with teeth	34
Press with fingers	18
When storage is done	
After threshing, cleaning and drying	92
After threshing and cleaning	5
After threshing only	3
Length of storage period	
1-5 months	68
More than 5 months	31
Less than 1 month	1
Type of storage structure	
Room within the house	98
Raised platform near house	2
Construction material for storage structure	
Concrete	37
Wood	34
Clay	29
Period of using storage structure	
More than 4 seasons	90
Three seasons	7
Two seasons	2

Management practice	Farmers practicing (%)
One season	1
Uses of storage structure	
Store beans and other foodstuffs	98
Store beans only	2
Measures undertaken in storage structure before storing	
Clean the store	85
Reinforce with dung or concrete	15
Treatment of storage structure	
Apply no treatment	61
Apply some treatment	39
Type of storage treatment	
Commercial insecticides	80
Wood ash	15
Smoke	5
Methods for solving storage problems	
Expose and sundry stored beans	58
Apply chemicals	41
Physically kill insects and pests	1

4.3. Nature and contribution of social networks in seed quality control

Social networks describe the pattern of resource sharing among the farmers. Analyzing social networks in detail can improve the understanding of social learning in the context of seed acquisition decisions and can help seed policy makers to develop more targeted strategies to improve bean seed systems (Matuschke and Qaim, 2009). The study revealed that farmers obtained their bean seeds from a range of sources or were aware of the sources. These sources include; farmer groups, local seed dealers, certified seed stockists, neighboring farmers, and extension service providers. These resource centers are consequently referred to as the actors/events. This is visualized in Figure 5. Table 6 indicates the various measures of centrality generated using UCINET.

Seed acquisition through social networks is influenced by a confluence of factors. It is a continuous process involving farmers' processing information from a variety of sources including; their own experiences, the experiences of other farmers, and the nature of their ties (strong or weak) with other farmers and network members. Social network analysis (SNA) provides a set of representational techniques for the analysis of the social ties and underscores the importance of the ties in influencing behavior or information and resource transmission among the actors (Williams and Hummelbrunner, 2011). The SNA methods applied in this study are discussed in detail in chapter three.

4.3.1. Strategic position and important actors

The concept of centrality highlights the most important actors and the strategic positions of the network (Faust and Fitshugh, 2012). The main question of centrality is to define what makes one actor more central than another one (Butts, 2008; Faust, 2007; Garry *et al.,* 2007; Patrick *et al.,* 2005; Scott and Wasserman, 2004). Different criteria have been considered to define centrality, and the chosen criteria enable to obtain different information about the position of actors. The three main definitions of centrality are resumed by Jackson (2014); Knoke and Yang (2008); Jackson (2008); Wasserman and Faust (1994): the degree centrality, the betweenness centrality and the closeness centrality (Table 6).

The degree centrality refers to the number of direct links an actor has with others, hence it is a measure of the actor's activity. It considers nodes with the highest degrees (number of adjacent edges) as the most central. It highlights the local popularity of the network, actors that influence their neighborhood and ones who are highly visible in their community as depicted in Table 6, farmers who relied on fellow farmers to get seeds had the highest in degree centrality of 48 links followed by farmer groups, 25 and extension service providers, 24. Multiple direct links accord these farmers numerous seed sources options with a positive implication on seed security. In Tanzania, Kasambala (2007) found that the multiple seed sources initiated and maintained by farmers ensured seed security in the informal sector. Conversely, certified seed stockists and local seed dealers have the least number of direct links within the network, with lowest in degree centralities of 4 and 2 respectively. The fewer direct links indicate less reliance on the formal seed sources by smallholder bean farmers and explains why the informal seed sources continue to thrive in the county.

Betweenness centrality measures the level of control that a particular actor can exert over others. The betweenness centrality is positively correlated to the level of control that an actor or group of actors has over other actors (Wasserman and Faust, 1994). Within the segments of the network, fellow farmers exhibit the highest (2690) betweenness centrality followed by extension service providers (1599), farmers groups (1161), local seed dealers (86) while the certified stockists had the least (19). The plausible explanation is that farmers' agricultural decisions are highly influenced by fellow farmers (Kasambala, 2007). Extension service providers also have relatively high control over farmers' decisions due to repeated interactions at various forums such as field days, seed fairs, agricultural shows, chiefs' *baraza* and home visits. The control of farmers groups is limited to members of a particular group, which explains the lower betweenness centrality compared to that of extension service providers who can access both members and non–members of a group (Naegasha, 2011).

Certified stockists and local seed dealers exert the least control over farmers because their interaction with the farmers is purely on business terms and occurs only once in a season (Kasambala, 2007). Among the individual actors, farmer number 89 exhibited the highest level of control over other farmers, with betweenness centrality of 562 links. The farmer is linked not only to other farmers but also to all the segments of the network. In many communities, such a farmer may be referred to as opinion leader or model farmer (Bonyo, 2011).

Closeness centrality takes indirect relationships into account and calculates the average distance between an actor and the rest of the network. It gives an idea of an actor's accessibility and relative autonomy. The shorter the average distance, the more accessible an actor is within the network (Hanneman and Riddle, 2005). Among the network segments, fellow farmers exhibit greatest accessibility with closeness centrality of 161 links. Farmer groups have a lower closeness centrality due to the effect of non-members; this is because only the members have unlimited access to groups as opposed to non-members who are considered autonomous.

On the other hand, local seed dealers and certified seed stockists have the autonomy and lower accessibility with closeness centrality of 327 and 247 links respectively. This is because farmers are interdependent and interact more frequently and openly, while local seed dealers and certified seed stockists are detached from farmers due to their business orientation. This is consistent with results of a study in Rwanda by Nsanzabera (2009) who found that farmers were more efficient in technology dissemination due to their interdependence. Farmer number 89 had the highest accessibility with closeness centrality of 175 links. This is because being the opinion leaders/ model farmers; they entertain frequent consultations with fellow farmers and other network segments.

Table 6: Linkages among network segments and individual actors, by measures of centrality

	Network segments (seed sources)					**Individual actors**		
Categories of centrality	Fellow Farmers	Farmer group	Local seed dealer	Certified seed stockist	Extension service provider	Farmer 89	Farmer 31	Farmer 64
Betweenness	2690	1161	86	19	1599	562	365	170
Degree	48	25	2	4	24	3	3	2
Closeness	161	211	327	247	213	175	201	243

Figure 5 below shows a social affiliation map indicating the key structural features at individual and network levels and how the emergence of subgroups pivots around involvement in the flow of information and other resources. For instance, the network has five interlinked subgroups including fellow farmers, farmer group, extension service providers, certified seed stockists, and local seed dealer. These subgroups and individual actors within subgroups are identified by the color and size of nodes. The larger the node of a subgroup implies more direct ties affiliated to it (Williams and Hummelbrunner, 2011). The nodes for fellow farmers, farmer group, extension service providers, certified seed stockist and local seed dealer are indicated by the colors pink, white, green, grey and yellow respectively. Fellow farmers have the highest number of direct ties followed by farmer group, extension service providers, certified seed stockist and local seed dealer in that in descending order. The strength or weakness of the ties is depicted by the length of the line connecting the nodes between the subgroups and between the individual actors with a particular subgroup (Bandiera and Rasul, 2002). For instance, there is a weak link between farmer number 95 and fellow farmers while farmer number 79 exhibits the strongest tie to that subgroup.

Most of the farmers in the county sourced been seed from fellow farmers and from farmer group while least of them sourced from certified seed stockist and local seed dealers in that order respectively (Figure 5). However, some farmers are pivotal in creating the linkages with other farmers and subgroups. This can be explained using betweenness centrality principle which focuses on the ability of an actor to be an intermediary between any two other actors in the network. Consequently, a network is highly dependent on actors with high betweenness centrality and these actors have a strategic advantage due to their position as intermediaries (Tatlongari *et al.,* 2012). For instance, in the Figure 5, farmer number 95 and 89 are key intermediaries between three subgroups; fellow farmers, farmer group and extension service providers. Similarly, farmer number 54, 44 and 88 are key intermediaries between farmer groups and fellow farmers.

In the social affiliation map, the concept of closeness centrality is used to reveal the ability of a node to quickly connect with all the other actors of the network. The smaller the value of centrality and the shorter the line between nodes implies the quicker a node connects actors within the network. Affiliation to fellow farmers has the least closeness centrality measure of 161 (Table 6) and shorter lines connecting individual actors. This increases the probability of resource sharing between the individual actors and fellow farmers given the shortest geodesic distance in the network (Erdem *at al.,* 2008).

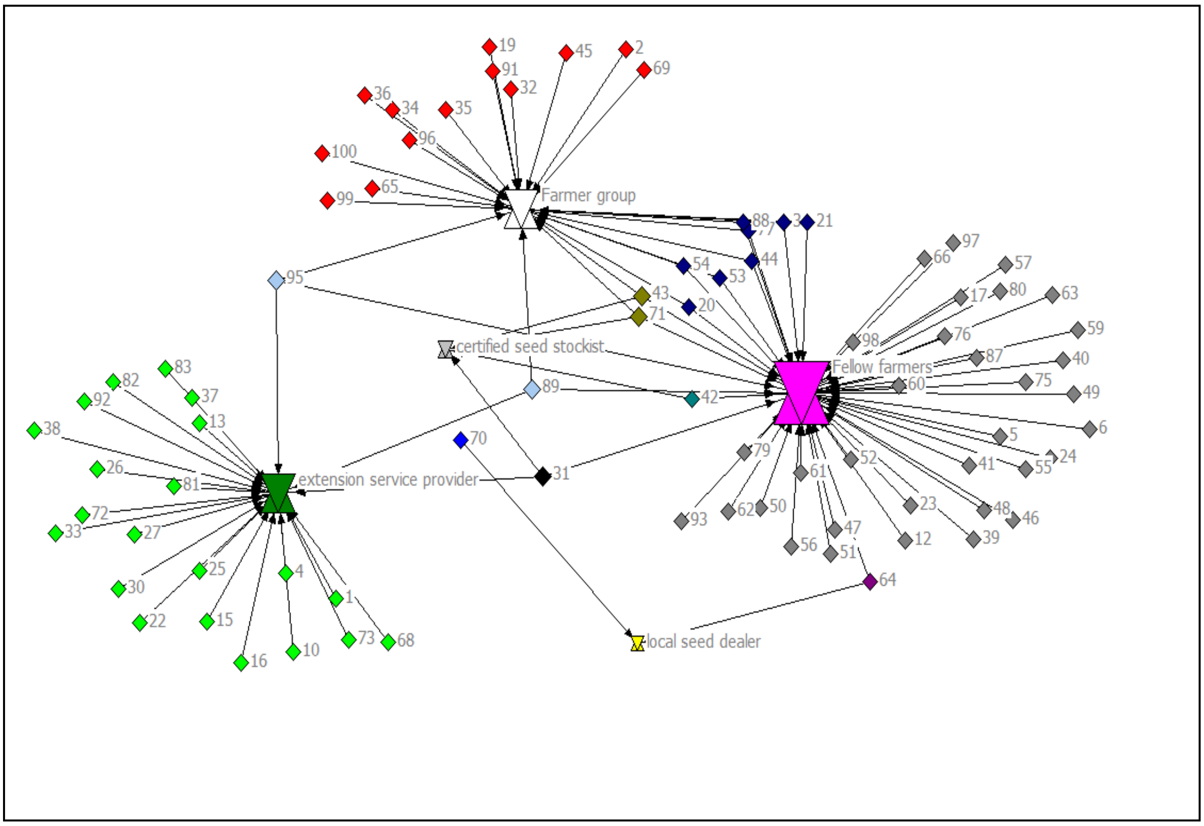

Figure 5: Social affiliation graph showing the nature of social networks and strength of ties between actors.

Source: output from analysis of field data using UCINET computer software package.

4.3.2. Events overlap

Affiliations can be presented in form of events-overlap map in which nodes correspond to entities (such as farmers and events) and lines correspond to ties of affiliation among the entities (Williams and Hummelbrunner, 2011). One justification for relying on co-affiliation is the idea that co-affiliation provides the conditions for the development of social ties of various kinds. For example, the more often people attend the same events, the more likely it is they will interact and develop some kind of relationship (Bandiera and Rasul, 2002). Feld (1981) suggests that individuals whose activities are organized around the same focus (for example voluntary, workplaces, hangouts, or family) frequently become interpersonally connected over time and are driven by cohesion. Members of a cohesive group are likely to be aware of each other's opinions, because information diffuses quickly within the group. These groups also encourage reciprocity and compromise which increases resilience of opinions of other members, over non-members (Adamic, 2011).

Bean farmers tend to source their seeds from four distinct sources. Why this happens is a question of their social economic difference and attributes. Figure 6 captures members who share a common event. Social network theories argue that affiliation to similar events leads to development of social ties (Matuschke and Qaim, 2009). The farmers indicated in red act as a bridge between the farmers and events and therefore act as bridges between the subgroups. The nodes of the other farmers within the network are indicated in blue.

In social network analysis, the role of the farmers indicated in red can be explained using the concept of brokerage positions; cut points and mediators. Actors who are cut points control the flow of information from one part to another part of the network, while mediators exert this function either between groups or within groups (Williams and Hummelbrunner, 2011). The actor number 64, 31, 95 and 89 were identified as brokers between the other actors. Through their multiple linkages with other actors, they have the best access to information and can be considered as network hubs. Similarly, they are also cut points, with the ability to control the flow of information between parts of the network. The implication is that they may be bottlenecks of information and resource flow – and given the dependence of the network on them, if they pull out then the network falls apart (Williams and Hummelbrunner, 2011). However, these actors have structural similarity. They are not directly connected but they occupy similar position in the network structure. As such, they have similar interests in the outcomes that relate to their positions in the structure. This similarity is not conditioned on visibility. The actors must be aware of being in similar positions, but the effect of similarity might be conditional on communication frequency (Adamic, 2011).

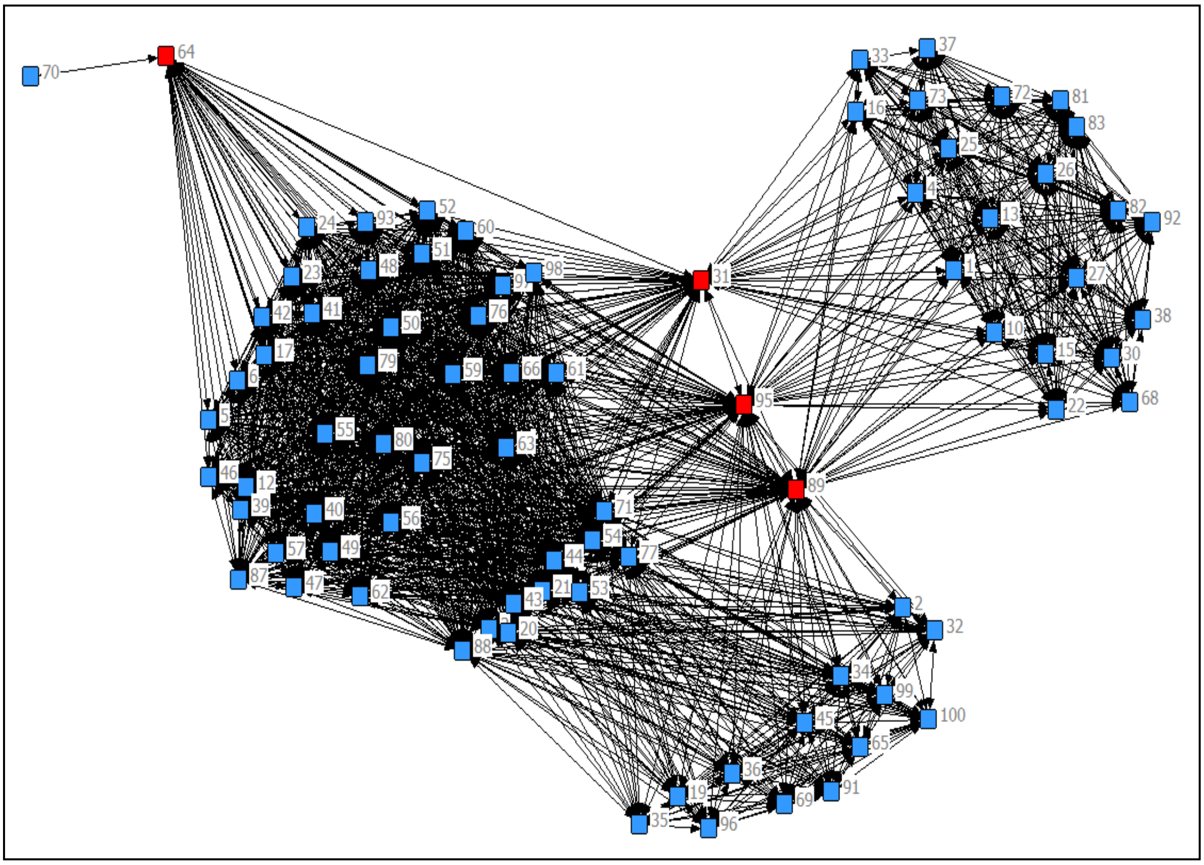

Figure 6: Two-mode actor by event overlap graph showing brokerage positions and interlink between subgroups within a social network

Source: output from analysis of field data using UCINET computer software package.

4.4. Sources of bean seed

To understand the role of different seed sources in bean seed supply, the formal and informal seed sources were characterized based on the farmers' preferences. The role of bean variety preference as a proxy for seed source preference was also determined.

4.4.1. Farmer preference between formal versus informal seed sources

The preferences for various bean seed sources are presented in Table 7. Majority of the farmers (97%) preferred to source bean seed from the informal sector while only 3% used the formal sector. The results corroborate those of Rubyogo *et al.* (2009) and Nasirumbi, (2010) who found that the informal sector supplied 90-100% of seed requirement by smallholder farmers especially for beans in Tanzania. In Ethiopia, Rubyogo *et al.* (2007); Teshale *et al.* (2006) found that the informal sector supplied nearly 99% of bean seed to smallholder farmers. In Malawi, over 95% of the bean seed planted by the smallholder farmers is farm-saved seed, obtained through social networks and/ or from local seed sources such as grain markets or neighbors (DARTS, 2010). The dominance of the informal sector in supplying bean seed (Sperling *et al.,* 2013) can be attributed to the crop's attributes as identified by Rubyogo *et al.* (2010). Being self-pollinated, beans exhibit low varietal deterioration, minimum loss of desirable genetic quality traits and low carryover of seed borne diseases. As such, there is little interest in getting seed from the formal sector since farmers tend to recycle seed from previous harvests for several seasons (Asfaw *et al.,* 2013). When seed is bought from formal channels, the cost of certified seed is 2 to 4 times what farmers would pay for seed obtained in the informal sources and yield gains are not commensurate (Rubyogo *et al.,* 2007).

Among those who sourced bean seed from the informal sector, 40% sowed their own saved seed (from previous harvest); 30% obtained bean seed from local grain market (open-air assembly market), 27% from neighboring farmers and 3% from local seed dealers. There were other seed sources available and 44 percent of households were aware of other informal seed sources while 56% knew they could source seed from the formal sector including research institutions (39%) and certified seed stockists (17%) other than the informal sources.

Despite being aware of other bean seed sources, farmers had various reasons for preferring certain seed sources. The major reasons cited included affordable price (27%), seed readily available (41%), good quality seed (28%) and accessibility (4%). These results are consistent with Rubyogo *et al.* (2007), who concluded that the informal sector has unique aspects which make it particularly suited to small scale farmers' needs: it has a greater social reach, costs less, offers farmers a greater variety of options, is accountable for the quality of its product to the community and has greater geographic reach (Sperling *et al.*, 2013).

Table 7: Distribution of farmers by seed sources preferred and reasons for preference, Bondo sub-County, 2015

Seed sources types	Percent of farmers (%)
Seed sector preference	
Informal	97
Formal	3
Preference for informal seed sources	
Own saved seed	40
Neighboring farmers	27
Local grain market	30
Local seed dealers	3
Other known seed sources	
Certified seed stockists	17

Seed sources types	Percent of farmers (%)
Research institutions	39
Informal sources	44
Reasons for preferring certain informal seed source	**Percent of farmers (%)**
Affordable price	27
Seed readily available	41
Good quality seed	28
Accessibility	4

4.4.2. Bean varieties preferences as a proxy for preferred seed source.

The bean varieties planted, reasons for preferring them and other varieties known by the farmers are shown in Table 8. Preferences for certain bean varieties would be a pointer to the farmer's preferred seed source. A total of eight varieties were identified by farmers across the four sub-locations in their local names including GLP2 (37%), GLP585 (10%), KK15 (15%), NUA1 (18%), KKRB16 (4%), GLP92 (2%), KK18 (3%) and KATB1 (11%). Of these varieties, NUA1 and KATB1 are improved varieties bred for tolerance to multiple constraints and were newly introduced to the area; while the others are old varieties which have been planted for decades. This attests to the ability of farmers to maintain, adapt, and increase genetic diversity to suit their production needs.

However, the emergence of abiotic and biotic stresses such as root rots and drought implies that some of the farmers' bean genotypes are no longer adapted to their growing conditions. At the same time, increasing demand for beans due to its nutritive value means that some of the local varieties are no longer among the most preferred by the consumers in general. For both reasons, many farmers are eager to get access to and experiment with new bean varieties; complementing (and not necessarily replacing) their own local types (Rubyogo *et al.*, 2007).

Farmers knew of at least one other bean variety apart from the one they planted in the previous season. The major varieties cited by farmers in their local names as known but not planted included KATB9 (28%), NUA4 (26%), KK8 (23%) and KATX56 (23%).

Table 8: Distribution of farmers by bean varieties planted or known, Bondo sub-County, 2015

Varieties and attributes	**Percent of farmers (%)**
Varieties planted	
GLP2 (*Rosecoco**)	37
GLP585 (*Nyaboda**)	10
KK15 (Pioneer*)	15
NUA1 (N*yakodongo**)	18
KKRB 16 (*Pocho**)	4
GLP 92 (*Nyaela**)	2
KK18 (*Nyamango**)	3
KAT B1 (Yellow-green*)	11
Other varieties known	
KAT B9 (*Dombolo**)	28
NUA4 (*Nyabondo**)	26
KK8 (*Okuodo**)	23
KATX 56 (*Nyasindori**)	23

*local name of the variety

Farmers selected bean varieties based on the attributes summarized in Table 9. High yields stood out as a critical attribute looked for by farmers across all the varieties planted. The variety GLP2 was favored for high yields by 60% of farmers who planted it, GLP585 (50%), KK15 (60%), NUA 1 (65%), KKRB16 (60%), GLP92 (25%), KK18 (40%) and KATB1 (15%). High yielding varieties are important because farmers want to be food secure by having enough beans for consumption over a longer period. This also explains why farmers are increasingly adopting new and improved varieties. Improved bean varieties not only increase yields by 30-50% but are also an economical and nonintrusive means of improving the livelihoods of poor farming households (Kalyebara and Andima, 2006).

Duration to maturity was considered as critical by farmers while choosing bean varieties for planting. Sixty percent and 10% of farmers who planted the varieties KATB1 and NUA 1 respectively preferred them for being early maturing. Since beans serve as poor man's meat (Audu *et al.*, 2014; Audu *et al.*, 2013; Leterme, 2002), smallholder farmers value varieties with short growth cycle (Rubyogo *et al*., 2010), which deliver food quickly (Sperling *et al*., 1996). In cases where rainfall patterns are unpredictable, production risks can be reduced through planting of early maturing varieties to take advantage of short rains (Legesse *et al.,* 2006). Relatively shorter cooking periods exhibited by the varieties KATB1 and NUA 1 attracted a 15% and 10% preference by farmers who planted them. Shorter duration for cooking is critical for cost saving in terms of reduced fuel usage and time spent preparing bean meal, which may then be transferred to other home chores.

Similarly, the two varieties were preferred by 10% and 20% of farmers who planted them for having better taste on eating. Better taste has to do with palatability and is critical in increasing bean consumption levels and therefore enhanced nutrition status, especially with increased awareness about the health benefits of beans (Audu *et al.*, 2014; CRS, 2014; Olaofe *et al.*, 2010; Katungi *et al.*, 2009; Leterme, 2004).

Except for the two varieties; NUA 1and KKRB16, marketability was a critical attribute considered by farmers when choosing varieties for planting. The variety GLP92 was preferred by 45% of farmers who planted it, KK15 (40%), GLP2 (30%), GLP585 (20%), KK18 (15%) and KATB1 (10%) for high marketability. Although smallholder farmers grow beans for subsistence (Katungi *et al.,* 2009), marketability is important because the crop is steadily transforming into market oriented one (Buruchara *et al.,* 2011). This is motivating farmers to sell part of their produce for extra income (PABRA, 2014; Asfaw *et al.,* 2013) and also to meet other household cash needs.

Finally, bean farmers would go for varieties that are readily available as indicated by farmers who planted the variety GLP92 (45%), KK18 (40%), GLP585 (30%), GLP92 (30%), KK15 (10%) and GLP2 (10%). This is logical because unavailability of bean variety is associated with increased transaction costs including search costs and time spent in obtaining varieties from distant sources; which can be reduced or eliminated if the variety is obtained within the farmer's locality (Asfaw *et al.,* 2013).

Table 9: Distribution of bean varieties by reasons for farmers' preferences, Bondo sub-county, 2015

Variety	**Reasons for preference and percent of farmers stating (%)**					
	High yielding	Early maturity	Better taste	Cooks fast	Readily available	Highly marketable
GLP2	60	-	-	-	10	30
GLP585	50	-	-	-	30	20
KK15	60	-	-	-	10	40
NUA1	55	10	20	10	-	-
KKRB16	60	-	-	-	40	-
GLP92	25	-	-	-	30	45
KK18	40	-	-	-	45	15
KATB1	15	50	10	15	-	10

4.5. Factors influencing farmers' preferences for seed sources

A Multinomial Logistic Regression Model (MLRM) was used to determine the factors influencing smallholder bean farmers' preferences for seed sources in the informal seed sector. The effects of the explanatory variables on the likelihood of choosing a certain informal seed source from a number of alternative sources available to the farmers relative to the formal sources (certified seed stockists) were examined.

Overall test of relationship

The presence of a relationship between the dependent and a combination of independent variables is based on the statistical significance of the final model Chi-square (Table 10); termed the model fitting information. The significant value (also known as p-values) show whether a change in the independent variable significantly influences the Logit at a given level (Gujarati, 2007). In this analysis, the distribution reveals that the probability of the model Chi-square is 90.490 and p= 0.000 (Table 10); hence smallholder bean farmers are influenced by socio-economic factors while choosing their seed sources.

Table 10: Model fitting information

Model	**-2log Likelihood**	**Chi-square**	**df**	**Sig**
Intercept only	217.513	.	.	.
Final	127.023	90.490	28	0.000

As indicated in Table 11, some predictor variables influence the choice of informal seed sources significantly relative to the formal sources. Of the ten independent variables used in the model, five variables in own saved seed, five in neighbouring farmers and four in local grains market seed sources were statistically significant at 0.05 level. In eight out of ten cases, the signs of the estimated log odds were consistent with the *a priori* expectations.

The results suggest that the probability of the choice of own saved seed (from previous harvest) as a seed source relative to certified seed stockists; is significantly influenced by family size (FAMSIZE), age of the household head (HHAGE), distance to the nearest seed source (DISTSEEDSRC), and area under beans (AREABEANS), main activity of the household head (HHMAINACTVY) and group membership (GRPMSHP). The choice of neighbouring farmers as seed source relative to certified seed stockists; is significantly influenced by age of household head (HHAGE), distance to nearest seed source (DISTSEEDSRC), family size (FAMSIZE), nature of land ownership (OWNSHPLAND), main activity of the household head (HHMAINACTVY) and membership to a group (GRPMSHP). The choice of local grains market as source of bean seed relative to certified seed stockists; is influenced by family size (FAMSIZE), distance to the nearest seed source

(DISTSEEDSRC), nature of land ownership (OWNSHPLAND) and main activity of the household head (HHMAINACTVY).

There was a positive and significant coefficient of family size (FAMSIZE) in choice of own saved seed relative to certified seed stockists. The logit estimate for a unit increase in family size is 0.399. When the size of household increases by one individual, the log-odds of preferring saving own seed planting relative to obtaining seed from certified stockists increases by 39.9%. The plausible explanation is that the larger the household size, the more likely they will prefer to source bean seed from their saved stock. Such households may be obliged to keep their own seed for planting; to reduce or eliminate expenditures on seed from certified seed stockists owing to limited disposable income. These results corroborate those of Sonamo (2008) and also Gani and Adeoti (2011).

Similarly, family size positively influenced the choice of neighbors as seed source relative to certified stockists. In this case, the logit estimate for a unit increase in family size is 0.722. A unit increase in family size triggers a 72.2% increase in the log-odds of preferring neighbors as seed source relative to certified stockists. The plausible explanation is that the larger the size of a household, the more intense and closely knit are the interactions between and among different households of similar social class (smallholder farmers). These interactions increase the chances of exchanging information and other resources including seed with their neighbors relative to obtaining seed from certified stockists.

Sourcing of seed from the local grains market relative to certified stockists is positively influenced by family size; with a logit estimate of 0.623. An increase of the family size by one individual triggers an increase in chances of farmers choosing to get their bean seed from the local grains market by 62.3% relative to certified seed stockists. This is possibly attributed to the fact that the larger the size of a household, the higher the amount of beans consumed such that at the time of planting, there is too little or no seed reserve. This prompts the purchase of beans from the local grains market to either replenish the finished stock or supplement the little seed reserved for planting. Also, the farmers will resort to local grains market relative to certified stockists due to the latter's prohibitive costs (Rubyogo *et al.,* 2007).

The age of household head (HHAGE) positively influences the use of own saved seed for planting relative to certified stockists with a logit estimate of 0.059. An increase in the age of household head by one year would increase the chances of choosing own saved seed relative to certified stockists by 5.9%. The rationale is that as farmers advance in age, they device effective methods for controlling quality of their own bean seed (Asfaw *et al.,* 2013) and develop trust in their own seed over other sources (CRS, 2014). Moreover, age is also a proxy for experience in bean production and farming in general.

Results also indicate that an increase in the age of the farmer by one year increases the chances of the farmer preferring to get seed from a neighbor relative to certified stockists by 7.2%. The intuition here is that the more aged a farmer becomes, the more they build trust in their neighbors – and the more they tend to share information and other resources. This trust is premised on the notion that if information given is incorrect, it will be found out and the rest of the community will know. In many rural settings, sharing resources is the norm rather than exception hence, many farmers try their level best to be faithful with regard to the quality of the resource being shared. For instance, giving poor quality seed to a neighbor would amount to breaching the societal norm. In some cases this is punishable through sanctions. More aged farmers also interact often through neighbourhood visits. These are avenues for sourcing seed and information on new varieties from their neighbouring farmers.

Distance to nearest seed source (DISTSEEDSRC) was significant at 5% for the choice of own saved seed relative to certified stockists. The logit estimate for a unit increase in family size is 0.127. When distance to nearest certified seed stockist increases by one kilometer the log-odds of farmers preferring their own seed relative to certified stockists increases by 12.7%. Smallholder farmers do plant relatively small amounts of seed and covering long distances in search of the small quantities of seed may not be cost effective to the farmers (Rubyogo *et al.*, 2008). Distance also influenced seed sourcing from neighborhood relative to certified stockists with a logit estimate of 1.35. A unit increase in distance to nearest certified stockist increases the log-odds of farmers resorting to source bean seed from the latter relative to the former by more than 100%. This is logical because farmers cannot spend money to buy seed at a distant source when it can be found at the neighbourhood. Smallholder farmers are often cautious about their expenses and would wish to access production resources at the cheapest possible cost. This is also because many farmers live in areas with poor physical infrastructure thus, accessing the seed sale points may be a challenge. However, the logit estimate for the choice of local grain market relative to certified stockists was -1.25. When the distance to local grains market increases by 1 kilometer, the chances of choosing to source seed from it relative to certified stockists decrease by more than 120% –especially where seed stockists are closer to the farmer than the local market. Farmers would prefer sourcing bean seed from the nearest outlet more so if there is variation in quality (CRS, 2011) and if additional costs – in terms of time and physical energy spent in obtaining seed from far off grains market are not justified (Suri 2006; Farrow *et al.,* 2010).

Area under beans (AREABEANS) positively and significantly influenced the farmers' preference of own seed for planting relative to certified stockists with logit estimate of 0.867. The results indicate that when area under beans increases by one hectare the log-odds of farmers preferring to save and use their own bean for planting relative to sourcing seed from certified stockists increases by 86.7%.This is because the larger the area dedicated to bean crop, the more the amount of seed required. This translates into higher expenditure on seed. These costs are reduced or even eliminated when farmers keep their own seed from previous harvests (Rubyogo *et al.,* 2007).

The main activity of the household head (HHMAINACTVY=2) has negative influence on the choice of own seed, neighbors and local grains market for accessing seed relative to certified stockists with logit estimates of -0.611, -0.052 and -2.735 respectively. Specifically, civil servants show less preference for own saved seed and neighbors' seed and seed from local grains market relative to certified stockists; unlike those who practice farming as their major occupation as well as those who had retired. A unit increase in chances of becoming a civil servant decreased the log-odds of preferring own seed, neighborhood and local grains market as source of bean seed relative to certified stockists by 61%, 5.2% and 273% respectively.

However, the choice of local grains market as a source of bean seed relative to certified stockists is positively influenced by the main activity of the household with log estimate of 0.735. When an individual's chance to be a civil servant increases by one unit, the log-odds of sourcing bean seed from the local grains market relative to certified stockists increases by 73.5%. These civil servants who are part-time farmers have the advantage of accessing the local grains market frequently and at no extra costs. This is because often they commute to work places and can conveniently stop by such markets to purchase beans.

The nature of land ownership (OWNSHPLAND=1) negatively influenced choice of neighbourhood and local grains market as source of bean seed relative to certified stockists. The logit estimates are -0.108 and -0.223 respectively. A unit increase in opportunity to own land with title deed reduces the log-odds of choosing neighbouring farmers and local grains market as sources for bean seed by 10.8% and 22.3% respectively. The possession of land title deed is an incentive to invest in bean production not only for subsistence but also as source of household income. Ownership of land with title deed is a critical element for higher levels of investment on land and intensification of agricultural production through enhanced access to credit as well as increased flexibility for reallocation of production factors to maximize allocative efficiency in land use (Dube and Guveya, 2013).

Membership to a group (GRPMSHP) positively influenced choice of own saved seed and neighbours seed for planting relative to certified seed stockists; with logit odds of 2.546 and 1.081 respectively; unlike non-membership. Where a farmer is a member of a group, the chances of saving their own seed or getting seed from neighbours would increase be 245% and 108% respectively. The plausible explanation is that farmers who belong to groups are more likely to share resources including seed. Group members are also more likely to gain knowledge and skills in seed quality control and hence have motivation to save their own seed (Asfaw *et al.,* 2013).

Table 11: Estimated results of the Multinomial Logistic Regression Model (reference category: certified seed stockists)

Variables	**Own saved seed**		**Neighbouring farmers**		**Local grains market**	
	Log odds	Significance	Log odds	Significance	Log odds	Significance
Intercept	-5.458***	.020	-4.121***	.036	4.322	.345
Age	.059***	.035	.072***	.005	.014	.690
Education level	.133	.290	.167	.324	.076	.126
Family size	.399***	.035	.722***	.003	.632***	.033
Distance to nearest seed source	1.268***	.001	1.353***	.000	-1.254***	.000
Farm size	-.566	.433	.022	.982	-.032	.743
Area under beans	3.867***	.021	1.883	.295	-1.723	.256
Sex of household head	.873	.313	1.132	.232	.789	.312
Marital status (Single=1)	2.802	.229	1.448	.277	1.325	.721
Marital status (Married=2)	5.250	.341	4.174	.067	3.241	.132
Nature of land ownership	-.2.056	.083	-3.108***	.012	-2.223***	.014
Main activity (Farming=1)	-1.741	.101	-.641	.583	.564	.138
(Civil servant=2)	-3.611***	.022	-3.052***	.005	-2.735***	.002
(Business=3)	-1.183	.380	-.095	.949	.854	.439
Group membership (Member=1)	2.546***	.032	1.081***	.007	.651	0.32
(Non-member=2)	-2.726***	.074	-1.312***	.262	-1.428***	.169

Note: ***significant at 0.05 levels

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

1. The study revealed that, bean farmers bear varying socio-economic characteristics. Bean farming is male-dominated; majority being middle-aged with appreciable levels of literacy, relatively large household sizes, small landholdings largely held with titles and have to cover long distances to get seed from alternative sources other than own saved seed and neighbours.
2. Smallholder bean farmers use different methods to control seed quality at pre-planting, planting, post planting, harvesting and post-harvest stage. Generally, farmers assess quality characteristics while sourcing seed and seed which is free from insect attack is considered as being of high quality. While majority of farmers do not treat seed at planting, most of the farmers use post-planting, harvest and post-harvest cultural methods for quality control. Nearly all farmers experience storage problems – most common being insects and rodents.
3. The Social networks are dominated by prominent farmer-to-farmer ties; which highly influences the farmers' choice of bean seed sources; with consequence on the quality of seed so accessed by farmers. It was also revealed that farmers play critical role in linking the subgroups within these networks both as cut-points and mediators.
4. The observed differences in farmers' socio-economic characteristics have implications on the choice of bean seed sources in the informal sector. For instance, as the age of a farmer advances they tend to prefer sourcing bean seed from either their own harvest stock or from neighbours. On the other hand, farmers who practice bean farming alongside other occupations would less likely prefer seed from their own stocks, neighbours and local grains market.

5.2. Recommendations

1. Given the dominance of the informal seed sector in supplying seed to smallholder farmers, a locally-based seed system should be designed, which utilizes farmer-to-farmer social networks to enhance bean seed supply among smallholder farmers. The system can then be tested across the study area among the farmers and possibly scaled out to other legume crops facing similar seed situation as the common bean. For instance, whereas farmers practice seed quality control, the methods they use may not be efficient enough to

prevent post-harvest losses. The formal sector can therefore take a lead in providing technical backstopping to enhance farmers' skills in pre and post-harvest management of beans.

2. Farmers preference for certain bean varieties can be used as a strategy by bean breeders, seed systems specialists and agencies engaging in seed aid to target seed development, delivery and interventions based on the preferences. This can indirectly contribute to high rates of acceptability and adoption of such varieties. Consequently, this can prevent any wasteful use of resources on development of varieties which might otherwise be rejected by farmers.
3. Age plays a critical role in farmers' choice of seed source. Younger farmers can be a prime avenue for introducing new varieties as well as non-varietal technologies in the communities. A viable approach would be to use youth groups as springboards for such initiatives.
4. The high degree and betweenness and low closeness centralities for farmer-to-farmer ties evidenced in this study should be exploited to hasten diffusion of resources (seed, information) and other improved technologies to other farmers. This is based on the premise that farmers trust one another and would easily accept a new technology if a fellow farmers has approved of it. The starting point would be to identify the key person with highest influence in the farmer-to-farmer ties and brokers in the farmer-to-subgroup networks; then exploit these influences in scaling out seed-related interventions and information to the entire community.

REFERENCES

Almekinders, C. (2000). Increasing the Resilience of Farmers' seed system through linkage with formal sector, technology and Agrarian Development. *Targeted seed aid and seed systems interventions* (pp. 69-73). The Netherlands: Wangenigen University.

Asfaw, A., Almekinders, M., Struik, C. and Blair, W. (2013). Farmers’ common bean variety and seed management in the face of drought and climate instability in southern Ethiopia. *Academic Journals*: 1022-1037.

Audu, S., Aremo, O., Lajide, L. and Oko. J. (2014). Functional Properties of Processed Pinto Bean (*Phaseolus vulgaris* L.) grown in Plateau State. *Chemical and Process Engineering Research.* Lagos, Nigeria.

Audu, S., Aremu, O. and Lajide, L. (2013). Influence of traditional processing methods on the nutritional composition of black turtle bean (Phaseolus vulgaris L.) grown in Nigeria. *International Food Research Journal*: 20 (6) 3211 –3220.

Baniya, B. D. (2003). Factors affecting seed systems, experience from Nepal, Nepal Agricultural Research Institute. Pucallpa, Peru.

Birachi et al. (2011). Factors influencing smallholder farmers’ bean production and supply to market in Burundi. *African Crop Science Journal:* 19 (4) 335-342.

Bouchenak, M. and Lamri-Senhadji, M. (2013). Nutritional Quality of Legumes and their Role in Cardiometabolic Risk Prevention, a review. *Journal of Medicinal Food*: 16 (3) 185-198.

Buruchara, R. (2011). Development and delivery of bean varieties in Africa: the Pan Africa Bean Research Alliance (PABRA) model. *African Crop Science Journal*: 19 (4) 227-245.

Buruchara, R. (2007). Background information on Common Beans (*Phaseolus vulgaris* L.) in Biotechnology, breeding and seed systems for African crops. *African Journal of Biotechnology*: 7 (3) 84-92.

Butts, T. (2008). “Social network analysis: A methodological introduction” *Asian Journal of Social Psychology:* 11 (1) 13-41.

Case, K.E. and Fair, R.C. (1992). *Principles of Microeconomics. 2nd Ed.* Prentice Hall Inc. Eaglewood cliffs, New Jersey.

Carrington, P., Scott, J, and Wasserman, S. (2004). *Models and Methods for Social Network Analysis.* New York: Cambridge University Press.

CRS. (2014). Introduction – Improved Seed Storage Briefs. Nairobi: Catholic Relief Services.

CRS. (2013). Documenting and Socializing Lessons Learned from 7 OFDA Grants on Household Seed Storage. Workshop held: April 15–19th 2013. Bujumbura, Burundi.

CRS. (2011). From relief to resilience – linking Burundian farmers and researchers in evaluating improved bean varieties. Catholic Relief Services: Bujumbura, Burundi.

Chai, S. (2001). *Choosing an Identity: A general model of preference and Belief Formation.*The University of Michigan press. Michigan, USA.

Claude R., Dickinson M., Mayes S. and Assefa T. (2009) 'Seed- Health Assessment of Different Bean Seed Grades and Sources from Ethiopia Using Molecular Tools' *Journal of New Seeds:* 10 (4) 293-310.

DARTS. (2010). Annual Report. Seed Services. DARS: Lilongwe, Malawi.

Doreian, P., Vladimir, B. and Anuska, F. (2005). "Positional analyses of sociometric data." Chapter 5 pages 77-97 in Carrington, Peter J., John Scott, and Stanley Wasserman (eds.) *Models and Methods in Social Network Analysis.* Cambridge: Cambridge University Press.

FAO. (1999). *Seed Policy and programmes for Sub Saharan Africa.*Food and Agriculture Organization of the United Nations. Rome, Italy.

FAO. (2004). Seed Multiplication by resource-limited farmers. *Proceedings of the Latin American workshop, Goiania Brazil, 7-11 April, 2003.*Food and Agriculture Organization of the United Nations. Rome, Italy.

Faust, K. (2007). Very Local Structure in Social Networks." *Sociological Methodology*: 37 (1) 209-256.

Faust, K. and Fitshugh, S. (2012). Social Network Analysis: An Introduction. *2012 ICPSR Summer Program in Quantitative Methods of Social Research*. The Odum Institute, University of North Carolina, Chapel Hill, USA.

Friedman, D. and Hechter, M. (1988). The contribution of Rational Choice Theory to Microsociological Research. *Sociology Theory:* 6 (2) 201-218.

Hanneman, A. and Riddle, M. (2005). Introduction to social network methods. Riverside, CA: University of California, Riverside.

Jacknon, M.O. (2008). *Social and Economic Networks*. Princeton University press, Princeton – New Jersey, USA.

Jones, K. (2013). The political ecology of market-oriented seed system development and emergent alternatives. *The Journal of Peasant Studies*: 7 (1)1-26.

Karrfalt, R.P. (2013). The importance of good seed. In: Haase, D.L., Pinto, J.R., Wilkinson, K.M, technical coordinators. National Proceedings: Forest and Conservation Nursery

Associations—2012. Fort Collins (CO): USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-69. 49-52.

Katungi, E., Farrow, A., Chianu, J., Sperling, J. and Beebe, S. (2009). *Common bean in Eastern and Southern Africa: a situation and outlook analysis.* International Center for Tropical Agriculture. Kampala, Uganda.

Katungi, E., Wozemba, D. and Rubyogo, J.C. (2011). A cost benefit analysis of farmer based seed production for common bean in Kenya. *African Crop Science Journal*: 19 (4) 409-415.

Kothari, C. (1990). *Research Methodology, Methods and Techniques.* New Delhi-110002, India: New Age International (P) Ltd., publishers, 4835/24.

Knoke, D. and Yang, S. (2008). *Social network analysis* (Vol. 154). Sage publishers, London.

Legesse, H., Negussie, D., Setegn, G., Geremew, B. and Firew, M. (2013). Multivariate Analysis as a Tool for Indirect Selection of Common Bean Genotypes (Phaseolus vulgaris L) for Soil Acidity Tolerance under field conditions. *Science, Technology and Arts Research Journal*: 2 (3) 7-15.

Leterme, P. (2002). Recommendations by health organizations for pulse consumption. *British Journal of Nutrition*: 88 (S3) 239-242.

Louwaars, N. and Gam, M. (1999). *Seed supply system in developing countries.* The Netherlands: CTA.

Maredia, M., Dancun, B., Anwar, N., Maria, W. and Kajia, K. (1999). *Increasing seed system efficiency in Africa; concepts, strategies and issue.International development working paper.* Michigan: MSU.

McGuire, S. (2005). *Re thinking seed system analysis and reform for sorghum in Ethiopia*. The Netherlands: Wangenigen University.

McCloskey, D.N. (1996). *The Economics of Choice. Neoclassical Supply and Demand, Economics and the Historian.*University of California Press.Berkeley, Los Angeles

Miller, R.L. (1994). *Economics Today, the Micro View. 8th Ed.* Harper Collins College Publishers. New York.

Mugonozza, S. (2001). *Seed system in Africa* . International center for agriculture research in the dry areas (ICARDA).

Olaofe, O. Famurewa, V. and Ekuagbere, A. (2010). Chemical and functional properties of kidney bean seed (*Phaseolus vulgaris* L.) flour. *International Journal of Chemical Sciences*: 9 (8) 51-69.

PABRA. (2014). Innovation partnership: Agricultural research in Africa. *End of 2009–2014 Phase Report and Partnership in Research for Impact*: Case of Common Beans in Ethiopia.

Parkin, M. (1997). *Microeconomics. 3rd Ed. Updated Edition. The Addison-Wesley Series in Economics.* Addison Wesley Longman Inc. New York.

Powell, A. (2009). The importance of quality seed in agriculture. *What is seed quality and how to measure it?.*University of Aberdeen, UK.

Rebello, C. (2014). A review of the nutritional value of legumes and their effects on obesity and its related co-morbidities. *Journal of Food and Nutrition Research*: 15 (5) 392-407.

Robins, G., Pip P., Yuval, K. and Dean, L. (2007). An introduction to exponential random graph models for social networks. *Social Networks*: 29 (2) 173–191.

Rohbarch, D. (2002). *Comparative study of three community seed supply strategies in Tanzania, International Crops Research Institute for the Semi-arid Tropics.* Bulawayo, Zimbabwe: ICRISAT.

Rubyogo J.C., Sperling L., and Buruchara R. (2010). Bean Seed Delivery for Small Farmers in Sub-Saharan Africa: The Power of Partnerships. *Society & Natural Resources: An International Journal*: 23 (4) 285-302.

Rubyogo J.C., Sperling L. and Assefa T. (2007). A new approach for facilitating farmers' access to bean seed. *LEISA Magazine:* 23 (2) 27-29.

Rule, J. (1997). *Theory and Progress in Social Science.* Cambridge University Press.New York.

Secretariat, Bondo District (2005). *Bondo district strategic plan 2005-2010 for implementation of the national population policy for sustainable development.* Nairobi.

Secretariat, Bondo District (2006). *District Environment Action Plan (DEAP)-Bondo district (2006-2011).*Nairobi.

Shi, J. (2004). Saponins from edible legume: chemistry, processing and health benefits. *Journal of Medicinal Food*: 7 (1) 67-78.

Soniia, D., Roger, K. and Sarah, K. (1999). Assessing the impact of bush bean varieties on poverty Reduction in sub-saharan africa: evidence from Uganda. Paper presented at the workshop "Assessing the Impact of Agricultural Research on Poverty Alleviation", San Jose, Costa Rica, 14-16 September 1999.

Sperling, L. and McGuire, S.J. (2010). Understanding and strengthening informal seed markets. *Experimental Agriculture:* 46 (2) 119-136.

Sridhar, S. and Kumar, A. (2013). Seed Treatment Techniques. Centre for Indian Knowledge Systems (CIKS) Seed Node of the Revitalising Rainfed Agriculture Network. PM Digital products - Peters Road, Chennai, India.

Stone, G. (2004). Boitechnology and the political ecology of information in India. *Human Organization*: 63 (2) 127-140.

Sylvester, S. (2013). Land tenure reforms and investment in Tanzania. *Masters dissertation, University of Dar es Salaam*, Tanzania.

The crops Act (2013). Assented on 14th January, 2013. *Kenya Gazette Supplement No. 16,* pp. 25-29. Nairobi.

Tsgedingile, M. (2002). *Potential and limitation of smallholder seed production in Ethiopia: the case of Soro district. An MSc thesis presented to Sokoine University of Agriculture.* Morogoro.

Varian, H.R. (1999). *Intermediate Microeconomics: A modern approach. 5th edition.* Norton and Company. New York.

Venn, B. (2004). Cereal Grains, Legumes and Diabetes. *European Journal of Clinical Nutrition:* 58 (11) 1443-1461.

Walelign, G. (2008). *Determinants and role of farmers' seed and seedling multiplication in the SNNP region seed system. A thesis submitted to the Department of Agricultural Economics, School of graduate studies, Himaraya University.* Addis Ababa: Himaraya University.

WBG. (1999). *Sub saharan Africa seed initiative, program description, World Bank Group.* African Region: World Bank Group.

Welfzien, E. and Brocke, K.V. (2001). Seed systems and their potential for innovation; conceptual framework for analysis, Hohenheim University. *Targeted Seed and Seed-system interventions; Strengthening Small-Farmers seed systems in East and Central Africa* (pp. 1-112). Kampala: Hohenheim University.

APPENDICES

Appendix I: Questionnaire

Title: Analysis of quality control in the informal seed sector: case of smallholder bean farmers in Bondo sub-county, Kenya

Name of enumerator_______________________________ Mobile No._________________

Questionnaire Number_______________Date of interview____/____/____/ (day/month/year)

GENERAL INFORMATION

Respondent's Name (optional) ____

Sub-location ___________________Location ________________Sub county____________

A: SOCIO ECONOMIC CHARACTERISTICS OF BEAN FARMERS

01. Age of head of household (years) …………………..

02. Sex of the head of household
1 = Male2 = Female

03. Educational level of the head of household (Years of schooling) …………………..

04. Marital status of the head of the household
1 = Single2 = Married 3 = Divorced 4 = Separated

05. Family size (Number of members in the farmer's household) ………………..

06. Nature of ownership of land
1 = owned with title deed 2 = Owned without title deed 3 = Lease

07. Size of farm (indicate the units as stated by the farmer) ……………

08. What is the main activity of the head of household?
1= Farming 2 = Civil servant 3 = Businessman 4 = Retired with pension
5 = Retired without pension 6 = others (specify)……………………

B: SEED SOURCE PREFERENCES

09. Does your household grow beans?
1= Yes 2 =No

10. If yes, what area was planted with beans last season? …………. acre

11. How many seasons do you produce bean per year?

1 = one 2 = two

12. Where did you get seed bean for planting in the last season?

1 = Own saved seed 2 = Neighbouring farmers 3 = Local seed producer

4 = Local grain market (open-air assembly market) 5 = Certified seed stockist

13. Do you know any other source where you can get bean seed?

1 = Yes 2 = No

14. If yes, which one?

1 = Agrodealers shops 2 = Local grain market 3 = Neighbouring farmers

4 = Local seed producer 5 = others (specify) _______________

15. Why do you prefer to get seed from the source stated in (12) above? (Probe and document the major reason for preference).

1 = Affordable price 2 = readily available

3 = good quality 4 = others (specify) ________________

16. Which bean variety did you plant last season?

17. Do you know any other bean variety?

1 = Yes 2 = No

18. If yes, which one?

19. Why do you prefer to plant the variety stated in (16) above? (Probe and document the major reason for preference)

1 = high yielding 2 = early maturing 3 = better taste 4 = cooks fast

5 = readily available 6 = highly marketable 7 = others (specify) _________

C: METHODS USED FOR SEED QUALITY CONTROL

C1: Planting practices

20. Do you assess quality characteristics when you get seed for planting?

1 = Yes 2 = No

21. If yes, which major quality characteristic do you look for when procuring seed for planting?

1 = Seed type 2 = Free from soil 3 = Free from chuff 4 = Free from insect attack
5 = Proportion of discoloured seed 6 = Proportion of broken seed 7 = Seed colour

8 = Seed size

22. Do you treat the seed at planting? (If yes proceed to question 23, No skip to question 24)

1 = Yes 2 = No

23. How do you treat the seed?

1 = Apply chemicals 2 = Apply wood ash 3 = others (specify)………………

24. How do you control pests/diseases when the beans are still growing in the field?

1 = Apply chemicals 2 = Use cultural practices 3 = both

25. Which chemical do you apply?
1 = Altrocon 2 = Karater 3 = Wood ash 4 = others (specify) ______

26. Which cultural practice do you use?

1 = weeding 2 = early planting 3 = intercropping 4 = mixed cropping

5 = roguing 6 = others (specify) ____________________

C2: Harvesting and post harvest management practices

27. When do you consider the beans ready for harvesting?

1 = When leaves fall out 2 = when the pods are completely dry

3 = when the pods begin shuttering 4 = others (specify) __________________

28. How do you harvest?

1 = Cutting the whole plant at the collar region 2 = Uprooting the whole plant

3 = collecting the pods 4 = Others (Specify) ___________________________

29. Do beans shutter in the field while harvesting?

1 = Yes 2 = No

30. What do you do with the bean seeds that shutter in the field?

1 = Leave then in the field 2 = Collect and mix them with other seeds in the store

3 = Consume them 4 = Sell them

31. When do you thresh to remove seeds from the pods?
1 = 1 day after harvesting 2 = 3 days after harvesting

3 = 7 days after harvesting 4 = 14 days after harvesting

32. Where is threshing done?
1 = Field 2 = farm house 3 = in gunny bag 4 = open yard

33. Do you clean the seeds at this stage?
1 = Yes 2 = No

34. How do you clean the seeds?
1 = completely remove the chuff 2 = Remove broken seeds

3 = Sort out discoloured beans 4 = Sort out by size

5 = All the above 6 = Others (Specify) ________________

C3: Storage practices

35. When do you store the harvested beans?

1 = after threshing 2 = after cleaning 3 = after drying 4 = All three

36. How do you know when the beans are dry enough to be stored?

1 = Bite with teeth 2 = press with fingers 3 = others (specify) __________

37. For how long do you store beans?

1 = Less than one month 2 = 1-5 months 3 = More than five months

38. What storage structure do you use? Document also from observation

1 = A raised platform on the farm 2 = A raised platform near the house

3 = A room in the house 4 = A space in the ceiling 5 = others (specify) ______

39. Where is your storage structure located?

1 = in the courtyard 2 = behind the house
3 = inside the house 4 = Others (Specify) __________________________

40. Construction material for storage structure?
1 = Wood 2 = clay 3 = metal 4 = others (specify) _______________

41. Why did you use the material stated in (36) above?
1 = affordable 2 = readily available 3 = others (specify) _________

42. For how many seasons have you used this type of store?
1 = one season 2 = two seasons 3 = four seasons 4 = over four seasons

43. Do you use it to store other foodstuffs?

1 = Yes 2 = No

44. What do you do to the storehouse before storage?

1 = Clean 2 = Reinforce the floor with cement 3 = Reinforce with cow dung

4 = Apply insecticides on the floor 5 = Remove old seed/grain

6 = Others (Specify) ______________________

45. Do you apply any treatment to the store before storage?

1 = Yes 2 = No

46. If yes, which treatment?

1 = Ash 2 = sand 3 = smoke 4 = manure 5 = insecticides

6 = others (specify) ___________________________

47. Have you experienced any storage problems? (If yes proceed to question 48)

1 = Yes 2 = No

48. What are the most common storage problems?

1 = Moisture

2 = insects

3 = rodents

4 = mould growth

5 = others (specify) ______________________________

49. What did you do to solve this problem?
1 = applied chemicals (insecticides/rodenticides)
2 = physically killed the insects/rodents
3 = others (specify) _________________________

D: NATURE AND CONTRIBUTION OF SOCIAL NETWORKS IN SEED QUALITY CONTROL

50. Where do you get information about bean production?

1 = Neighbouring farmers
2 = Local seed dealer
3 = Extension service providers
4 = Certified seed stockist
5 = Farmer group
6 = others (specify) _____________

51. How frequently do you get information from the source stated in (50) above?

1 = Daily
2 = Weekly
3 = fortnightly
4 = once per season

52. What type of information do you get?

1 = General Bean production
2 = Seed selection
3 = Bean seed business management
4 = others (specify) _________________

53. Where did you get seed bean last season?

1 = friend
2 = family member
3 = some farmer group

4 = some Church
5 = others (specify) ________________

54. How often do you get seed from the source stated in (53) above?

1 = every season
2 = Once in a while

55. What else do you get from that source?
1 = advise on seed production
2 = advise on seed selection
3 = advise on seed business management
4 = others (specify) _____________

56. Do you belong to a group?
1 = Yes   2 = No

57. If yes, what are the functions of the group?
1 = collective seed marketing
2 = seed acquisition
3 = financial support
4 = collective seed production
5 = others (specify) _____________________

58. For how many years have you been a member of the group? (Number of years)

59. How did you learn about the group?

1 = through group leader
2 = through neighbour
3 = through family member
4 = through Media (e.g. TV, Radio)
5 = through extension staff
6 = Chiefs baraza
7 = others (specify) ____________________________

60. What is the size of your group? (Number of group members)

Males……………   Females…………….

61. What is your role in the group?

1 = Official   2 = Ordinary member

62. Which two people do usually discuss information on bean production with? (Tick 2 that apply)
1 = Neighbour
2 = Input suppliers
3 = Financial institution
4 = Researcher

5 = Relative

6 = other (specify) ____________________

63. Why is person 1 and person 2 selected in (62) above important to you? (Tick all that apply)

Person 1		**Person 2**	
1. Provides social support	☐	1. Provides social support	☐
2. Source of information	☐	2. Source of information	☐
3. Experienced in bean production	☐	3. Experienced in bean production	☐
4. Opinion leader in the community	☐	4. Opinion leader in the community	☐
5. Respects my ideas	☐	5. Respects my ideas	☐
6. Gives advice	☐	6. Gives advice	☐
7. Provides credit to farmers	☐	7. Provides credit to farmers	☐
8. Source of seed	☐	8. Source of seed	☐
9. Source of labor	☐	9. Source of labor	☐
10. Other, specify……………………………	☐	10. Other, specify………………….	☐

64. How frequently do you meet person 1 and person 2? (Tick appropriately)

Person 1		**Person 2**	
Daily	☐	Daily	☐
Weekly	☐	Weekly	☐
Fortnightly	☐	Fortnightly	☐
Monthly	☐	Monthly	☐
Once every season	☐	Once every season	☐
Yearly	☐	Yearly	☐

65. Who has influenced your decisions on bean seed access in the past three seasons?

1 = Relative 2 = Neighbouring farmer 3 = Researchers

4 = The Media (e.g. TV, Radio) 5 = Extension agent

6 = Farmer group members 7 = others (specify) ___________________

66. What has been the most important factor in your bean production venture?

1 = Support from micro-finance institutions 2 = Support from farmer group members

3 = Support from researchers 4 = Support from extension agent

5 = Own experience in bean production 6 = others (specify) _________________

Please give any suggestions on how access to good quality bean seed by smallholder farmers in your sub-county can be improved____

Thank you for your time.