APPLICATION OF SOCIAL NETWORK ANALYSIS TOOL TO INFORMATION FLOW AND ITS INFLUENCE ON THE ADOPTION OF SUSTAINABLE AGRICULTURAL INNOVATIONS IN BUSIA COUNTY, KENYA.

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A Thesis submitted to the School of Agriculture and Veterinary Sciences in partial fulfillment of the requirement for Award of Doctor of Philosophy in Sustainable Agricultural Systems of Masinde Muliro University of Science and Technology

DECLARATION

This thesis is my original work prepared with no other than the indicated sources and support and has not been presented elsewhere for an award of degree in any other university.

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology a thesis entitled '**Application of Social Networks Analysis (SNA) tool to information flow and its Influence on the Adoption of Sustainable Agricultural Innovations in Busia County, Kenya.**

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ABSTRACT

The growth of Agricultural productivity in Western Kenya has lagged behind largely due to low adoption of agricultural innovations. The low adoption is attributed to deficiencies in the existing agricultural extension system. The system for a long time has embraced the linear top-down model of information generation and dissemination. In this model, farmers are regarded as spectators of the innovation development process yet; a lot of information is shared through interpersonal channels within social networks. To help address the issue, Social Network Analysis (SNA) was used to map, measure and analyze social relationships among farmers, agricultural extension service providers and researchers who act as channels for the transfer of information. The study was conducted in 4 villages randomly selected in Nambale Sub-county namely; Elwanikha, Ibanda, Budokomi and Ekisumo. The specific objectives of the study were; to determine flow of agricultural information among the farmers through their social networks, to document relational and structural factors that influence flow of agricultural information within the social networks, to describe the formal and informal communication and their influence on adoption of agricultural innovations and to provide recommendations how extension service providers can make use of social networks to increase the of adoption of agricultural innovations. The study adopted ethnographic research design which comprised of social mapping and in-depth interviews. Initial respondents in each village were purposively identified followed by snowballing to generate subsequent respondents. Data was collected using sociometric technique, semi-structures interviews and in-depth interviews to investigate flow of agricultural information and adoption of three selected agricultural innovations within social networks; 1.) Use of Desmodium (*Desmodium uncinatum)* to smoother Striga (*Striga hermonthica)* 2.) Use of lime to control soil acidity 3.) Use of hermetic bags in post-harvest storage of maize. Socio-metric analysis was done using UCINET VI *version 6.624*. Net draw *version 2. 160* an interphase program was used to create illustrative maps. The socio-metric analysis of the villages produced 716 nodes (actors) with 1,952 ties (relationships). The socio-grams showed a mixture of weak and strong and weak ties with a minimum and maximum clustering co-efficient of 0.214 and 0.612 respectively. The study established that the social networks of Nambale Sub-county are characterized by both weak and strong ties which are traits in network structure that are significant in sharing of information on sustainable agricultural innovations. However, agricultural extension workers have failed to take advantage of these existing social networks to disseminate agricultural information because the adoption of the selected innovations was low in all the three villages. By leveraging on the power of social networks, the extension service providers can use the method to map information networks which can be used to disseminate agricultural information that would stimulate adoption of innovations among farmers.

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LIST OF ABBREVIATIONS AND ACRONYMS

DoI	Diffusion of Innovations Theory
FAO	Food and Agriculture Organization
FEW	Frontline Extension Worker
FFS	Farmers Field Schools
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoK	Government of Kenya
IPM	Integrated Pest Management
IRDP	Integrated Rural Development Project
LGB	Larger grain borer
LM1	Lower Midland Zone1
NALEP	National Agriculture and Livestock Extension Program
NEP	National Extension Project
NGO	Non-governmental organization
PALWECO	Program for Agriculture and Livelihoods of Western Communities
PRA	Participatory rural appraisal
SMS	Subject Matter Specialist
SNA	Social network analysis
T&V	Training and visit

USA	United States of America
KNBS	Kenya National Bureau of Statistics
SCAO	Sub-county Agricultural Officer

CHAPTER ONE

INTRODUCTION

1.1. Background

Farming in Kenya is characterized by low agricultural productivity. This poor productivity is attributed to low-or non-adoption of existing agricultural innovations. One of the major reasons associated with non-adoption of innovations and low agricultural productivity is the ineffective agricultural extension system and approaches. The current system is characterized by low number of government extension staff. The extension staff to farmer ratio stand at 1:1500 in Kenya (GoK, 2015). The low ratio hinders the flow of agricultural information and the subsequent adoption of agricultural innovations.

The current extension system is also linear top-down. Innovations are generated at the research stations then handed over to agricultural extension staff who are expected to disseminate them to farmers (Anderson & Purcell, 2007). In this the linear top-down system farmers are regarded as spectators in the innovation development process. The system is restrictive in nature and hinders the ability to stimulate free exchange of information that would lead to adoption of innovations. When innovations are developed in isolation of the final users, they may serve as a disincentive for adoption when the innovations are finally introduced to them.

The government extension system is also characterized by budgetary constraint which slows down sharing of information and adoption of innovations. This budgetary constraint affects the mobility of the extension staff to efficiently reach the farmers. To demonstrate some of the innovations is costly and this slows down their adoption. Consequently, most the extension agents target the farmers who seem to be better-off and show signs of adopting the innovations (Davis K. , 2008).

To overcome these deficiencies, participatory extension methods have been previously applied but, the concept has been misinterpreted by the extension staff and its implementation has faced a lot of challenges. For example, application of participatory methods by the extension staff have been ineffective because even them have not mastered the methods and their technical knowledge can be questioned by the farmers. These methods by extension service providers raises farmer's expectations but can also expose extension staff to criticism if the solutions they are proposing do not solve the farmers' problems immediately. Another limitation of the participatory approaches is the tendency to marginalize vulnerable or otherwise less-influential farmers.

Adoption of agricultural innovations is a 'social process'. This is because the individual's decision to adopt an innovation will largely depend on whether or not the people he closely associates with are adopting or have adopted. For instance, the farmers' benefit from adopting a new agricultural innovation depends on whether his/her associates have also adopted that innovation, and the benefit to his associates of adopting in turn depends on who of their associates have adopted, and so on (Crona & Bodin, 2006). A network structure will therefore illustrate the degree to which the innovation is spreading.

To overcome the issue of the apparent disconnection between researchers, extension agents and farmers occasioned by deficiencies in the current extension approaches a Social Network Analysis tool (SNA) is proposed. This is because the environment in which farmers operate is on with complex web of relationships consists of complex networks of social relationships with varied interests. Access to information and resources can be influenced by factors such as gender, ethnicity, social and economic status.

Social Network Analysis examines groups of unrelated actors who interact in the generating, exchanging, and use of agricultural innovations. It also investigates the institutional factors that stimulate their actions and relations. This approach shifts the knowledge dissemination away from the linear, input-output model to an innovative model that illustrates a network of related individuals that learn, change and innovate through iterative and complex processes. (Borgatti, Everett, & Freeman., 2002)

Proponents of this approach argue that it is ideal for information sharing and interactive learning. A process that can stimulate adoption. Studies have been done to establish how network structure can influence diffusion of innovations. A decision weather a farmer would adopt a new crop variety or seed depends on the action of the neighboring farmers (Bandiera & Rasul, 2006). In another study, villagers' adoption of a mosquito nets or sanitation methods was influenced by their adopting neighbors (Dupas, 2014). (Munshi & Myaux, 2006), established that the use of birth control or the form of contraceptive used can be influenced by what others using.

1.2. Statement of the problem

Use of agricultural innovations that can improve productivity in Kenya is still low despite a well-developed agricultural research system (GoK, 2015). Low agricultural productivity in western Kenya can be attributed to several factors. Firstly, Striga weed (*Striga hermonthica)* infestation which is present in most fields. The weed reduces maize production by injecting its phytotoxins into the crop leaving it stunted and wilted (Khan, et al., 2009). Secondly is the increased soil acidity resulting from continuous use of inorganic fertilizers. The high soil acidity prevents water and nutrients from being accessed by the plant hence reducing yields (Kanyanjua *et.,al* 2002). Thirdly, infestation of post-harvest grains by Larger Grain Borer (*Prostephanus truncatus*) a post-harvest pest. The pest reduces the yields by up to 30%. (GoK, 2015)

To address the above problems, farmers are still using methods which are not only outdated but ineffective. For example, to control Striga weed (*Striga hermonthica)*, farmers pull the weed and throw them on the pathways. Some opt to burn the entire field. The efficacy of these practices remain questionable and insufficient because season after season the farmers lose a lot of produce to Striga weed (*Striga hermonthica)* which has become established and is fast spreading to non-affected farms. Farmers also continue using post-harvest control chemicals to control Larger Grain Borer in cereals. But three months after their application, the cereals become infested with the pests.

However, agricultural innovations with demonstrated productivity gains to address the above problems exist. For example, Striga (*Striga hermonthica)* weed infestation can be controlled by use of Demosdium (*Desmodium uncinatum)*, larger grain borer can be managed by use of hermetic bags for post-harvest storage of maize and use agricultural lime can reduce soil acidity. However, these innovations have not been widely adopted.

The low or non-adoption of these agricultural innovations can only be linked to the ineffective sharing of agricultural information. This is due to the weak linkage among agricultural extension workers, researchers and farmers. The most common approach to information sharing is linear and does not catalyze adoption of innovations. But, the adoption process starts with sharing information with the potential users i.e. the farmers and the extension staff. In essence, a lot of information is disseminated via interpersonal relations through social networks. This is where diffusion and adoption studies need to focus.

Accordingly, there is need to research on how information on innovations can be shared among farmers using a methodology that can map, measure and analyze social relationships among farmers within the social network context and the existing agricultural extension approaches.

1.2.Objectives of the Study

The overall objective of the study was to examine application of social network analysis (SNA) in exchange of agricultural information among farmers, researchers and extension service providers in Nambale Sub-county.

The specific objectives of the study were to:

i. To determine flow of agricultural information among the farmers through their social networks

ii. To document relational and structural factors that influence flow of agricultural information within the social networks.

iii. To describe the formal and informal communication and their influence on adoption of agricultural innovations.

iv. To provide recommendations how extension service providers can make use of social networks to increase the of adoption of agricultural innovations

1.4. Research questions

1. Which networks are present in the villages and how active is each social actor within the network?
2. What are structural and relational structures that influence flow of agricultural information in social networks?
3. How does formal and informal networks interact in exchange of agricultural information.
4. How can extension workers take advantage of social networks to spread agricultural information.

1.5. Justification and Significance

The complexity of agricultural problems cannot be solved by the linear model of information transfer currently used by the agricultural workers. Similarly, the existing agricultural extension approaches have failed to stimulate adoption of agricultural innovations to increase agricultural productivity. An alternative approach that focuses on information sharing among the farmers, extension workers and researchers has to emerge.

Social network analysis (SNA) is one such approach. This is because; with Social Network Analysis (SNA) it is possible to map, analyze and measure the connections between people and organizations which other approaches lack. Understanding the social networks among farmers and how they function, can provide an entry point for innovation information sharing. Researchers and extension staff can exploit these social networks to introduce innovations and other interventions farmers need. Consequently, this can support and complement the existing extension approaches that would improve adoption of sustainable agricultural innovations.

Effectiveness of SNA is well illustrated by (Rogers E.M, 1981) who studied networks in Korean villages on family planning innovations. In this study, he concluded that mothers who adopted the family planning methods had gotten the information from other mothers who had adopted earlier the family planning methods. Research from Mali by (Madhavan & Adams, 2003) confirms the need for use of SNA. Their study established that seeking of maternal health services among women was based on how close the women lived to those with secondary or higher education. This suggests that proximity networks strongly influence health decisions. Characteristics such as credit partners, kinship and other social groups revealed low fertility, giving an indication that these relations influenced decision making on family planning. A follow up study by (Gilda Sedgh, 2007) revealed that seeking of prenatal care by women was influenced by their neighbors. While the use of SNA has proved useful in dissemination of information in the health sector, its use in agriculture is limited and has not been investigated extensively.

Findings from this study will add to the academic body of literature. It will also elicit discussions on new areas of research into Social Network Analysis (SNA) and its application in agriculture in improving the existing agricultural extension.

1.6. Scope of the Study

The study covered the four villages of Nambale Sub-county, Busia County. The study area was purposely selected due to low agricultural productivity compared to the neighboring Sub-counties of Teso and Butula. The study was limited to farmers in these area. It was also limited to extension service providers and researchers in the study area. The sharing of information through social networks was limited to only agricultural information.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This chapter critically reviewed related literature organized according to the study objectives. The review was on the concept of information sharing among farmers, extension service providers and researchers. Agricultural extension methods and models were reviewed. Also reviewed were the sustainable agricultural innovations. Theoretical and conceptual frameworks were also reviewed.

2.2. Agricultural innovations and Information flow.

Adoption of agricultural innovations that enhance productivity play a critical function in agricultural development. Yet, adoption rates in Sub-Saharan Africa is still low (Kondylis, 2014). Gaps in information flow and sharing are key contributors to low adoption of agricultural innovations. This calls for concerted initiatives to improve the flow of information to catalyze adoption of agricultural innovations (Kondylis, 2014). Adoption of agricultural innovation depends on the benefits that are anticipated on investment for the innovation. The bigger the benefits the faster the adoption. Information is a key determinant that shape a household production function. This is because it motivates the farmers' perception the anticipated returns. Production function is affected by the skills one has.

Information sources can be through several channels such as direct information transfer for example the organized formal trainings; direct observation of the already practicing farmers and finally through experimentation. For better results, a farmer can combine these channels to realize returns on a given enterprise depending on the innovation in practice. Direct information transfer is effective for knowledge intensive technologies and whose investment is high. Although formal trainings can provide broad information on how to apply the innovations and the average returns upon adoption, they do not provide detailed information on how the farmer can achieve productivity considering the farmers input, crops to be produced and the farm characteristics (Foster A. D., 2010).

Observing the prior adopters is cost effective form of learning because the observer does not incur any cost for learning about the innovation. Nevertheless, learning through observation does not provide additional information on other aspects of production and how they assimilate with the new innovation. For example, observation cannot provide information on the interaction between the innovation and soil quality (Maertens, 2012). Consequently, for innovations that have mixed earnings, learning-by-doing would be the appropriate method because it provides a comprehensive information both on expected returns and optimal allocation and application of inputs with the new innovation.

2.2.1. Diffusion of Innovations

Diffusion of innovations is determined by speed at which they are adopted within a given area. Adoption of innovations can be categorized in two stages namely; the first stage involves being aware that the innovation exists and learn about it. Secondly, decide if they will adopt the innovation. (Foster & Rosenzweig, 2010). Being aware that innovations exist you have to learn about them. Leaning will involve all sets of information one has about the innovation. This information includes; using the innovation, benefits upon investment and associated costs of the innovation. Social learning and experimental learning enables farmers to learn about new innovations.

Social learning is the sharing of information through social networks. In social learning information flow is through existing interpersonal relationships which may be accomplished through direct conversation or observing the peers who are practicing the innovation. Learning through experiment involves learning by doing. This is where learning is achieved by individuals experimenting about the new innovations.

In making adoption decision, information received through social learning may be less accurate compared to the original information. (BenYishay & Mobarak, 2014; Hanna *et al*. 2014). Failure to adopt an innovation does indicate that learning has not occurred. (Foster & Rosenzweig, 2010).

Studies indicate that flow of information is effective in one to one interactions that exist in social networks in a given area (Hardy, 2015). Network structures maps out the routes and direction by which information flows. Exposure to new information frequently enhances the chances that an individual gets to know the about its existence and make adoption decision. (Sinan Aral, 2009; Centola, 2010)

Exposure to information about an innovation does not necessarily result in adoption decision. This is because some network ties have a stronger social influence compared to others. For example, when one receives information from an influential social network, there is a greater likelihood that behavioral change would occur and result in adoption decision compared to a network that is not influential. Individuals considered to be experts are likely to influence other members in the network compared to individuals that have same characteristics in a network (BenYishay & Mobarak, 2014; Centola & Macy, 2007). In complex innovations, it may be necessary that the source and the recipient connect to bridge the knowledge gap (Foster and Rosenzweig, 2010).

In a social network structure, exposure and influence are fundamental components. This is because behavioral change and the information content are determined by the network structure. Flow of information and the network structure are derived from the interpersonal relationships and communication.

Adoption of new innovations in the community can be well understood when studied at the community level. Members who are influential in the community can be identified using the generated social networks. These individuals can then be used to disseminate information on innovations (Barahona and Pentland, 2007). The identified individuals can be used as entry points of new information about the innovation into the community. As a result, the information moves faster and adoption occurs because the critical threshold for adoption has achieved. Once mass adoption occurs, the application of innovation becomes a common practice (Aral, 2013).

In a network, individuals who are influential tend to cluster in a network. This shows that such individuals are well connected to equally other members who are influential in the network. These clusters identify actors who are influential who are then used as entry points to the community. These influential actors can increase adoption of new innovations. (Aral , 2012)

2.2.2. Information Diffusion Through Networks

Agricultural extension programs recognize diffusion of information through interpersonal relationships. Taking advantage of social networks could be important in generating positive impact on agricultural extension programs. However, the implementation of can be expensive for agricultural extension service providers. This is because members in a network have implicit and insufficient evidence about the network structure in which they belong to.

Socially influential individuals influence their peers' behavior and beliefs which ultimately would influence adoption decisions. This means, influential individual's information is given more weight (Valente & Pumpuang, 2007). It is thought that, socially influential individuals stimulate flow of information and adoption of innovations by reducing lag time between the introduction of the innovation and its adoption by others (Valente & Davis, 1999). This therefore means, to realize higher adoption rates, the socially influential individuals should be well positioned in the network structure to effectively disseminate information.

To identify socially influential individuals, there is no known socioeconomic traits that have been determined to differentiate network influencing individuals from non-influencing individuals (Aral *et al.* 2013). However, social influence for adoption of innovations are believed to increase depending on the level of expertise one has on a given subject/topic. Socially influential individuals have a significant position in the structure of the social network. (Eck, Jager, & Leeflang, 2011). Social influence has more to do with how credible is the information received by an individual, while the position in the network structure indicates the degree of information flow within the social network. Studies have put more emphasis on variation in the patterns of information flow through metric measures of connectedness (Cho & Lee, 2012,). Eigenvector centrality is one measure of social connectedness. It estimates an actor's likelihood of participating in network information flows.

2.3. Agricultural Extension in Kenya

The advent of agricultural extension in Kenya dates back to the early 1900s, but it is until the late 1960s and early 1970s when notable success was realized for its ability to disseminate hybrid maize technology. The main extension service provider by then was the government through the Ministry of Agriculture (MOA). But, the implementation of the structural adjustment programs (SAPs) in the 1980s compelled the Kenyan government to ease its dominance in the national economy (FAO 2012). As a result, the budget for agricultural extension budget was significantly reduced which led to reduction of extension staff. The reduction in the number of extension staff affected the effectiveness of the public agricultural extension service (Gautam & Anderson, 1999). Since then, the public extension system has been linear and top-down, uniform, paternalistic, and inflexible. The service is also a subject of bureaucratic inefficiencies. This make the service unable to deal with the dynamic demands of modern agriculture.

Nonetheless, extension methods have a positive influence on adoption of innovations because they can help in creating awareness about the technology and it's potential. Also, agricultural extension service providers are important in the diffusion of innovation. For example, the extension agent acts as a personal coach for change and as a communication medium who closes the gap between farmers and the innovation. For this reason, extension officers must understand where and how to use various communication media and extension methods available to them to reach more clients more frequently, and to give extension efforts more impact (FAO, 2016).

2.4. Agricultural Extension Methods

2.4.1. Commodity based extension systems

Commodity based extension system evolved during the colonial times and it is still applicable to many developing nations that are producing export cash crops such as coffee, tea, cocoa and cotton. In general, the approach is more common among the government parastatals or private firms that are involved in production of these crops. The farmers may be dispersed over a large area or connected closely in a case of a rice producing scheme with a common irrigation system.

The strength of the system is that because it serves farmers within a specific agro-ecological area producing a particular crop. This makes the system effective and efficient in providing extension services. This is because the advisory services provided are just restricted to one product. Also training of both the extension service providers and farmers is comparatively simple and straightforward. Control of farmers and service providers is easy because they are assessed in terms of defined targets. The farmers themselves would like to produce higher yields and therefore they have no choice but to follow the recommended practices.

Despite the celebrated history and notable successes of the commodity based extension system, the method has significant limitations. First, the system bestows monopoly power to the parastatals, processing and marketing firms which enables them to make superfluous profits at the expense of the farmer. Second, farmers are likely to get poor returns for their produce due to poor management or changes to terms of trade and pricing. This is because farmers cannot react to price fluctuations. Third, quality standards are subjectively set to by the organization with an intention of increasing profits. Forth, the approach ignores the local area specific needs by focusing on one crop. Finally, the approach is rigid and top down in practice as it no freedom to farmers to make their own choice.

2.4.2. Training and Visit Approach (T&V)

The concept of Training and Visit (T&V) extension system was developed in the early 1970s by the World Bank. The motivation for this system was to disseminate the Green Revolution innovations to farmers, mainly in Asian and African countries (Daniel Benor, 1984). The system was first implemented in two regional irrigation projects, the Seyhan (Phase 2) project in Turkey, and the Chambal (Rajasthan and Madhya Pradesh) project in India, both funded by the World Bank in 1974. Since then the system has been implemented in more than 70 countries worldwide.

The spread of T &V was due to the fact that it resulted in impressive increase in agricultural production. In their study (Bindlish & Evenson, 1997) showed that the T&V extension system improved the effectiveness of agricultural extension, resulted in agricultural growth with better returns on investment. For instance, for the case of Seyhan project in Turkey, to over 3 tons per hectare just in three years after its introduction. In Chambal India, the paddy rice yields increased from 2.1 tons to 3 tons per hectare 2 years after the introduction of T&V. Also, in the same region average wheat yields increased from 1.3 tons to 2 tons after two seasons.

Kenya was the first African country to implement T&V extension system. It was introduced in Kenya in 1982 with an aim of addressing the weaknesses in the previous extension systems. These weaknesses were attributed to deficient in-service training and the inability of field-level extension workers (FEWs) to effectively communicate technical messages to farmers; the lack of work programs for staff; irregular farm visits by FEWs; and the poor supervision of FEWs. The system was first introduced on pilot basis in Kericho and Nandi districts in 1982, and then expended on a national scale through the Kenya National Extension Project (NEP) starting in 1983 (Bindlish & Evenson, 1997).

To address the weaknesses identified with the previous system, T&V emphasizes fixed work programs and schedules, and routine supervision of the staff. It also emphasizes regular visits by frontline extension workers (FEW) to contact farmers or, as is more likely to be the case in Kenya now, to farmer groups. It places particular emphasis on the regular (preferably fortnightly) training of FEWs by subject matter specialists (SMSs) in the messages to be disseminated to farmers. In addition, to ensure the appropriateness of these messages, it encourages feedback from farmers and strong links between extension and research. Subject matter specialists are expected to discuss innovations, and the feedback from farmers, with research scientists at monthly workshops. Similarly, it is expected that FEWs will discuss recommendations and farmers' problems with SMSs at their training sessions.

The T&V realized quick and visible results. The most notable was the attitude change among the agricultural extension service providers. The regular training of farmers, the service providers felt that their technical expertise was put in proper use. Farmers responded positively to service providers who visited them frequently and predictably disseminating the technical information. The system strengthened the bond between the extension service providers and researchers. The system improved service delivery to farmers through efficient deployment of technical staff and judicious allocation of resources. The T&V spread quickly as an agricultural extension method due to the fundamental principles embedded in the system which are simple and can be replicated in other situations.

2.3.2.1. Why T&V was not efficient and effective

First, the system involved a routine field schedule that was inflexible to a predetermined list of contact farmers in a defined area. To implement the approach successfully, trained public extension staff, were to regularly visit predetermined contact farmers, in line with the prepared detailed schedule and work plan (Schwartz & Kampen, 1992). The assumption was that the contact farmers would embrace the technical information and pass it to other farmers. This was not the case. In Ethiopia for instance, (Dejene, 1989) found that the communication system from contact farmers to the rest of the community did not work as expected because, 25% of the sampled contact farmers lacked the required knowledge and skills. It was established in Cameroon, (Tchouama & Steele, 1997) that only 30% of farmers who indicated to have had contact with the service providers and were finding it hard to apply the recommendations. In other countries such as Nigeria, the service providers did not have the requisite skills, had limited transport to the field and cultural barriers hindered their functions (Asiabaka & A.I Bamisile, 1992).

Secondly, the system was top-down because most of the important decisions were made at the headquarters. This made it hard for the service providers to modify the message to suit the local agro-ecological, climatic and even social and economic conditions. (Mitti *et al*., 1997; Sulaiman & Hal, 2000). Consequently, the innovations promoted were not appropriate at local level. A World Bank study by (Anderson & Purcell, 2007) established that the system failed to adapt to local conditions and that the extension messages were inadequate. This is supported by evaluation studies to review the T&V system by Farrington *et al.*, 1998.

Thirdly, the T&V model was criticized in the 1980s because of the costs involved, not responsive to the farmer’s needs, ineffective and lack of equity (Sulaiman & Hall, 2002).

The funding of the system was of great concern because large sum of money was spent on travelling and accommodation of the service providers while attending frequent trainings and seminars. The implementation of the system came with substantial rise in the number of extension workers who were funded by the project. The increased salaries and other emoluments caused a long-term recurrent budgetary problems for governments (Anderson *et al.*, 2006). Because of the financial constraints occasioned by this system, the service providers were left with nothing to plan with and implement the extension programs. Consequently, the implementing nations had serious budgetary constraint after the end of the project.

Fourthly, due to inadequate training a good number of service providers did not possess the requisite skills to implement complicated extension activities. The service providers were expected to act as information brokers to help farmers improve on their farming systems. This is so because, most extension staff appointed in the 1980s only had a high school qualification and did had not received technical training in technical areas, management and marketing. Since most extension workers were not sufficiently trained coupled with their lack of work schedule and lack of transport, most the field-level extension workers spend the majority of their time sitting in offices.

Finally, the system was good at promoting quantity rather quality. This is evident in the routine and rigid field visit schedule to predetermined contact farmers. This was then followed by strict supervision by officers from the headquarters. This resulted in lack of accountability among the extension workers towards farmers (Anderson *et al.*, 2006). A review study by (Salmen, 1999) in nine countries established that the system was beneficial to farmers who were better-off and also to male staff. It was poor among women and youthful farmers (Mitti, Kalonge, Drinkwater, & Pub, 1997).

2.4.3. Farmer Field Schools (FFS)

The concept of Farmer Field School (FFS) started in Indonesia. The approach was meant to teach farmers how to include the integrated pest management (IPM) practices into rice production and other farming systems. Primarily, the approach uses non-formal education methods to teach farmers on the best ways to reduce use of pesticides and how to increase farm income.

Farmers field schools (FFS) up to date function in several countries including Kenya. It varies from "T&V" extension because they are 'participatory' rather than expecting farmers to adopt indiscriminate approvals formulated elsewhere. Anderson & Feder, (2007), note that participatory methods aim to enable farmers to become self-teaching experimenters and train peers.

The key features of FFS farmer experimentation, discovery learning, farmer and group action. The FFS as agricultural extension approach endeavors to enable farmers to be technical experts in farming through interaction and practical training methods. During the FFS sessions, farmers are assisted to carry out research, identify problems and propose solutions to the identified problems. The approach encourages cost sharing to guarantee sustainability and sense of ownership.

Evidence suggests that, FFS significantly reduced the use of pesticides and increased yields according to (Vanden-berg, 2004) who conducted an impact evaluation of 25 different case studies. Additionally, FFS stimulated continuous learning and strengthened the social and political skills of farmers. Consequently, these developments activated various local development activities, relationships, and policies.

The FFS has numerous success stories and benefits. However, the approach has been criticized on its impact and the financial requirements to implement the activities. For instance, the approach has demonstrated a significant impact in reducing use of pesticides, increase in farm productivity and improved knowledge among farmers. Though, these effects were only evident among the most directly-engaged farmers.

The notable drawback of FFS is that the model is comparatively expensive and labor-intensive. This is because more field extension workers 10 or more are required to conduct the weekly training sessions. To accomplish the targets, it means that the extension workers would require travelling allowances. Generally, this extension approach is only useful to only number of interested farmers (Godtland *et al*., 2004, Rajalahti, Janssen, & Pehu, 2007 ,Amudavi & Pickett., 2007)

2.4.4. Demand-driven extension

According to (Neuchatel-Group, 2006) ‘Demand’ refers to what people request for, need and value so much that they are ready to invest their time and money for them to receive the services. The term offers an alternative to the definition of technology transfer and might be defined as “an agricultural advisory service based upon the idea of two-way communication promoting knowledge facilitation, knowledge generation, or knowledge sharing in a community development context and with focus on human resource development” (R.Haug, 1998).

In general the approach involves distribution of responsibilities among the government, the farmers who are the clients and the extension staff (Rivera & Alex, 2004). The guiding principles of the demand driven extension approach is that the services should be demanded by the farmers who can choose the service provider of their choice and the extension staff should provide service ((Neuchatel-Group, 2006).

Demand-driven extension can be likened to the concept of privatization and a shift away from free public services. The approach supports the continuation of some forms of 'subsidized' extension, but under much different criteria than the strategies which focus on production only. It proposes that the public extension should concentrate on more marginal areas, take account of the diversity of rural livelihoods, be innovative in its organization, and develop the capacity for strengthening the demand side of extension (Farrington *et al* ., 2002). Before demand-driven extension systems can take root, farmers must first develop their capacity to articulate their collective demands and exert pressure on the system to deliver what they want (Rivera & Alex, 2004).

The principle of demand-driven agricultural extension approach is that to serve farmers better, the extension service providers should prioritize farmers needs at the planning phase. Farmers needs are identified through public participation during the planning process. During this stage the farmers would identify their needs and come up with a demand-for-extension plans with the assistance of the extension service providers.

2.5. Sustainable Agricultural Innovations

2.5.1. Use of Desmodium ssp. (*Desmodium uncinatum)* in Controlling Striga Weed

Maize and sorghum are important crops in Kenya. Most farmers depend on it for food security and farm income. Despite these benefits, production of this crop is under serious threat of the parasitic weed, *Striga hermonthica* (Amudavi *et al*. 2007). The weed produces thousands of seeds which stay in the soil for many years. When maize is planted, the roots releases chemicals that favor the germination of Striga plants. The plants do not grow their own roots to draw nutrients from the soil but attach themselves to the crop hence denying the crop the nutrients while injecting the crop with phytotoxins leaving the crop stunted and wilted.

Affordable alternative strategies to combat the menace for smallholder farmers exist (De Groote, et al., 2007). These strategies include: use of Striga tolerant or resistant cultivars and use of nitrogenous fertilizers. However, many small scale farmers resort to digging and pulling the weed which is labor intensive and ineffective. Scientists at the International Centre of Insect Physiology and Ecology (ICIPE) in Kenya, in collaboration with colleagues at Rothamsted Research in the UK, have discovered that intercropping cereals with a perennial forage crop, Desmodium. (*Desmodium uncinatum)*, effectively eliminates the most significant constraint to cereal production in sub-Saharan Africa, the parasitic weed Striga (*Striga hermonthica)*. The technology called "Push pull". Desmodium (*Desmodium uncinatum)* roots produces chemicals the affect Striga in two ways. First, they stimulate the germination of Striga (*Striga hermonthica)* seed. Second, they inhibit the growth of Striga (*Striga hermonthica)* to prevent parasitism. Also Desmodium (*Desmodium uncinatum)* fixes nitrogen to the soil, adds organic matter into the soil, smothers the weed by the dense ground cover and has allelopathy effect (Khan *et al.* 2009). A field trial at ICIPE-Mbita in western Kenya indicated a substantial increase in total nitrogen in field plots under maize intercropped with various species of Desmodium (*Desmodium uncinatum)* as compared to maize monocrop or maize–cowpea intercrop (Khan *et al.* 2009).

The adoption of the new method is slow; one reason for this is that the farmers doubt the methods (Khan, *et al*. 2009). They say that they hear rumors about how these new methods do not work and are therefore unwilling to test them. Another reason is that the returns of the new methods in terms of higher yield do not appear immediately (Khan, et al., 2008).

2.5.2. Use of Agricultural Lime to Reverse Soil Acidity

Soil acidity is a wide spread limitation to crop production in many parts of the world (Van Straaten., 2007). Attempts have been made towards understanding the extent and behavior of Kenyan soils. According to (Kanyanjua, Ireri, Wambua, & Nandwa, 2002), acidic soils occupy 13% of the Kenyan land area. Most of these soils are found in the highlands east of Rift Valley and Western Kenya regions.

Soil acidity affects plants in two principal ways: by increasing the presence of toxic substances like aluminum (Al), manganese (Mn) and hydrogen ions (H+), and by reducing the availability of important plant nutrients like phosphorus (P), calcium (Ca), magnesium (Mg), and molybdenum (Mo).

In most cases, toxic levels of aluminum are the main problem. At low pH, much of the CEC is occupied by Al and when the saturation reaches 60%, Al3+ increases to toxic levels in the soil solution. This toxicity results in shallow roots with swollen tips, preventing water and nutrients from deeper soil layers to be accessed. Also, legumes show poor nodulation. These changes are clearly visible in many crops at pH below 5. In Western Kenya, soil pH ranges from 6.5 to less than 4.5, meaning it is slightly to extremely acid.

The low availability of plant nutrients reduces the yield and increases susceptibility to pests and disease. Liming acid soil makes the soil environment better for plants and associated microorganisms as well as increase concentration of essential nutrients by raising its pH and precipitating exchangeable aluminum (Kisinyo et al., 2005, Kisinyo P. , 2012)

Use of agricultural lime is the standard remedy for acid soils. Lack of awareness is the main obstacle to liming: In Western Kenya few farmers are aware of the problems with acid soils and the options of using lime. Instead the poor performance of crops is seen as a nutrient problem only and the response is therefore to buy N fertilizer which will just add to the acidity problems. Many trials have shown the benefit of liming soils in Western Kenya, but high costs of lime and transport are major obstacles.

2.5.3. Hermetic grain storage systems

Larger grain borer (LGB) *Prostephanus truncatus* is the common post-harvest pest. The insect attacks stored maize resulting into huge losses of up to 20% (Vowotor, 2005). To control the insect, farmers use traditional storage methods which are ineffective. For example, farmers believe that shelling maize earlier would make it escape the insect attack as shelled maize is less susceptible to LGB (Cowley, 1980.) The shelled maize is then stored in polypropylene bags. However, these bags reduce aeration that accentuates the insect attack.

Scientists have come up with a simple innovation that is cheap and effective to control LGB (Jones, 2011). The bags consist of two layers of high density (HDPE) bags inserted in the polypropylene. Besides maize, the bags have been shown to be effective in protecting cowpeas against bruchid beetles (Baoua., 2012). Hermetic bags to prevent post-harvest losses works by eliminating the exchange of gases inside and outside the grain storage bag. If the exchange of gas is low, the larger grain borer inside the bag will exhaust oxygen and produce carbon dioxide which will eventually kill them or render them inactive due to low oxygen. The hermetic grain storage is an appropriate innovation to farmers. The innovation eliminates the use of insecticides which are expensive and unavailable for farmers. There are also reported cases of misuse of insecticides which has caused death and environmental problems (Baributsa *et al* 2010).

2.6. Social Networks

Social networks are described as "*a finite set of sets of actors and a relation or relations defined on them"* Wasserman & Katherine Faust, (1994). Ideally, social networks depict connections, communication and collaboration in communities (Reinhardt, Moi, & Varlemann, 2009). Hanneman & Riddle (2005) supports the view that social network comprises individuals that are related to one another. In this case the actors could be individuals, organizations or any other grouping and that are linked to one or more than one relations. Such relationships are the bedrock of social networks. Depending on the relationship, the networks could be described as weak or strong. Strong ties consist of high level of frequency, reciprocity and trust. Weak ties have less frequency but can act as potential sources of new information.

The principal components of social networks are: transactional component and configuration component. Transactional component refers to the relationship existing between individuals, whereas configuration component refers to the shape and structure of the network and the position of the individuals in the structure (Nelson & Hsu, 2011). Social networks are predominantly informal in nature and influence the speed and efficiency with which information is generated and shared within organizations (Murale, 2014).

2.6.1. Role of social networks in flow of agricultural information

The speed with which the agricultural information flows through the network depends on the selection of entry points in the network. The interval between the introduction of the innovation and the point at which it is adopted in mass is reduced through smart targeting of entry-points. As a result, diffusion of innovations is hastened (Foster & Rosenzweig, 2010). Smart targeting which is the selection of influential individuals is based on opinion leadership literature (Valente & Pumpuang, 2007). Centola (2010) established that clustered selection of social network entry points was more effective for complex innovations. This is due to increased which increased the probability of adoption. Banerjee (2013) developed another measure of centrality to be used to identify actor who are central who in turn would be used as entry-points in the social network to maximize the sharing of information on new innovations. Beaman (2015) applied complex-contagion simulations to identify social network entry-points. It was established that the dissemination of innovations was greater than the contemporary selection processes that do not apply social network metrics. Conversely, other studies do not find application of social network selection of entry points effective. For example, Aral (2013) in his study established that there is no variation in dissemination rates of new innovations using different selection of entry points.

A number of studies have been done in support of peer effects on adoption of innovations. A study carried out in China on adoption of agricultural insurance Cai (2015) established that respondents who had a substantial number of friends who were trained on agricultural insurance adopted the scheme easily. In another study, Oster & Thornton, (2012), studied the influence of peers-friends and acquaintances on the adoption of menstrual cups among school going girls in Nepal. The study established that, the girls who had many of their friends who were using menstrual cups were likely to adopt the use of menstrual cups too. A study by Bandiera & Rasul, (2006), on the adoption of sunflower farming in Mozambique concluded that as more friends adopted the sunflower farming is their friends and friends of their friends. Many studies, comprehensively reviewed by (Rogers E. M., 2003), find that social networks are important in adoption of new innovations. This is because, social networks act as channels for sharing information and learning avenues.

Small scale farmers rely on informal sources of information more that the formal sources. This make social networks an important tool for them to facilitate sharing of information because the formal sources such as extension services do not fill this gap. Taking advantage of the existing social networks would be cost effective and save time. (Conley & Udry, 2011) established that social networks can play an important role in influencing the adoption decision of individual farmers. This is because the more farmers continue sharing information through interpersonal the more their attitude and behaviour changes. Therefore, farmers are likely to be influenced by their fellow farmers who they interact with more and have common attributes.

Crona & Bodin (2006) assert that networks are important in collective community actions. Social network characteristics can influence adoption of innovations in a community. This is because of their ability to facilitate diffusion of information and knowledge. When the informal networks are connected to agricultural service providers they can facilitate sharing of information from researchers and vice-versa. However, Davis K (2008) observes that, the nature of linkages influences the information exchange. Weak linkages will impede information exchange. This explains why most agricultural extension approaches have failed to yield results due to poor linkage of farmers, researchers and private sector

Introducing agricultural innovations without the input from farmers is a major contributor to the low adoption of these innovations (Ansu-Kyeremeh, (2008); White, (2008)., Tarawalie, (2008). Farmers should be encouraged to identify the problem they are facing and propose solutions to these problems in participatory forum consisting of farmers, researchers and extension agents. (Nair & White, 1993; Chambers, Pacey, & L-A., 1989), agree that participatory research communication process is the starting point for establishing a trusted partnership between the farmers, researchers and extension service providers and Social Network Analysis provides for this kind of arrangement where participatory process can be nurtured.

Behrman *et.,al*, (2002), investigated the changes in of contraceptives in Kenyan villages and role of social networks on their adoption. They concluded that networks provide information to both men and women primarily through social learning and not by exerting social influence. Barber, (2002), investigated how exposure to voluntary association on fertility limiting behavior is influenced by participation. The study concluded that participating in voluntary association led to adoption of use of contraceptives.

2.6.2 Social Network Analysis (SNA)

Social Network Analysis (SNA) is an exclusive method that studies the relationships between groups, individuals, and institutions Kapucu *et al*. (2010). Using SNA, the researchers can visualize relationships within the network and analyze them statistically Scott & Carrington, (2011). Application of SNA has been around for some time. However, its application in agricultural extension and dissemination of agricultural information has been limited.

The social network comprises two elements: the actors or nodes and relationships or ties. Actors can be individual farmers or group of farmers or agricultural institutions while the relationships can be formal or informal Davies, (2009). In a network where the relationships have an in and out direction, then the network is referred to as directed network. The directed network is one in which a relationship is formed between two actors. For example, a tie originates from the first actor directed to the another actor Kadushin, (2012). The strength of a network is affected by the direction of ties present. Nodes and ties can be visualized in a network map. Nodes can characterize different participants' attributes, for example gender, the farming enterprise, membership to a social group or organization and religion. In a network these attributes can be represented by different node patterns, layout or colors.

According to Hanneman & Riddle (2011a), the size of the network is an indicator of the resources within the community. The size of a network is indexed by simply counting the number of nodes. *Density* shows the proportion of all possible ties present in the network. the efficiency of diffusion of information in a social network is measured by *Distance*. The distance between two actors is referred to as *Geodesic distance* which is measured by the number of relationships in shortest possible pathway form one individual to another in a network Hanneman & Riddle, (2011b). In social networks there are subsets with the networks which are referred to as *Cliques*. These are actors who are tied closely tied to one another in compared to other members of the network. It is simply defined as the maximum number of actors who have all possible ties existing amongst themselves. In a network there are possibilities of certain members of cliques disconnecting. If this happens the network is weakened. To identify the weak points in a network usually called the *Cut points,* a bi-component analysis is used (Hanneman & Riddle, 2011b). The divided parts are called *Blocks.* The strength of a network is therefore determined by the absence of the cut points and blocks.

The role of individual actors within the network can be analyzed using *Centrality* measures. The measure points out the advantages and disadvantages of certain individuals within the network. the influential actors within the network are those that are central. One measure of centrality is *Degree* which refers to the number of ties from and to a node. The *In-degree* of a particular node is the number of ties that node is receiving while the *Out-degree* is the number of ties that particular node is sending.

The individual having many other individuals having direct ties with him/her is considered to have a higher *In-degree*. This trait is an indicator of a high prestige in a social network. An individual having more direct ties to other many individuals is regarded as having a higher *Out-degree.* The measure is an indicator of influence within the network (Carolan, 2013).

Previous social network studies have concentrated on the individual and group behavior ignoring the relational information that exist between the individuals and among the groups

Carolan, (2013). Social Network Analysis as a tool makes it possible for researchers to identify relational information between and among individuals or groups to gain a better understanding of behavior. The tool (SNA) has been previously used to in studying diffusion of innovations, determination of social interactions and influence, the effectiveness of interventions and belief systems Carolan, (2013). Using SNA methodology, Hoppe & Reinelt (2010), evaluated a leadership network, in the study four types of leadership networks were analyzed including the organizational leadership, peer leadership, collective leadership and field policy leadership. Kapucu *et.,al* (2010) studied the friendship networks of students in a collaborative learning class. (Prell *et.,al* (2009) studied the networks of the stakeholders in conservation of natural resources.

2.6.3. Why Social Networks Analysis?

Social network analysis has unique advantages in dissemination of information compared to other methods. Social network analysis examines relationships together with their direction and strength. This is because, the method analyses patterns of interpersonal communication determining 'who talks to whom' or 'who influences whom' Valente & Rogers (1995). The method reveals the directions of communication among individuals in a social system.

Using social network analysis, socio-grams or social maps are generated which show the relationships among the members in the social network and how they share information. Computer software is used in social network analysis to map, measure and analyze information. UCINET and Node XL are the popular software. The maps generated by the software indicates the direction of the relationship and the strength of that relationship. using this maps, it is possible to identify the individuals who are at advantage points in the social network to receive and share information.

Data for social network analysis is obtained by contacting most of the population or even the entire population in a social group. This make the methodology to provide realistic results. The method simulates scenarios on the basis of the anticipated changes in the relationships. The different scenarios would answer questions such as; what happens to the social network when on individual is disconnected from one another? How does inclusion of new members or exclusion of existing members affect the social network? Social network analysis maps, measures and analyzes the results to respond to the anticipated changes. The analyses will predict how the social network structure would change in a social group. The procedure in this methodology of including and excluding for prediction is quite similar to adding and dropping variables as applied in a multiple regression. Based on these advantages, the social network analysis is a strong, persuasive and attractive method for agricultural extension service providers for dissemination of agricultural information that would stimulate adoption of agricultural innovations. This is because even those who can't digest the complex scientific analyses can easily interpret the social maps which identifies individuals who are at the center of communication in a network.

2.6.4. Social Network Metrics

To measure network properties, the Social network analysis metrics are applied. (Lazega *et al.* 2012). To understand pattern of information flow and relationships between individuals, the social network metrics are key Benhiba *et al.* (2013). Social network analysis metrics can isolate the unknown influencers, the bottlenecks and the leverage points. Social network analysis provides structural measures that can describe the whole network especially in situations where social networks have actors that have individuals connected by one or more ties. Similarly, the social metric measurements can identify actors and their role in the network. Benhiba *et al.* (2013, identifies sets of metrics that illustrates the structure of networks. *Table 2.1*.

Table 2 1 Social Network Analysis Metrics

WHOLE NETWORK ASSESSMENT	
SNA Metric Measure	**Meaning**
Network size	It is an indicator of the size of the network. It is denoted by the total number of member nodes within a network.
Network reachability	It is the extent to which any member of a network can reach other members within the network.
Network Centrality	It is the extent to which relationships in a network revolve around one or a few central network members. High network centrality is an indicator that information flow in a network depends on one or few individuals. Removal of these individuals can affect the information flow.
Network density	it is a measure of how strong a network is. It is a calculated by dividing the number of direct ties in a network by the total possible ties.
NETWORK STRUCTURE	
SNA Metric Measure	**Meaning**
Cliques (clusters of expertise)	Indicates existence of strong relationships, existence of similar information, resources, and more constraints or more support. They are helpful in influencing attitudes and behaviors both positively and negatively.
Hubs	Refers to nodes with high degree and betweenness centrality.
PROMINENCE (Prestige & Centrality)	
SNA Metric	**Meaning**
Betweenness centrality	Helps to identify knowledge brokers and gate keepers within a network. A node with high betweenness has significant influence over what information flows in the network.
Closeness centrality	The nodes with high closeness centrality have the best visibility on what is happening in the network because they can access all the nodes in the network faster than everyone else
Degree centrality	Tells who in the network has the most direct connections. It is an indicator of expertise and power of network members.
Eigenvector	Measures how connected an actor is and how much direct influence he has over other connected members in the network.
CONNECTIVITY	
SNA Metric	**Meaning**
Reciprocity	It measures the degree to two actors interchange information in the network. stronger and heathier relationships are indicated by many reciprocal ties.
Tie strength	Strong ties are associated with homophily, propinquity and transivity, while weak ties are associated with bridges.

Source; (Davel, 2017)

2.6.5. Application of Social Network Analysis

Use of social network analysis has been existence for many years. Crona & Bodin (2006), studied how social networks were used for communication of information related to natural resource extraction among villagers in a coastal seascape in Kenya. In this study, the villagers were experiencing over exploitation of fish resources and did not have an idea how to counter the problem. The researcher hypothesized that the inaction by the villagers to counter the fish problem was because they belong to different social networks. Data collected from the villagers using the social network analysis method, established that information sharing among the villagers take place in occupation networks. Discussions about natural resource management only took place among the fishermen who same type of fishing gear which was not found among other occupational groups in the community. The research also established that, the structure of social networks in the village affected the flow of information and the shared responsibility to take action.

In summary the study finds that uniformity among individuals in a community can result in faster flow and sharing of information. Conversely, if the group is too homogenous, information sharing is only limited to insiders and cannot be accessed by outsiders. The position of the influential leaders in the network and their characteristics were essential in organization and coordination of effective group action. This study demonstrated that SNA offered a valuable tool to map and identify actors within groups. The tool may be useful in analyzing collective community action and the associated constraints.

In another study by Darr & Pretzsch (2007) examined how different members belonging to different groups of farmers adopted wood lots in farms and intercropping. This was because the extension service providers prefer using farmer's groups to promote various innovations.

The research sought to find out how group characteristics would influence farmer's ability to innovate. The farmers' ability to innovate was presented as scores according to how complex the innovation adopted was. Social network techniques were used to tabulate social metric measures including density and, centrality for farmers' groups. These measures were analyzed to determine the farmers' ability to innovate. Results demonstrated that network structure characteristics significantly affected the ability of the farmers or group of farmers to innovate. Remarkably, researchers discovered that adoption of woodlots among farmers was influenced by a strong linear top-bottom decision from the management. However, the members were joined by weak ties with responsibility of coming up with agenda for the group. The study concluded that groups which were cohesive and actively sharing information among its members resulted in higher diffusion of innovations.

Raini, Zebnitz, & V.Hoffmann (2005), did a study among tomato farmers in Kenya to establish reasons for low adoption of integrated pest management (IPM) techniques. Social networks of IPM stakeholders including the farmers, extension service providers, agro dealers and other government agencies. It was established that networks among the participants had a low network-density an indicator that the flow information in the network is slow.

2.7. Theoretical Framework

2.7.1 Diffusion of Innovations Theory (DoI)

Approach to innovation diffusion has its roots in social sciences, communication, geography, health and anthropology. But, it is until 1960s that it was consolidated (Rogers E. , 1983). Diffusion of innovation (DoI) theory is a social process (Rogers, 1983). The diffusion research was developed in the field of rural sociology in the 1940s (Rogers and Scott,1997). The theory was influenced by a study which was conducted among hybrid corn farm in Iowa farmers in United States of America (USA). The motivation behind the study was to establish the reasons why spread hybrid corn seed had succeeded so as the same can be replicated to other farm innovations. By 1960s, the model had been adopted in fields of health, communication, business, education and many other fields.

According to Rogers & Scott, (1997), diffusion is a process of ‘communication by which an innovation in the form of new ideas, practices or products, is spread, through certain channels, over time, among the members of a social system’. The above definition identifies key elements of diffusion that is; innovation, communication channel, time and social system.

An innovation is an idea, practice or object that is perceived as new by members of a social system Rogers & Scott, (1997). Adoption of an innovation on five characteristics which are relative advantage, compatibility, complexity, trial-ability and observability of the innovation Rogers & Scott, (1997). The theory posits that simpler innovations are adopted faster than the complicated innovations.

Communication channels are the means by which message about the innovation are conveyed to members of a social setting Rogers, (2003). Sharing of information about an innovation is important for the introduction of the innovation and change the user's attitude to stimulate adoption. Time taken for diffusion to occur is important in decision making processes, innovativeness of individuals and the adoption rate (Rogers, 2003). Lamble, (1984) urgues that, communication channels and the efforts by the practictioners influences the adoption of new ideas. This clearly describes the role the agricultural extension service providers play as channels of information exchange.

The third element is time of diffusion, which focuses on three dimensions namely, the decision-making processes which is the time taken from the time a new idea is introduced and the decision to accept/reject the new idea. Individual's innovativeness and the rate of adoption are other elements of diffusion of innovations theory.

Social system is the forth element of diffusion. this refers to 'a set of interrelated units such as individuals, groups, organizations, subsystems, that are engaged in joint problem-solving to accomplish a common goal' (Rogers & Scott, 1997). Diffusion in a social system is influenced by opinion leaders and change agents.

This theory is still in use but it largely top-down because it does not analyse the needs of the end consumer and it is similar to modernising theory (Servaes, 2003). For instance, scientists develop innovations which are transferd to agricultural extension service providers who share the same information with the farmers through a linear model. Although the theory is linear and top-bottom in practice, it is live to the fact that horizonals.channels of communication are important.

2.8. Conceptual Framework

Low adoption of agricultural innovations is already affecting agricultural production in Kenya. This low adoption be attributed to poor information sharing among the farmers, extension service providers and researchers. This study analyzed the adoption of agricultural innovations and the flow of information within social networks

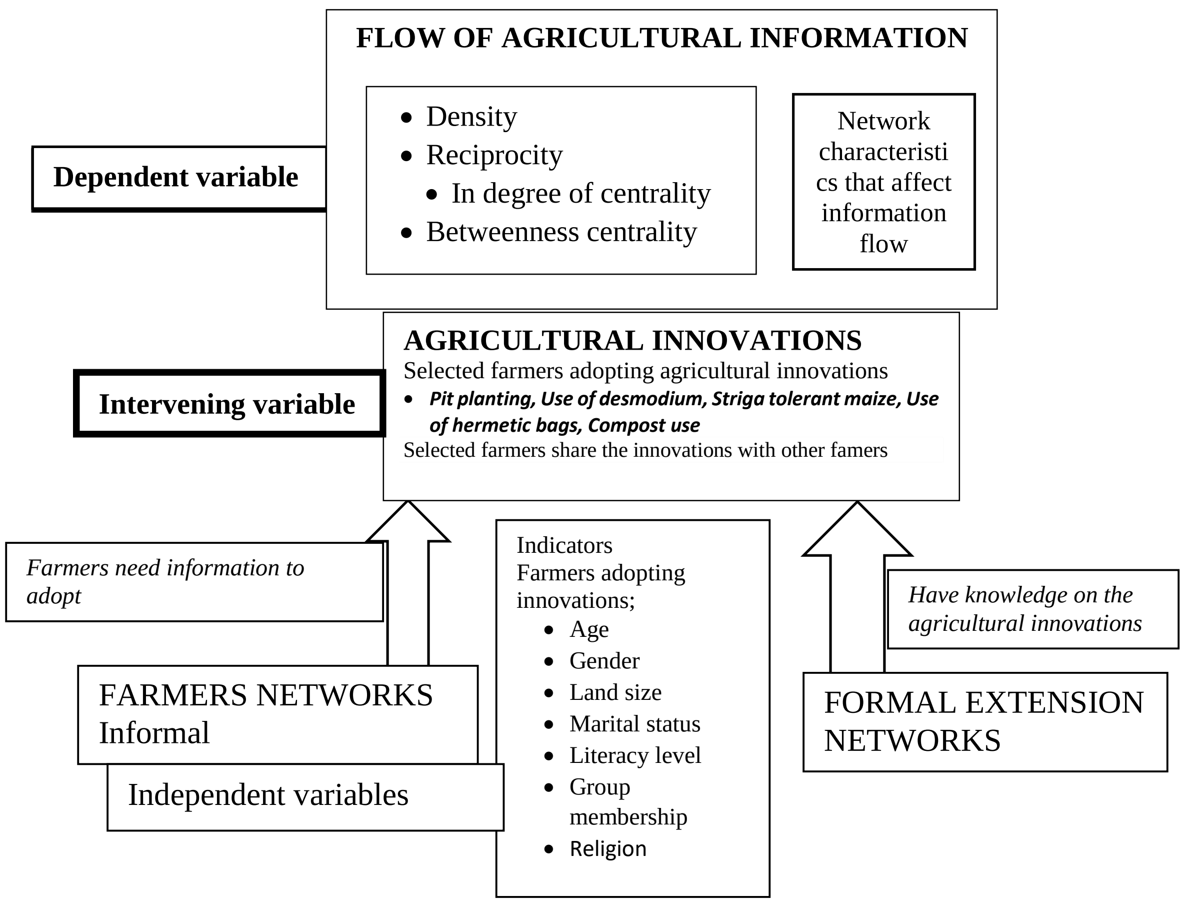
The research concept revolves around a scenario of farmers in four villages of Nambale Sub-county. adoption of innovations for these farmers, farmers need information from the agricultural. Extension officers. Farmers also have information in form of traditional/indigenous knowledge.

Flow of information on agricultural innovations is the dependent. The independent variables in this study are the individuals' characteristics in the villages such as gender, level of education, religion, group membership and age. The farmers' groups have been classified into the following three groups: -

1. Interpersonal information networks
2. Formal information networks
3. Farmers
4. Membership to groups: -

Adoption is indicated by the implementation of at least one of the suggested innovations. The formal information networks including extension service providers are important in the adoption of agricultural innovations because they have the correct information on various innovations that can increase agricultural productivity. These innovations include the use of Desmodium (*Desmodium uncinatum)* to control Striga (*Striga hermonthica)*, use of hermetic bags for maize storage, liming of soils to reduce soil acidity. Farmers also are important participants in the adoption of agricultural innovations. All the players should therefore be connected for effective sharing of information.

Figure 2. 1 The Conceptual Framework



Source; author, 2017

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

This chapter outlines the research methodology adopted for this study. It outlines the research design and describes the data collection and analyses methods.

3.2. The Study Area

This study was done in Nambale Sub-county in Busia County. The research was conducted in four villages of Nambale Sub-county namely Elwanikha, Ibanda, Ekisumo and Budokomi. The villages are comparable to each other in terms of climate, land form and soils. The area is categorized as Lower Midland Zone 1 (LM1), also known as the Lower Midland Sugar Cane Zone, is at an altitude of 1200-1440 meters above sea level and receives an annual rainfall of about 1800-2000mm. The rainfall is bimodal; the long rains normally come between March and May (long rains) and the short rains between August and October (Second season). The zone is climatically suitable to produce a variety of crops.

Crop and livestock production in this area, is characterized by low usage of agricultural inputs and poor crop yields (GoK, 2013). Repeated tilling of land has led to exhaustion of land which has drained nutrients from the soil. Crop production happens in long and short planting season. The long season is from march to August while short season is from August to December. The mean temperatures in the study area is about 20-27^0 Centigrade (Jaetzold *et al*. 2011). Despite two growing periods, it is estimated that 60% of the households are food insecure (GoK, Busia County Integrated Plan, 2013). The most dominant crop is maize although the yields per acre have significantly been declined as a result of depleted soil fertility (Jaetzold *et al* 2011)

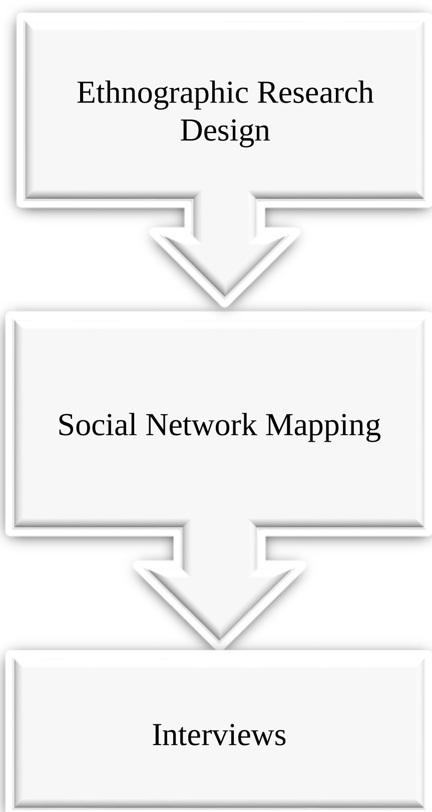
To improve agricultural productivity, the study area has had interventions from NGOs and National and County government programs. First, control of Striga weed (*Striga hermonthica)* using Desmodium (*Desmodium uncinatum)* the innovation that was promoted by ICIPE since 1993. Second, control of soil acidity through liming promoted by GIZ between 2010-2013. Third, control of large grain borer by use of hermetic bags an innovation promoted by PALWECO. Additionally, the study area has been under The National Agriculture and Livestock Program (NALEP) for 10 years since 2001 to 2011 among other extension models. Despite all these efforts, agricultural productivity still remains low. This has led to increased poverty levels which is estimated at 64.2% compared to national poverty level of 45.9 (KNBS, 2015)

3.3. Research Design

The study was an ethnographic case study which investigated flow of agricultural information among farmers through their social networks. The researcher, having worked as an agricultural extension service provider in the area enabled him to internalize the basic beliefs and attitudes of the study population. Once you have a research problem, a social interaction theory or behavior ethnographic case study can be utilized in data collection and analysis (Fetterman, 2000).

According to Scott Reeves, (2013), ethnographic research utilizes observation of the participants, secondary data from documentaries and interviews to comprehensively analyze different scenarios of social setting. Data collection was done using focused group discussions, interviews and socio-metric techniques. (Figure 3.1).

Using the design, the study obtained information with regard to sharing of agricultural information and adoption of agricultural information among farmers. The behavior, beliefs and philosophical way of life, culture and language in the informal setting were also obtained. Ethnographic research design enables researchers to appreciate the peoples interpretation of phenomena in the natural setting (Ejimabo, 2013) .



The design examined the village characteristics and the adoption of agricultural innovations. The research sought to understand why agricultural productivity was low yet, the study area has agricultural extension service providers who are promoting innovations that can increasing agricultural productivity.

Social Network Mapping involved use of socio-metric techniques to map out the farmers in the study area and identify their social networks. the. It also generated data about sharing of agricultural information among farmers and adoption of agricultural innovations.

The interviews were done to gain more insight in the structure of the networks and characteristics of individual farmers

Figure 3. 1 Research Design

3.4. Study Population

The study was conducted in four villages in Nambale Sub-county. The choice of Nambale Sub-county was motivated by the low agricultural productivity (Jaetzold,*et al*. 2011). The selected villages had prior exposure to the innovations under study and were the beneficiaries of programs sponsored by national government and non-governmental organizations with regard to agricultural innovations and dissemination of agricultural information (GoK, 2015). The target population were farmers and the agricultural extension workers (both public and private). The rationale of choosing farmers is because they are the producers and are the beneficiaries of agricultural information from extension workers.

3.5. Sampling Procedure and Sample Size

Purposive sampling, stratified sampling, and snowballing were used to in this study. Purposive sampling was used to select Nambale Sub-county which is characterized by low agricultural productivity compared to the neighboring Teso and Butula Sub-counties. Stratified sampling was used to identify the villages based on the known boundaries. purposive sampling was used to identify the initial respondents for the study. Snowball sampling technique was used to identify This was followed by snowballing which identified the subsequent respondents base who share and exchange information on agriculture. Social network methods do not draw samples. In social networks, population is identified and all the members (actors) of the population are included as part of the study. This is because network methods focus on relations among the members therefore, these members cannot be sampled independently for the study. For this study, all the farmers from the four villages were included for the study. However, 716 respondents (nodes) were interviewed and produced 1,952 relationships (ties).

3.6. Data Collection Procedure

Prior to collection of data, the respondents were guaranteed confidentiality to their answers and informed that to participate was voluntary. An informed consent letter (**Appendix A)** was given to participant for filling and signing. The anonymity of the participants in this study was not possible because it would be hard to identify next respondent if you don't have the details of the former respondent. Identities of the respondents are important for extension officers and researchers for easy identification for dissemination of information. Figure 3.2 shows the step by step approach to social network data collection and analysis.

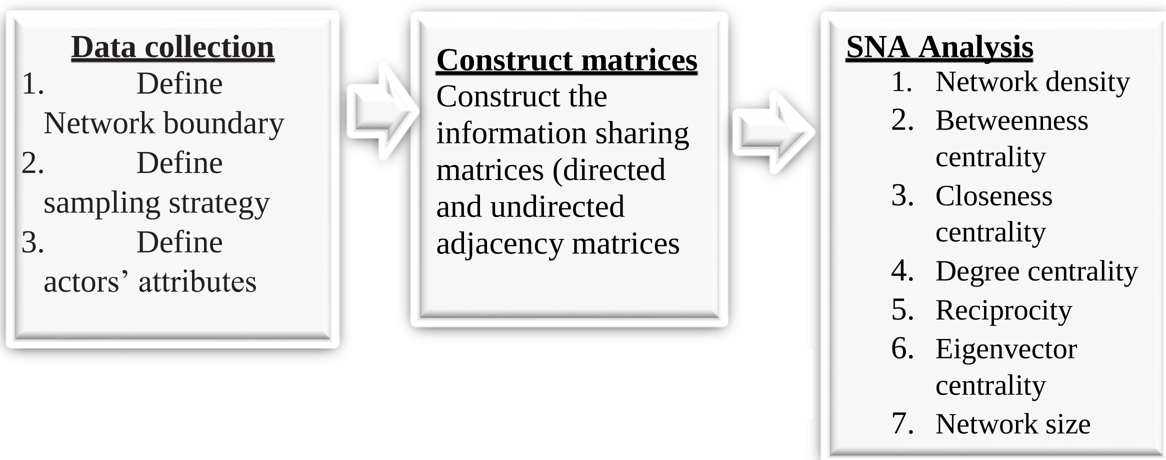


Figure 3 2 Step by step approach to Social Network data collection and Analysis

Data collection was done with the assistance of four enumerators. The research assistants were recruited from the villages so that they can effectively administer the questionnaire. Before the data collection exercise, they were thoroughly take through the questionnaire (**Appendix D**). A pre-test was conducted to ensure that the questionnaires are correctly filled. Data collection was conducted between 18th March 2016 to 6th August 2016.

3.6.1. Definition of Network Boundaries

SNA starts with identification of network boundaries. According to Scott J. (2017), defining the area of study and the population is important because in social network analysis, exclusion of important actors can result in erroneous conclusions. Identify the geographical area. For this study, Nambale sub-county was chosen as the study area. A survey of individuals who are involved the process was conducted. Individuals who were identified were then asked to other members in their networks

Network boundaries defines who is included in the network and who is not included. Failure to define network boundaries may include or exclude not only the important actors, but also existing connections between these individuals and others members in the network. Additionally, structural characteristics of interest like connectedness can be affected by the inclusion or exclusion some members in strategic areas such as connectors between two cohesive subgroups. Definition of network boundary if necessary because it will guarantee that succeeding analyses reflect that choice of boundary.

3.6.2. Sampling strategy

Boundary identification involves the identification of the geographic area it is followed by identification of the variable to be measured. There are two methods of collecting relational data

a. Non-probability sampling such as respondent driven sampling (Gile & Handcock, 2010).
b. Probability sampling

The study adopted respondent driven sampling design. The design is appropriate in cases where the size and boundaries of the sample are unknown and no standard sampling frame exists (Gile & Handcock, 2010). Eighty (80) focal farmers were purposively selected as a start-up list of farmers who would provide names of other farmers they share agricultural information with. Respondents were required to recall the names of their contacts with which they share agricultural information. The process continued until a comprehensive coverage of relevant population was attained. This design was preferred because it reduced the chances of that some data will be missing. The design allowed the investigation of the characteristics of the ego's network that would not be analyzed in situations where the sample population is randomly fixed in advance. In this case reciprocity in a relationship was measured. Additionally, the accuracy of some of the respondent's answers were verified by interviewing the ego's alters this is because accuracy of data that rely on individual's memory can vary. The design also allowed measuring of the network composition for example, homophily and homogeneity (DeJordy & Halgin, 2008)

3.7. Data collection Instruments

3.7.1. Primary Data

3.7.1.1. Questionnaire

Primary data was collected using a questionnaire **(Appendix D)** adopted from (Othieno, 2014). The pretest for reliability and validity of the questionnaires was done in Buyofu village. Questionnaires were administered face to face using an interview protocol **(Appendix C).** The questionnaire was divided into four parts; first was the farming systems and socio-economic aspects, second were questions to generate a list of the alters, third was to establish how often do the farmers meet and the type of relationship that exist among the farmers and finally, questions to determine the alter-alter relationship and because the alter prompt would have prolonged the survey (Borgatti H. &., 2012). The questions were limited to only a few alters (farmers). Table 3.1. indicates the number of questionnaires administered during the study.

Table 3 1 Number of Questionnaires administered

Village	*Number of questionnaires administered*	*Number of questionnaires analyzed*
Elwanikha	37	35
Budokomi	37	38
Ibanda	38	38
Ekisumo	38	36
Total	**150**	**147**

Source; Author 2018

3.7.1.2. Semi-structured group interviews

Semi-structured interviews were used to collect focused, qualitative textual data. The interviews were conducted with a fairly open framework which allowed for focused, informal, two-way communication. The group interviews were useful in identifying information which the respondents felt it was significant to them. The presence of multiple participants permitted issues from different perspectives to emerge which were discussed. It provided for opportunity for the group members digest opinions of other group members. The method was useful in interpreting results regarding the roles of the actors in a network and definition of individual’s characteristics. The groups were randomly selected form each village and consisted of 12-14 participants. The group interviews contextualized the social network findings.

3.7.1.2. Observation Check list

To get information about adoption of innovations, farm visits were conducted to directly observe evidence of adoption using observation checklist (**Appendix B**) adopted from

(Othieno, 2014). Observations were used to check for non-verbal expression of feelings, determine who interacts with whom, grasp how participants communicate with each other, and check for how much time is spent on various activities. The method assisted the researcher to observe events that informants may be unable or unwilling to share when doing so would be unwise, impolite, or insensitive.

3.7.2. Secondary Data

Secondary data was collected from policy documents, crop production data, management guidelines and procedures for agricultural extension at the local and national levels. The information from these documents provided useful information on the existing agricultural extension methods and adoption of innovations.

3.7.3. Social Network Data

Name generators a socio-metric technique was used to collect social network data. The technique identified network members by asking free recall questions that elicit alters from an ego's network. The respondents were asked to name the people who live outside their household, with whom they felt very close and fairly close. Very close people consisted of "people with whom you discuss important matters with, or regularly keep in touch with, or they are there for you if you need help". Fairly close people consisted of "more than just casual acquaintances, but not very close". This "closeness" approach defined two aspects. First, closeness becomes a tie strength measure: strong (very close), and weak (somewhat close). Second, closeness defined the social network "boundary" and thus the sociable activity-pattern captured in the data which excludes people who are only casual acquaintances.

To establish who were the most influential farmers or opinion leaders in the village, respondents were asked “which two farmers do you talk to most frequently?” and “Who do you consult for new ideas or better ways of farming?” By asking these kinds of relational questions, both methods generated data which showed not only directions of communication flow, but also communication structures of social systems.

To establish the strength of the relationship between the farmers, the respondents were asked how frequently they were in contact with their ‘friends’. The responses were separated into a dichotomized framework, with contact frequencies less than once in 6 months being coded with a "0" and contact frequencies greater than or equal to once in 6 months coded with a "1. This framework is selected after determining that collaboration occurring at least once in 6 months should be considered as part of their network and that collaborations occurring less frequently should not be considered. Six month represented a planting season. Additionally, each participant was asked how frequently he or she participated in forums promoting innovations related to agriculture. With this information it is possible to determine which stakeholders are involved in certain issues and their frequency of collaboration with farmers.

3.7. Validity and Reliability of Data Collection Instruments

Validity and reliability of data collection instrument was done to ensure that the data collected was representative, accurate and consistent.

3.7.1. Pilot Study

The pretest for reliability and validity of the questionnaires was done in Buyofu village which was not part of the study site. The pilot study was aimed at testing the consistency, clarity and sensitivity. The study was contacted for four days this gave the research assistant sufficient time to understand the questionnaire and seek clarification on areas that were not well understood. It also provided an opportunity to refine the questions for more clarity. In summary, the pilot study was important for improvement of the quality and efficiency of the main study. In addition, it was conducted in order to assess the safety of treatment or interventions and recruitment potentials, examine the randomization and blinding process, increase the researchers' experience with the study methods and provide estimates for sample size calculation.

3.7.2. Validity

Validity is the degree to which the results obtained from the analysis of the data represents the variables under. To test validity of the data collection instruments, the questionnaire, semi structured interview guide and the observation check list was given experts in the area of social networks for examination and correction. Their feedback was considered and included in the final copies.

3.7.3. Reliability

Reliability refers to a consistency of an instrument when applied to similar situations. To test consistency in producing a reliable result, a re-test method was used. The test determined the amount of error in a test score. Twenty respondents drawn from the study site took part in the pre-test. The interview guide was administered and to the respondents and repeated two weeks later. The answers were compared and analyzed. Cronbach’s alpha results showed a reliability coefficient of 0.815 which was above the 0.70 threshold for accepted reliability (Taber, 2017)

3.8. Ethical Considerations

A letter of informed consent (Appendix A) was issued to the respondents before administration of the data collection instruments. The respondents were at liberty to agree or decline to participate in the research. Those who consented to the request, were asked to sign the letter in duplicate with one copy kept for their records while the other copy was kept by the researcher. The respondents were again briefed about the nature of the study and the research objectives.

3.9. Limitations of the Study

Although the study contributes to the methodology and application of social networks in disseminating of agricultural information, some limitations were noted. First, the results of this study are from a case study. The research was conducted in one Sub-county and therefore cannot be generalized to other areas. Another limitation is that SNA can only measure a network of relationships at one point in time. Additionally, the very specific nature of this case study makes it difficult to generalize these results to other networks and organizations. Second, research relies on self-reports of interactions and trust. Individuals are reluctant to disclose personal information about the friends they interact with.

3.10. Assumptions

The network perspective stresses structural relations as key orienting principle where social structure consists of regularities in the patterns of relations among concrete entities. The central objectives in social structure consists of regularities in the patterns of relations among concrete entities. The central objectives in social network analysis are able to measure and represent these structural relations accurately, as well as to explain both why they occur and what the consequences are. The research made the following assumptions;

First, structural relations are often more important for understanding observed behaviors, than attributes such as age, gender, values, race, education and income. One's behaviors, such as with whom one talks to, how he or she talks, and what he or she talks about are highly contextual depending on the social context that is constructed by many other relations and ties between many other actors. Second assumption was that structural relations were viewed as dynamic processes. Third assumption was that networks affect perceptions, beliefs and actions through variety of structural mechanisms that are socially constructed by relations among entities.

3.11. Data Processing, Analysis and Presentation

Data was entered in an adjacency matrix described below. Because the data collected was in binary form, 1 or 0 was entered in each column and row to indicate the presence or absence of a relationship. Socio-metric analysis was done using UCINET VI *version 6.624*. Net draw *version 2. 160* an interphase program was used to create illustrative maps.

3.11.1. Construction of SNA Matrices and Network Graphs

SNA maps, measures and analyzes relationship patterns (ties) among individuals (nodes). The collected data is captured in an adjacency matrix form where nodes are assigned a column and a row in the matrix. The resulting matrix will have two cells representing the connection of any 2 nodes, i.e. 1 cell above and 1 cell below the diagonal. Existence of a relationship or tie between two nodes is designated by entering 1 in the matrix cell representing the connection of the two nodes. If no relationship or tie exists, 0 is entered in the cell representing the connection of the two nodes. For example, in figure 2.1. shows a directed adjacency matrix X seeks information from Y, but Y seek information from X. In this case, the cell at the connection of row X and column Y is entered a 1, but the connection of row Y and column X will be entered a 0. Figure 2.2 shows undirected adjacency matrix because the relationship is not directional that is the matrix cells above the diagonal are matching with those above the diagonal.

Illustrations of Adjacency Matrices

Figure 3 3 Directed Adjacency Matrices

	X	Y	Z
X	-	1	0
Y	0	-	1
Z	1	1	0

Figure 3 4 Undirected Adjacency Matrices

	X	Y	Z
X	-	1	0
Y	0	-	1
Z	1	1	-

The results provided a social map indicating how individual interact and exchange information in the selected villages. Table 3.2 shows the analysis plan. Upon analysis of the social networks, the roles played by individual farmers in the network was determined using social metric measures such as centrality, degree betweenness and closeness centrality. The analysis was important because it identified the farmers and their roles within the network for sharing and exchanging of information (Müller-Prothmann, 2007) namely;

- ***Experts*** *are* farmers who have comprehensive information in a specific experience in particular fields. These farmers occupy a central position because it has high number of external connections.
- ***Information brokers*** are farmers who have information on who has information on what. These farmers connect other members or group of members to others.
- ***Contact persons*** (or agents) are farmers who are in contact with the experts. They act as a link between the experts and the information consumers (network members who are at the periphery).
- ***Information consumers*** consists of farmers who seek information from the experts.

Table 3 2 Overview of analysis plan

Level of analysis	SNA Metric	Variable used	Importance
Network analysis	Network density	Frequency of contacts	The ratio of ties that are direct in a network relative to the total number of possible ties. Determine a farmer who is well connected.
	Betweenness centrality	Frequency of contacts	Helps to identify information brokers and gate keepers within the network. high betweeness is an indicator of an influential farmer. That is a farmer who has controls the information flow in the network. the absence of this farmer will starve others of the information.
	Closeness centrality	Frequency of contacts	Farmers who can access other farmers quickly in the network have high closeness centrality
	Degree centrality	Level of collaboration	It is an indicator of who has the most direct connections in the network which is a sign of expertise and power. He is the most active actor in the network.
	Reciprocity	Level of collaboration	Farmers who give feedback to the information received. Strong relationships are characterized by high number of reciprocal ties.
	Eigenvector centrality	Level of collaboration	Measures how important some members are in the network. Members with high eigenvector value can influence others directly or indirectly because they are linked to well-connected members.
	Network size	Level of collaboration	Measures health and effectiveness of a network.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter presents the results for the study.

4.1. Demographic characteristics of farmers

4.1.1. Ego attributes

The first questions of the survey were related to farmers' personal information, such as age, educational level, land tenure, farm size, and participation in any association.

4.2.2. Age of respondents

On age differentiation (*Figure 4.1*), 33.3% of the respondents were aged between 45 and 54 years which were the majority 29% were aged between 35-44years, 17.8% were aged above 55 years with 18.8% below 34 years. The respondents of ages less than 34 years were found to readily participate in embrace training opportunities, agricultural shows and exhibitions. This could explain their adoption of agricultural innovations.

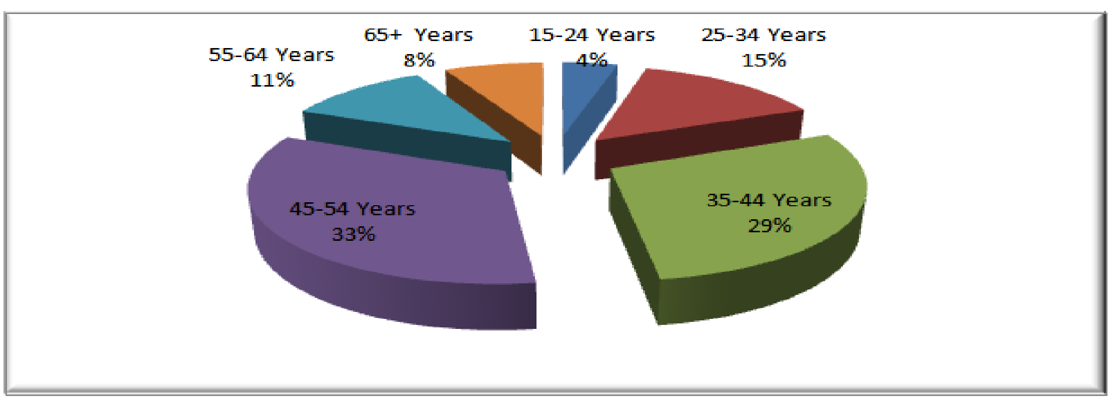


Figure 4. 1. Age of respondents

Source: Field data 2016

4.2.3. Gender of respondents

Among the sample household population in the study area, 66.7 percent comprises of females (*Figure 4.2*). However male member heads majority of households.

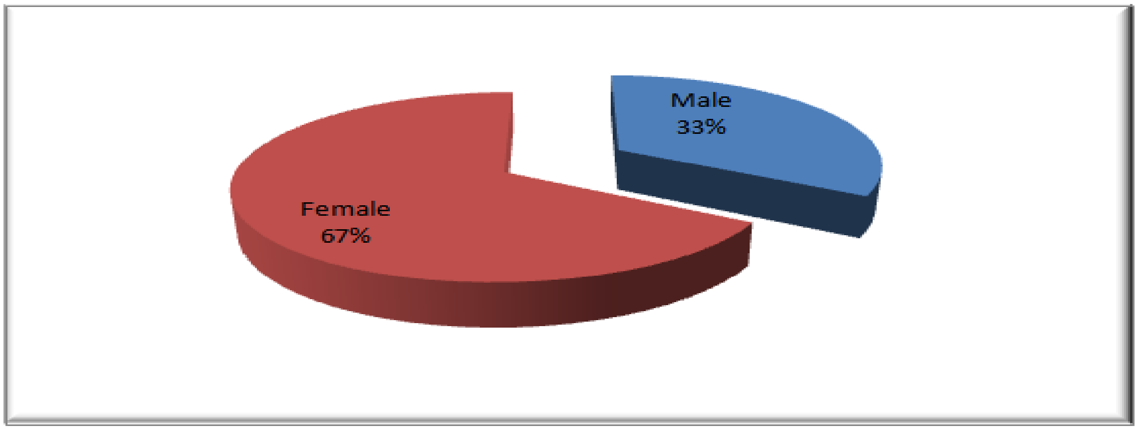


Figure 4. 2 Gender of Respondents

Source: Field data, 2016

4.2.4. Literacy level of respondents

Overall literacy was understood as their ability to read or/and write or attained some level of education. 15.4% reported not to have attended formal education, the majority of the respondents at 52.1% reported to have attained primary level education. Secondary level stood at 29.9%. Only a small population of 2.6% reported to have a college education. (*Figure 4.3*)**.** From the interaction with and simple observation of the respondents, the study established that those households that were more receptive to trainings and practiced modern farming belonged to household heads that had acquired secondary and tertiary levels of education.

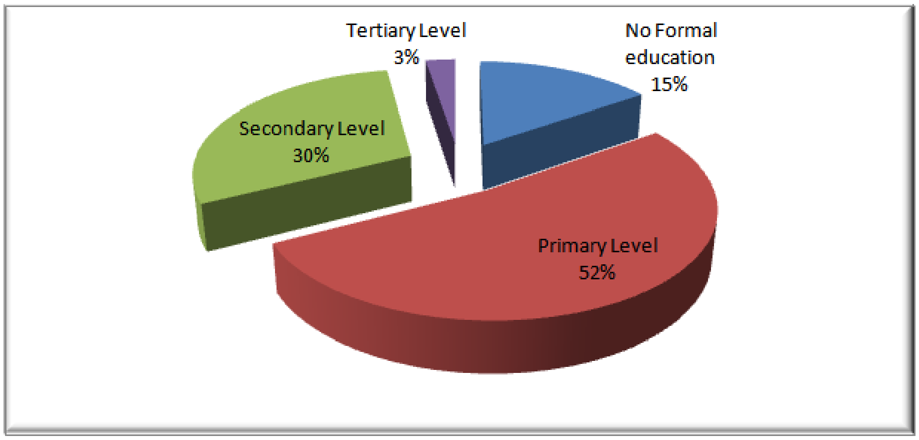


Figure 4. 3 Education level of Respondents

Source: Field data,2016

4.2.5. Land tenure

Most farmers own the farms acquired through either inheritance or purchase. The average land size was 2 acres (*Figure 4.4*). Time farmers have lived on their farms varies greatly, ranging from 2 to 58 years. Most of them have worked a lifetime in agriculture. However, investment in long time innovations such as "Push-Pull" have not been adopted.

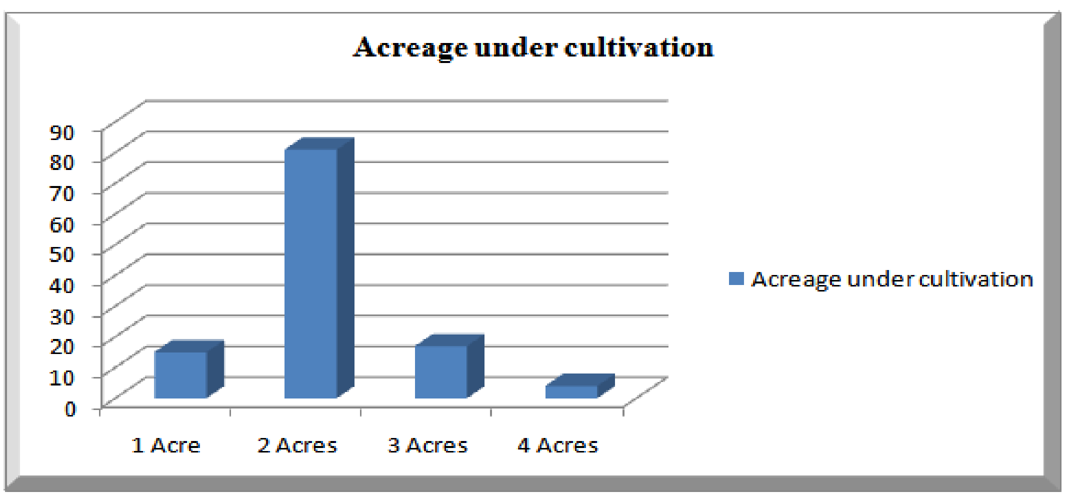


Figure 4.4 Acreage under cultivation

(Source: Field data, 2016)

4.2.6. Membership to social groups

Membership to agricultural groups was low at 9%, with welfare and religious groups most popular at 57% and 34% respectively. There is zero participation in cooperatives. This explains why past approaches to use groups to disseminate agricultural information have failed. This is because the existing groups were formed for other reasons and not agricultural production.

4.3. Flow of agricultural information in the village networks

This study investigated the flow of agricultural information in the villages in Nambale Sub-county. One hundred and fifty questionnaires were distributed to farmers in four villages in the study area, and the response rate was 98%.

4.3.1. Socio-metric analysis of Elwanikha Village

In Elwanikha village, 37 questionnaires were administered and analyzed. 91 nodes (actors) and 182 ties (relationships) were produced. The Network density of the village was 0.030. Network density measures the number of ties that exist between actors compared to the number of ties between actors that is actually possible. It is an indicator of how connected the network is in comparison to how connected it might be. The low network for Elwanikha village indicates that network farmers do not interact with each other frequently. This means that information does not flow efficiently because it has to move from one farmer to another rather than diffusing from one farmer swiftly to all other members.

The village networks are also characterized by many sub-groups have loose connection to one another. Loosely connected sub-groups indicates that social networks in the village are not cohesive. These village networks illustrate a mix of weak and strong ties (*Figure 4.5*).

Strong ties exist between farmers who are either family members, friends or colleagues. The weak network exists through farmers with distant acquaintances. Farmers with weak ties who are outside the key network are bridges to other networks (sub-groups).

The clustering coefficient for the village was 0.035. The measure shows how widely the farmers are connected in this village which is clearly illustrated by the village social map (*Figure 4.5*). The clustering co-efficient metric measures how connected how your friends are. If all your friends know each other then, you have a higher clustering co-efficient.

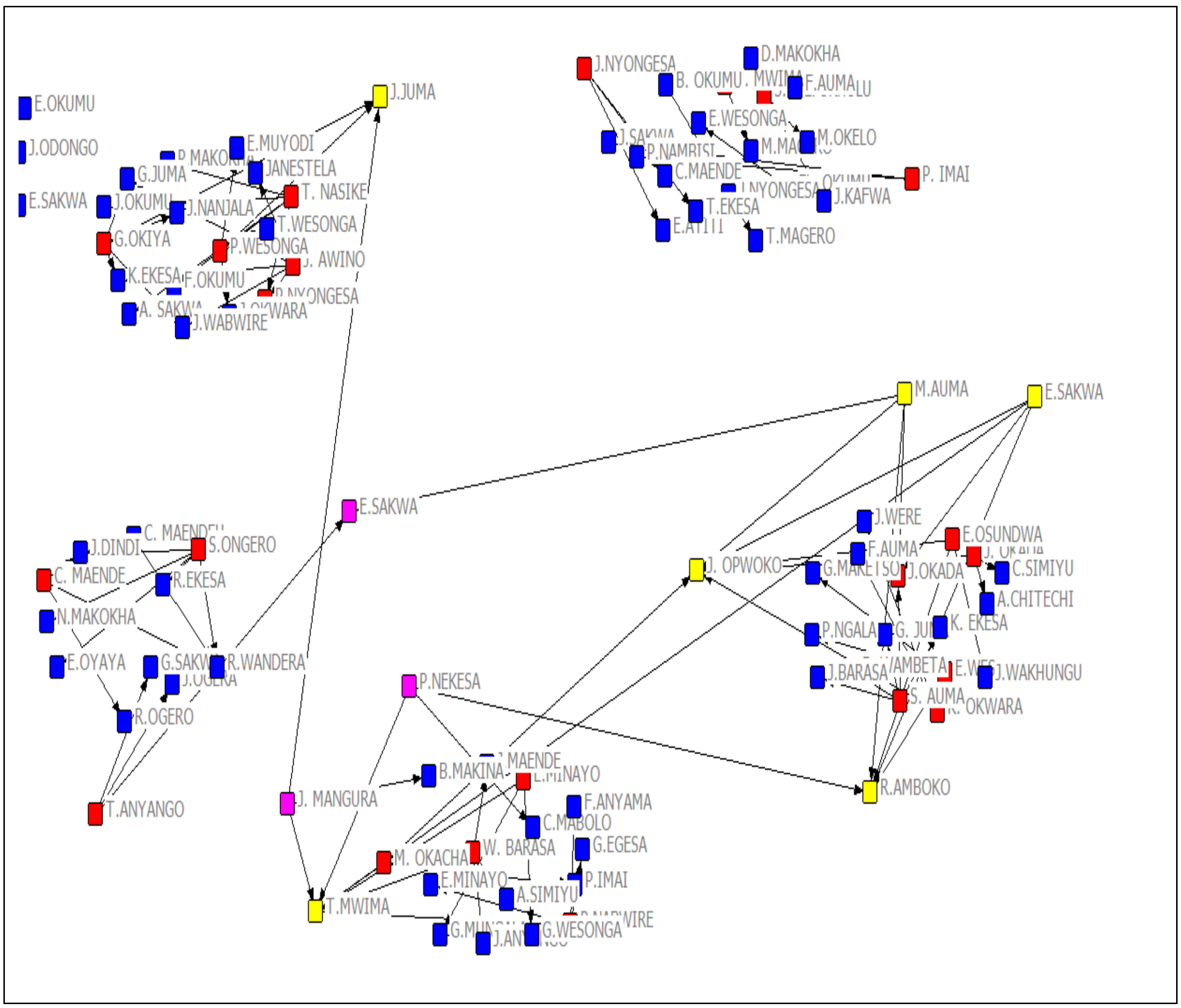


Figure 4. 5 Socio-metric map showing Elwanikha sub-groups

Source: Field data, 2016

Elwanikha village had an in-degree of 1.46 and an out-degree of 4. This implies that majority of farmers in the village rely on at least two interpersonal sources of information and also provide information to two other farmers. The most popular farmer (in-degree) receives information from four interpersonal connections in the village. In-degree centrality is an indicator of popularity and potential for influence and leadership while out-degree centrality is an indicator of the capacity for sociability and extent of dependency.

The average geodesic distance was 3.116 which indicates that on average a farmer in this village has to go through four encounters to access agricultural information. The maximum Eigenvector centrality was 0.208 (*Figure 4.6*). Eigenvector centrality is a social metric measure that identifies the important farmers in the network. This metric was used to identify farmers who have a wide reaching influence within the village. Low eigenvector value indicates that only few farmers are linked to other well connected farmers which may influence flow of agricultural information.

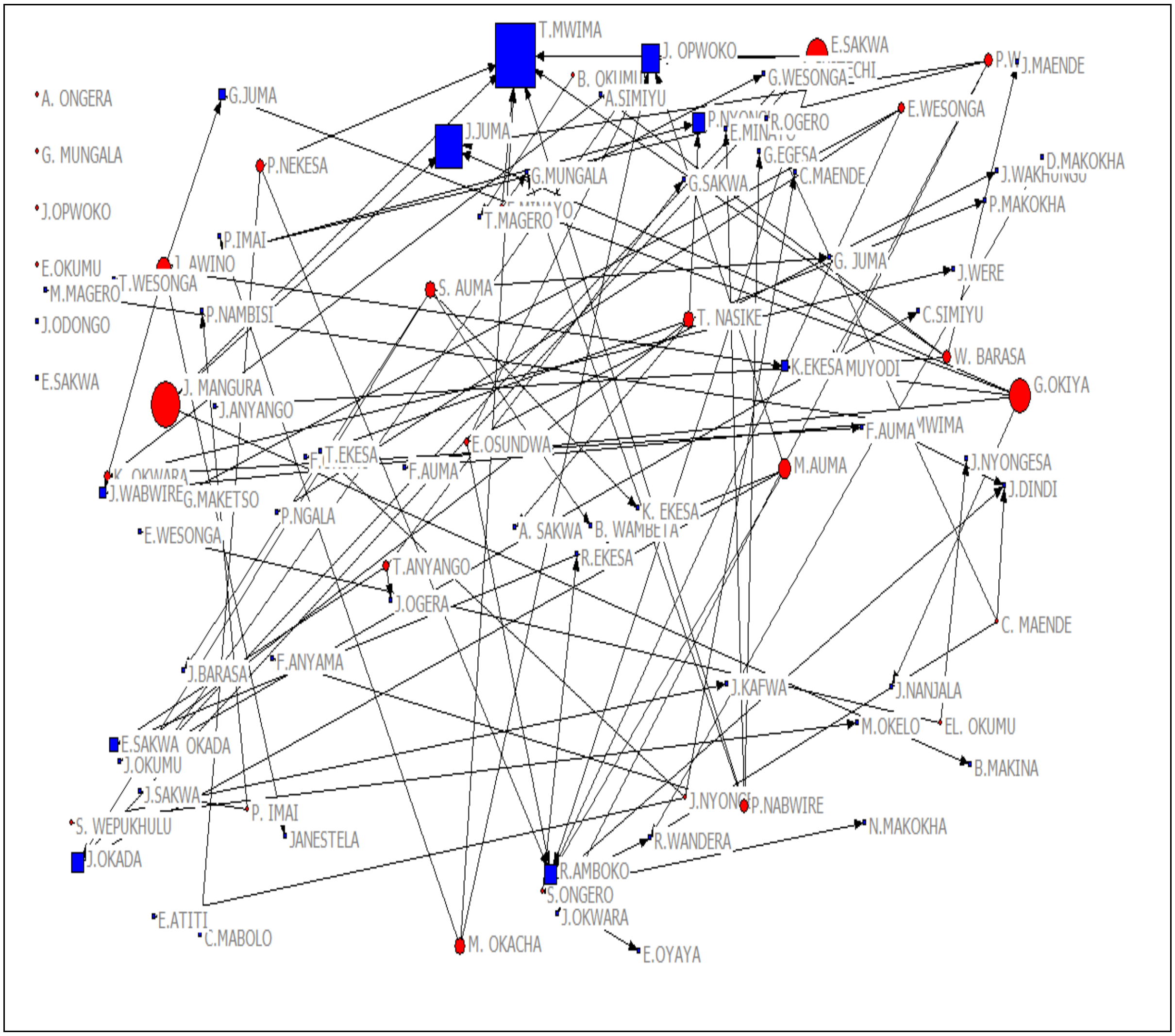


Figure 4.6 Socio-metric map showing Eigenvector Networks

Source: Field data, 2016

Importance of bridging actors

Elwanikha socio-grams illustrates the significance of bridging actors in a network. *Figure 4.5* shows farmers who act as connectors/bridges (yellow color) to other farmers or other sub-groups. On further analysis, the bridging farmers have high betweenness centrality. These farmers play important role in connecting the other farmers or sub-network. The farmers act as a link in disseminating information in the network given their positional advantage. They are positioned on a shorter geodesic path and central in the network. They play the role of information brokers or gate keepers. However, such farmers can also hoard information and therefore starve many farmers within the network key information. It is not a good indicator of the sustainability of the network. Even if this farmer is important in the network, displacement may lead to problems in the network and ultimately the collapse of the network.

Based on these centrality measures, the farmers occupying the central position in the network are identified as farmers ***J. Opwoko, T. Mwima, R. Amboko, J.Juma, J.Mangura, E. Sakwa*** and P.Sakwa. these farmers are either nodal or bridging farmers in the network. For example, farmer J. Mangura connects two central farmers (T. ***Mwima and T. Mwima)*** in two sub-networks. Similarly, farmer ***P. Nekesa*** is the connecting farmer between ***T. Mwima and R. Amboko*** who are central in two sub-networks.

4.3.2. Socio-metric analysis of Ibanda village

In Ibanda village, 38 questionnaires were administered and analyzed. The socio-metric analysis of Ibanda village produced 172 nodes with 429 ties. The social network structure of Ibanda village is different from Elwanikha as it a fairly closely knit structure. *Figure 4 7* shows a network structure that is more spread out characterized by strong bonded groups that are central and weakly connected farmers on the periphery. The village has a network density of 0.052. Network density measures the number of ties that exist between actors compared to the number of ties between actors that is actually possible. It is an indicator of how connected the network is in comparison to how connected it might be. The study established that interaction between members of this network was limited to two times in a week. Although most farmers in this village were reachable, the low network density slowed down the flow of agricultural information.

The village had a closeness centrality of 0.167. closeness centrality metric measured how close a farmer was to others within the village networks. Low closeness centrality indicates that farmer is connected to most of the farmers within the village. These farmers (with low centrality) will disseminate information faster to other farmers in the village. This is because they have positional advantage and are good broadcasters.

The village recorded an in-degree centralization of 0.141 and out-degree centralization of 0.164. In-degree is a measure of the number of ties directed to the node (actor) while in-degree is the number of ties the node directs to others. The farmers were either connected with incoming or outgoing ties. The positive centrality values make the network more stable and it cannot collapse even if the nodal household moves out of the network.

Eigenvector centrality score was 0.0072. Eigenvector centrality measures the level of influence of a node within the network. the low eigenvector centrality indicates that there are few farmers who are connected to other important.

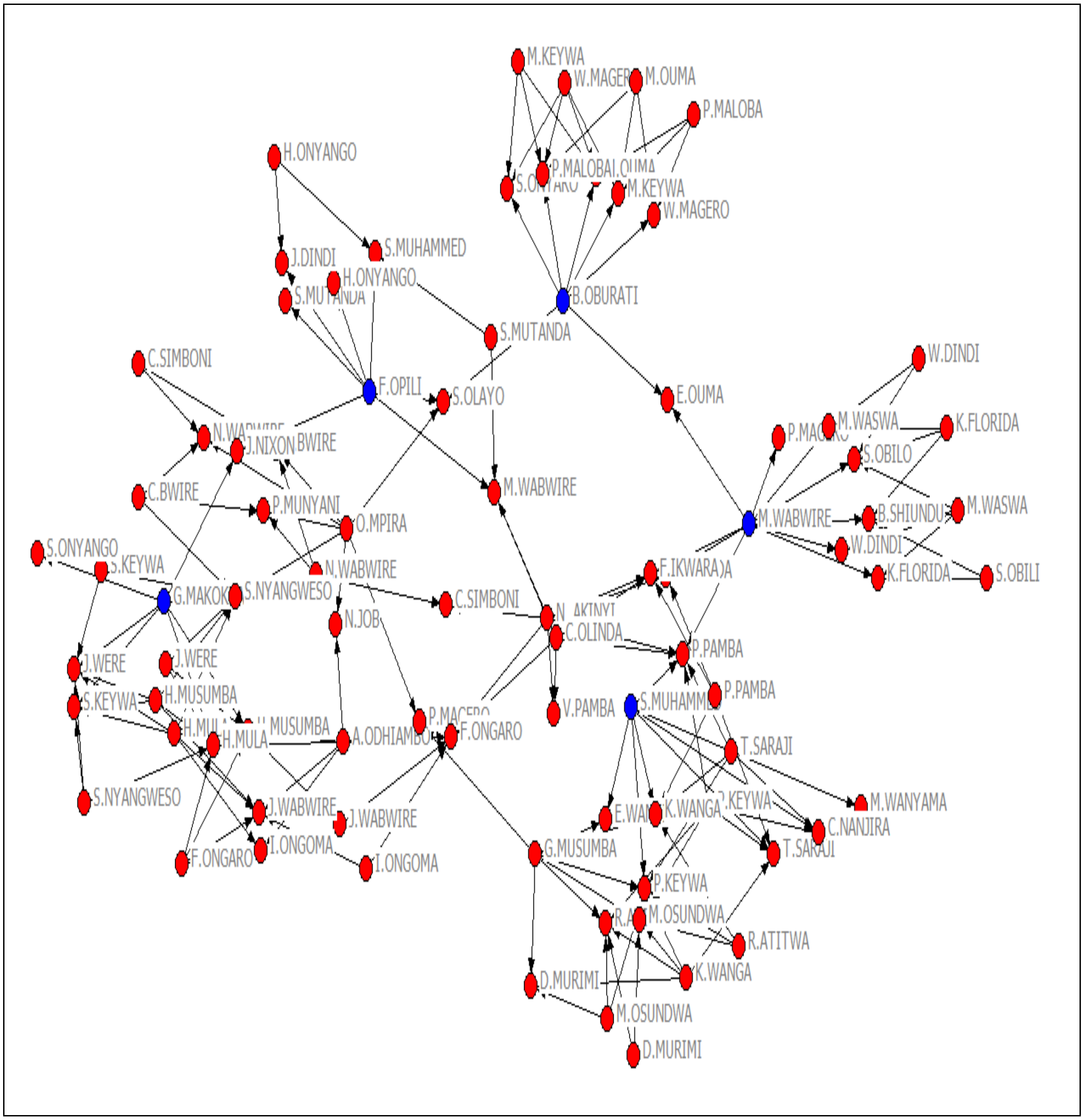


Figure 4. 7. Social-metric map Ibanda Village

Source: Field data, 2016

There were reciprocal ties in the village with a reciprocity score of 0.107. This indicates that there was positive feedback among the farmers (*Figure 4.8*). Reciprocity indicates some level of trust because it is a proof that information sharing is taking place in the network. (Scarbrough *et al* 2014).

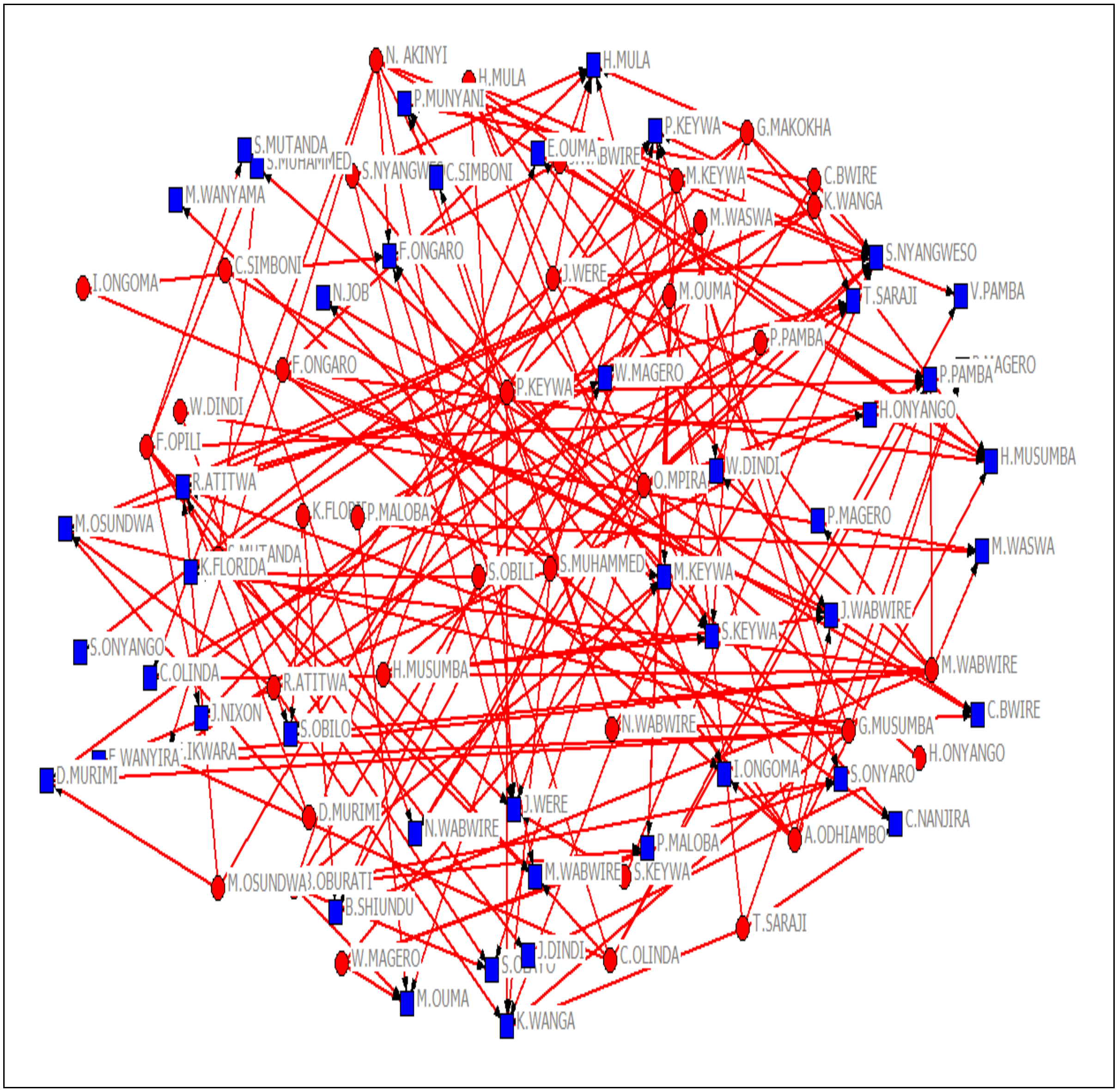


Figure 4. 8 Socio-map showing reciprocation in Ibanda village

Source: Field Data,2016

4.3.3. Socio-metric map of Ekisumo village

The social networks of Ekisumo village generated 375 nodes and 956 ties after administering 40 questionnaires. To describe the network structure and relational attributes of this village, socio-metric measures were used. Ekisumo network is fairly dense. This illustrated by the socio-gram (*Figure 4.9*) shows an extremely cohesive network with a density of 0.1038. This is also supported by the average distance score of 1.362 which indicates great proximity between people. Network density is a measure of the number of ties that exist between actors relative to the possible ties. Individual's network size varies from 4 to 13 contacts, revealing a wide range of interactions.

Eigenvector centrality of Ekisumo village was 0.034 (*Figure 4.10*). Eigenvector centrality measures the importance of the actor and his/her ability to influence others. The low eigenvector centrality implies there are a few opinion leaders in this village. Average centralization degree for the village was 2.549 which means that a household had direct relationships with 3 other households in the village. Out degree and In-degree are the 0.052 and 0.058. These measures identify the most important farmer in the network.

A careful observation of network map for the degree centrality that is the number of ties a household has with respect to information sharing reveals that most of the household have a good number of ties with other households. There are however a few households who stand out boldly and these are the focal points who are the source of information for the others i.e. ***J. Maroko and P. Namusonge.***

The average closeness centrality is 0.008. Closeness centrality measures how quickly an actor can access more actors more actors. Farmers with low closeness measure are able to have quick access to other farmers in the network. These farmers have shorter paths to reach other households and they are knowledgeable about what is happening in this network. They have high visibility. Interviews reveal that these households are not only able to have quick access to information from relationships with other households in their cluster but also enjoy the benefits with households belonging to their clusters.

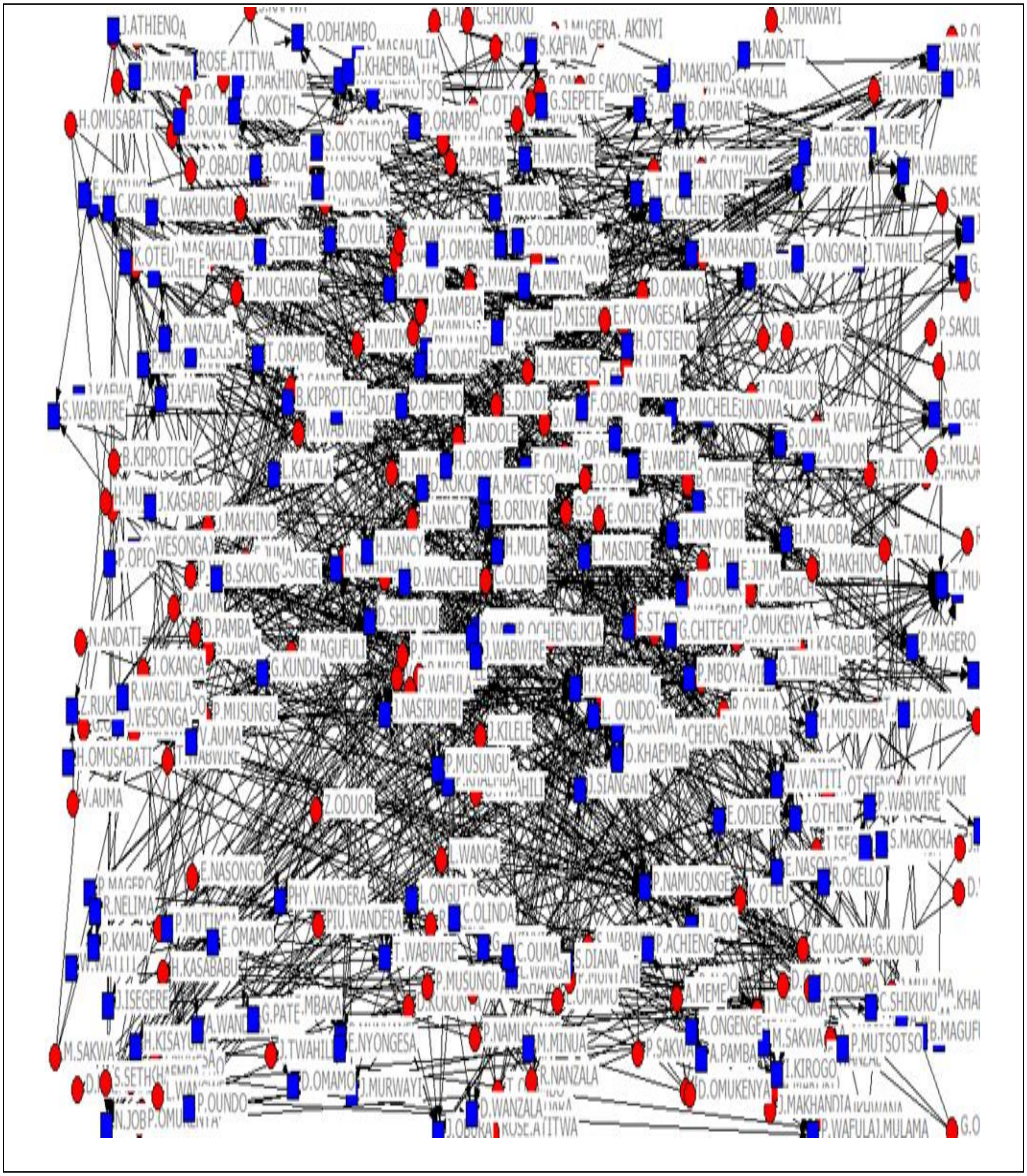


Figure 4. 9 Social networks Ekisumo Village

Source: Field data,2016

The village is also characterized by presence of strong ties. This means information sharing mostly occurs between the farmer's friends, neighbors and relatives. Although strong ties promote cohesion, it can lead a situation where information is confined to a much smaller network. also, strong ties deprive the village information from distant parts of social system (Figure 4.10).

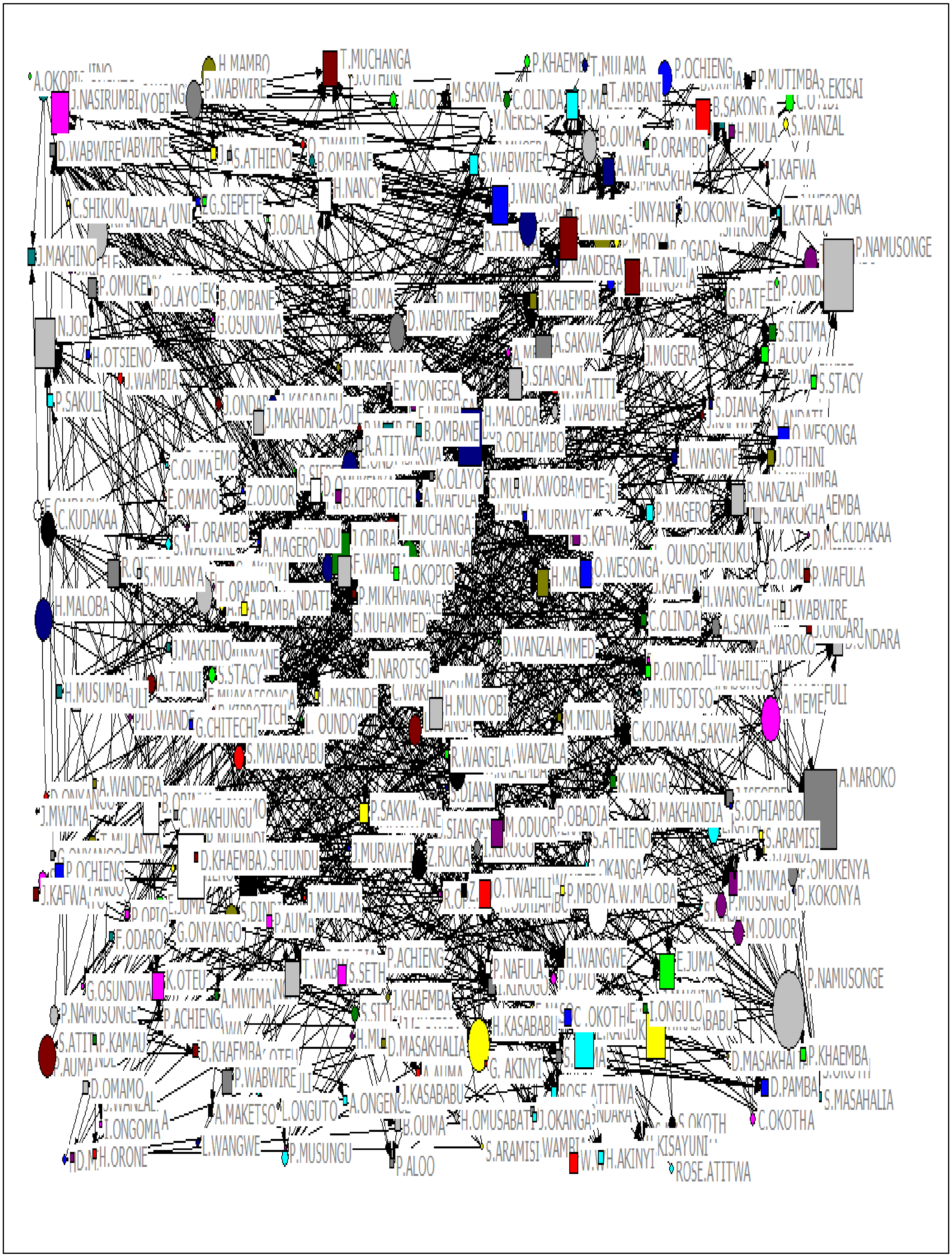


Figure 4. 10 Eigenvector Networks Ekisumo village

Source: Field data, 2016

4.3.4. Socio-metric analysis of Budokomi Village

The social network analysis of Budokomi village generated 172 nodes producing a total of 385 ties after administering 37 questionnaires. The social-gram (Figure 4.11) shows a fairly dense network with a density of 0.0720 a sub-group of farmers that are on the periphery. Network density is a measure of the number of ties that exist between actors relative to the possible ties. It is calculated by the number of connections the actor has, divided by the total potential connections the actor could have. Budokomi village has a low Eigenvector centrality of 0.12 (*Figure 4.10*). Eigenvector centrality measures the importance of the actor and his/her ability to influence others. This high eigenvector centrality indicates the presence of opinion leaders in this village.

The village recorded an in-degree centralization of 0.123 and out-degree centralization of 0.171. In-degree is a measure of the number of ties directed to the node (actor) while in-degree is the number of ties the node directs to others. The farmers were either connected with incoming or outgoing ties. The average in-degree was 1.28 meaning that farmers in this village have at least one source of information and act as a source for other farmer. Although centrality values in this network are positive, removal of certain farmers may destabilize the information sharing. For example if farmers such as ***S.Oduor, M. Makhandira, N.Job and W. Musumba*** move out, the system might collapse (Figure 4.11).

The Geodesic distance between farmers was 4.413. The measure indicates that a farmer in the social network has to go through other four farmers to access information. The closeness centrality was 0.011 indicating a farmer in this village relatively shares information with other farmers faster.

The social map a mixture of weak and strong ties. It shows a sub-group of farmers that are on the periphery (isolates). The data reveals that many of these households have links outside the village. This means that new knowledge or information can flow into the village through these points that are hanging in the periphery. The only limitation is that these nodes are not connected to others in the village. The isolated farmers find it hard to access information from social networks close to them. This type of farmers most likely could be the laggards who take long to either receive information or take long to adopt the innovations. The reciprocity score was 0.017, this indicates that farmers do give feedback to other farmers.

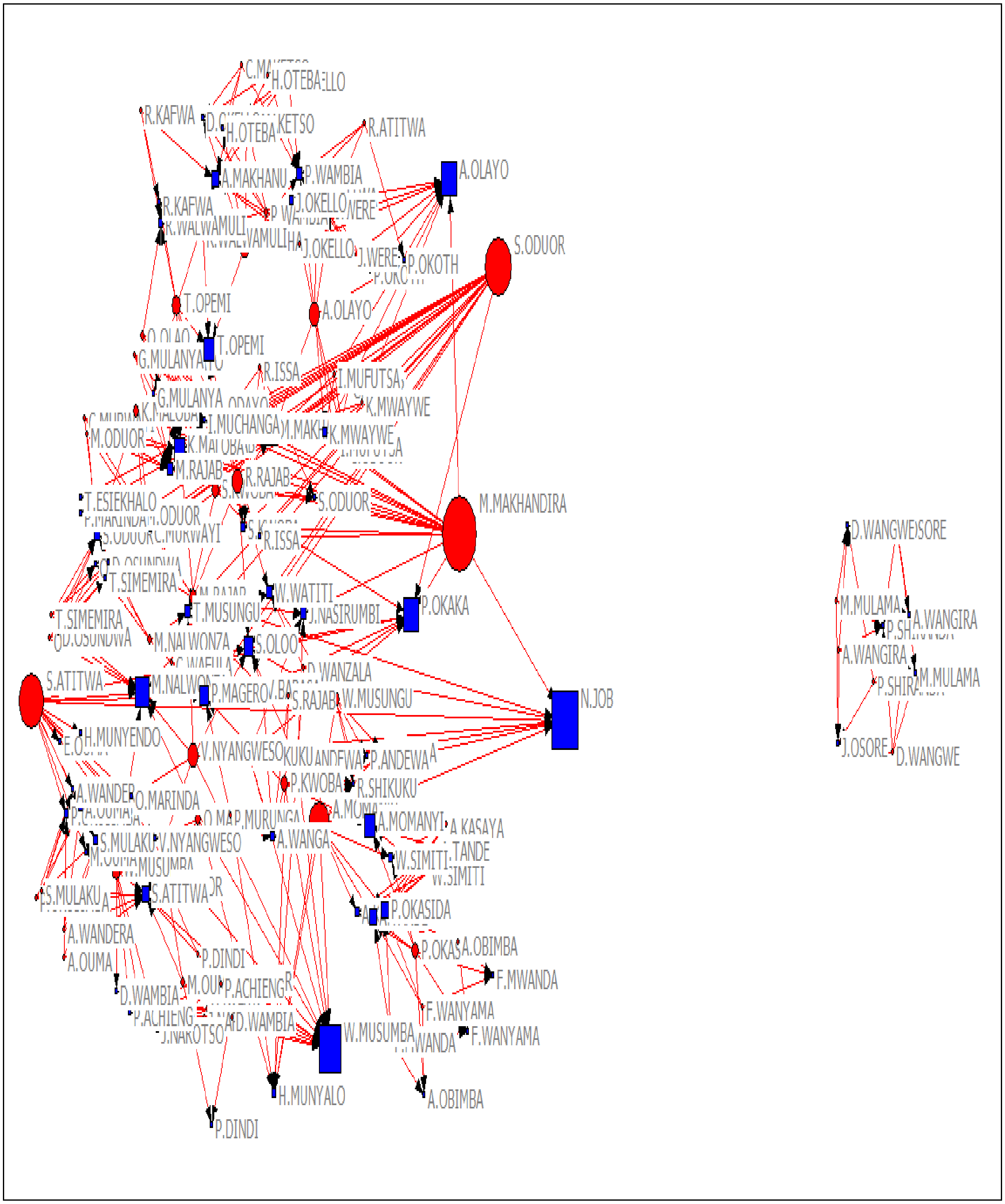


Figure 4. 11 Socio-metric map Budokomi village

Source: Field data, 2016

4.3.5. Sharing of information within networks

The research investigated the flow of agricultural information in Nambale Sub-county. Promoting the adoption of agricultural innovations can be difficult and time consuming. Adoption of innovations would be successful if individuals or organizations who are well connected are involved in dissemination of information or the innovations themselves. This would involve identifying individuals with high eigenvector centrality. Individuals with high eigenvector score have greater influence within the network.

It was established certain farmers had an intermediary role with regard to exchange of agricultural information and of agricultural innovations. These farmers have high betweenness centrality and are useful in dissemination of agricultural within and outside the villages. Given their positional advantage within the network, they can influence their colleagues to consider adopting agricultural innovations. The finding, resonates with (Burt, (2009) opinion that the third person is important to act as a bridge in networks where structural holes exist. This intermediary actors (high betweenness) fills the created gap. (Lin, (1999) further explains individuals proximal to these connectors have an advantage in that they can easily and quickly receive information that can influence their decisions and improve their social capital.

The information flow and the improved social capital is attributable to key farmers developing trusting relationships with other farmers. This is significant because, the success or failure of innovation acceptance depends on the ability to identify influential farmers who can help in its dissemination.

Another important finding is that information sharing and introduction of innovations occur in group setting which does not catalyze adoption. The groups were seen as the easiest entry points by the extension workers and researchers given their limited numbers. Most of the groups are self-help groups which were formed to address welfare issues of the members. Group contact methods are well suited to bringing specific information about practices, helping to move the individual through the desire for conviction and sometimes to taking action (FAO, 2016). Although a group was used for training and setting up of demonstration plots, the plots were not replicated by the group members and therefore the innovation ended at the demo plots.

Advice seeking happens more in one-on-one settings and this results in adoption. Farmers often seek advice from those closest to them. Geographic proximity plays a big role in determining who seeks advice from whom. For example, less than 4 percent of all advice relationships at the personal levels were outside the County. Most survey respondents showed a clear preference for seeking advice from colleagues within the villages.

Those who are seen as trusted sources of information are not necessarily the people that respondents trust most or seek out when they have questions. Respondents frequently mentioned NGOs as experts in provision of agricultural information. Although, the respondents recognized extension officers as experts in the provision of agricultural information, but cited them infrequently as sources of information. Most farmers seemed to lack personal connection with extension officers.

Interestingly, the farmers who were listed as source of information to other farmers seek information for the extension officers because they trust the officers and also believe that the officers are experts. But, these farmers also mentioned other extension service providers as their sources of information. It was established that they are the kind of farmers who would offer their farms for trials and field days.

In summary, the study established that farmers first turn to friends and family members who are geographically close for agricultural information and whose opinion matter most to them. Those who are considered as experts are disassociated from social networks and these hinders sharing of information within the networks. Instead, information held by non-experts weather it is useful or not it is disseminated. The quality of information being exchanged in the social networks can be enhanced by identifying the most influential farmers and connectors in the villages.

4.4. Relational and Structural factors that affect flow of agricultural information.

The study was conducted to establish structural and relational factors that influence flow of agricultural information in the social networks of farmers in Nambale Sub-county. Structural factors were described by the ties, density, reciprocity while relational factors were described by the quality of ties, defined in terms of the norms and values shared by the network actors.

4.4.1. Weak and strong ties

Social networks of Nambale Sub-county are characterized by weak and strong ties which are traits in a social structure that are important in sharing of information on sustainable agricultural innovations. The strong ties in Nambale Sub-county exist between people in the same social group an indicator of trust. This strong intra-group bond is an indicator of high frequency of interactions. Granoveter (1973) asserts that, the strength of a tie is important in studying the level of trust in the social networks.

Structurally, both weak and strong bonds are significant in information sharing. Strong ties have information and structural weaknesses. Information disseminated through the strong ties could be redundant because the members share the same location and have similar interests. Structural weaknesses of the strong ties are due to transitive closure of the network. this means that one farmer's friend is also a friend with one another. Flow of information is hard form such a closed triad to other farmers who are not part of the network.

Farmers with few weak ties will be disadvantaged of information from members who are not part of social network and will be confined to local news and information from their friends and neighbors. The farmers are insulated from receiving latest news as information is confined to a smaller network.

Farmers and individuals who do not have much in common are bonded by weak ties. These weak ties act as bridges through which information flows faster and widely within the network. the weak ties also do not spread redundant information to other network members. Consequently, farmers will have access to innovative and unique information. The weak ties are represented by the agricultural extension service providers, researchers and innovators. Granovetter M. S (1973), posits that dissemination of information within the network is faster when passed through weak ties than strong ties.

The study area also exhibits characteristics of both homogenous and heterogeneous community. The homophily is based on the fact that the farmers exhibit similar social and economic characteristics that are source of strong ties due to trust that has developed over time. Heterophily on the hand, connects the two groups. Heterophillic actors in this study are the agricultural extension service providers who disseminate information vertically through the weak ties given their occasional interaction with the farmers. The weak linkages are sources of new information to the farmer's networks.

4.4.2. Absence of Reciprocated Ties

Another significant finding of this study is that there are no reciprocated ties between the farmers and extension officers. Of the existing information sharing networks, on average 13% are reciprocated. The reciprocated networks occurred among the farmers. Analysis of the reciprocated relationship among the farmers and the extension service providers revealed a one directional information sharing. The extension service providers were the main source of information and there was no feedback from the farmers. This, may inhibit the flow of information that would stimulate adoption of information. This is attributable to lack of trust among the farmers and service providers.

4.4.3. Low Levels of Trust for extension service providers

In overall there is relatively low levels of trust within Nambale Sub-county. In terms of trust the farmers trust the area chiefs who were the most trusted at 2.64 in comparison to the government extension staff at 2.57. Low level of trust in the agricultural extension service providers negates the spirit of introducing new information and allowing farmers to freely express their opinions on the new information. Trust among the farmers and the agricultural extension service providers will allow them work together and this could be a real source of power and growth for the community. Therefore, trust becomes a critical factor in the success of these villages. This result echoes other similar studies. According to (Levin & Cross, (2004), trust and trustworthiness are essential for knowledge creation and transfer. However, (Bakker *et al* (2006) findings differs from this result. According to them, trust is necessary for information sharing but does not have a positive effect on information shared. Social exchange theory underscores the importance of trust in knowledge-sharing relationships.

The findings of this study suggest that there are limited frequent relationships through which information flow leading to low adoption of agricultural innovations. Networks with dense networks do not necessarily result into adoption of agricultural innovations. This is in contrast with (Gilsing *et al* 2008) who argued that networks made up of strong ties and trust, may be highly effective in exploiting innovation.

Networks that are cohesive at the core are effective for information sharing and trust building. These networks must also as a matter of necessity connect tor peripheral actors to access non-redundant information. In addition, the cohesiveness is required for greater success in the exploitation phase of the innovation process (Kijkuit & Ende, 2010; Zheng, 2010)

Practically, the findings suggest that the information sharing and adoption of innovations involves two simultaneous efforts: Identifying key individuals in the network to facilitate the discovery of agricultural innovations and networks that will support the adoption of these innovations.

The findings suggest that extension service providers, researchers and policy makers would do well to stretch to find appropriate network members who provide new information and ideas, even if the relationships involved seem uncomfortable.

4.5. Adoption of agricultural information through social networks.

The study was conducted to establish adoption of three selected innovations in Nambale Sub-county namely; use of Desmodium (*Desmodium uncinatum)* to smoother Striga weed

(*Striga hermonthica),* use of lime to control soil acidity and use of hermetic bags to control larger grain borer and other post-harvest pests. The study established that adoptions of agricultural innovations in the area is low. Despite the fact that farmers have had a long exposure to these innovations.

4.5.1. Adoption of Agricultural Innovations in a Friendship Network

Use of hermetic bags for post storage of maize to control larger grain borer was the most adopted innovation at 38% of the respondents. Use of Desmodium (*Desmodium uncinatum*) to control striga weed was adopted by 15% of the respondents and Liming of agricultural farms to control soil acidity was adopted by 6% of the respondents. (*Table 4.1*).

Table 4 1 Number of farmers Adopting innovations in Each Village

Village/Innovation	**Elwanikha**	**Ibanda**	**Ekisumo**	**Budokomi**	**Total**
Hermetic bags	12	19	12	13	56 (38%)
Desmodium (*Desmodium uncinatum)*	2	3	4	0	9 (6%)
Liming	6	3	4	2	15 (10%)

Table 7.1 presents agricultural innovations that were analyzed in this study.

4.5.2. Why Farmers Adopted Innovations

The farmers who had adopted the innovations were asked why the reason for adoption. 96 % of the respondents said that the main driving for is the desire to increase production (for use of Desmodium (*Desmodium uncinatum)* and liming) and to reduce post-harvest losses with use of hermetic bags. Only 3% indicated that they adopted the innovations because their friends did it.

4.5.3. Adoption of agricultural innovations in Budokomi village

Figure 4.12 shows the social map for Budokomi village and the adoption of hermetic bags for post storage of maize. In *figure 4.12*, the large green node***, S. Oloo***, represents the farmer with the highest centrality in the village. This farmer, has conversations with 14 other farmers but only one has adopted the use of hermetic bags. Further analysis of the individual characteristics of this farmer, it was established that According to the interview ***S. Oloo*** is an innovator farmer who also participates in agricultural training workshops organized by both government and private extension providers. Furthermore, since S.Oloo is an innovator, he has a higher network threshold.

The study established that not all the connections in a social network would result adoption of innovations. For instance, *Figure 4.12* shows farmers who have adopted hermetic bags (*Green color*) in Budokomi village. Although the farmers are sharing information with other farmers, few of their colleagues are adopting the use of hermetic bags for post-harvest storage. *Figure 4.2.* shows individuals who have adopted use of hermetic bags do not have good network connections within the village.

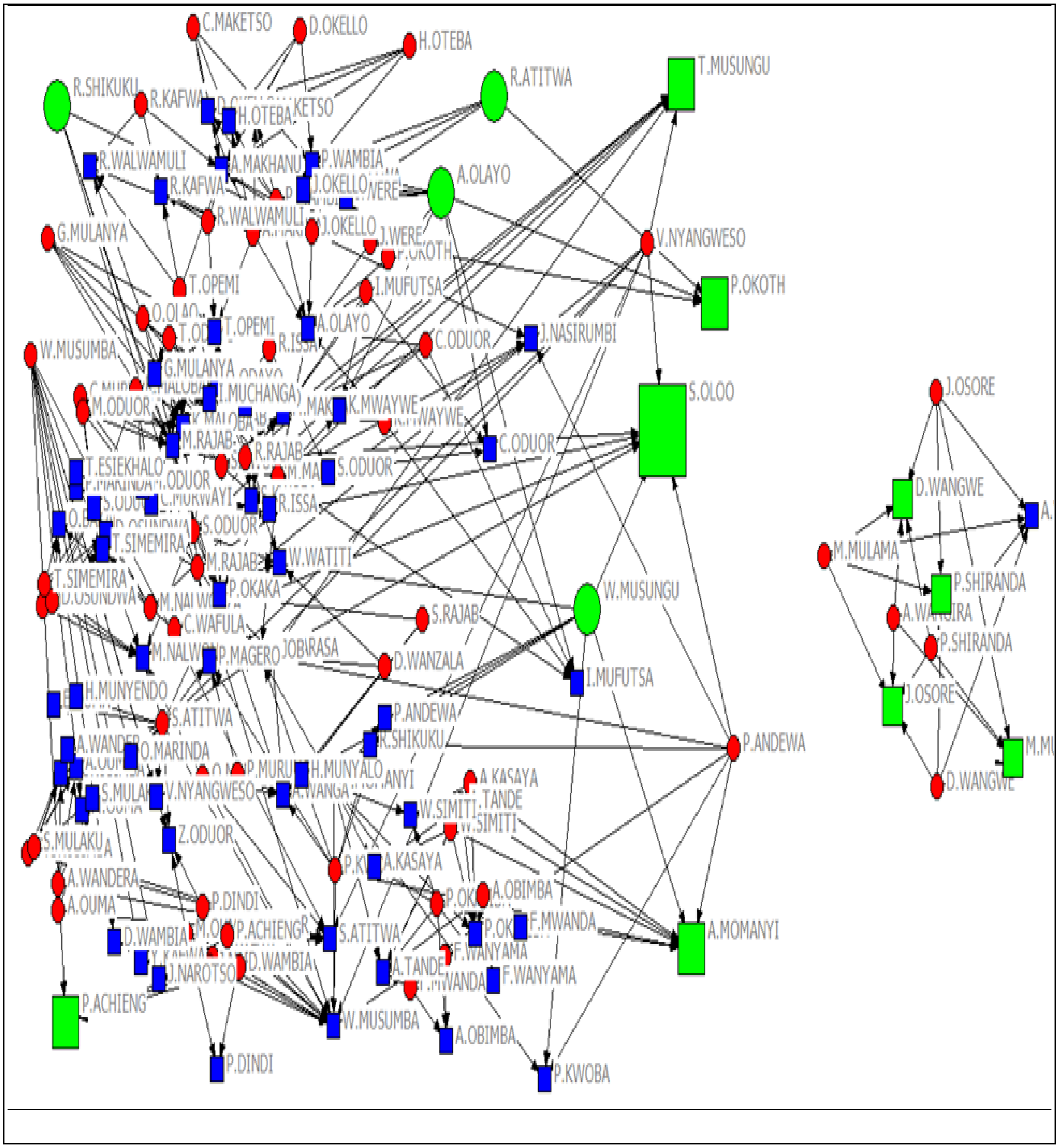


Figure 4. 12 Adoption hermetic bags Budokomi Village

Source: Field data, 2016

Despite the farmer being a source of information to 7 other farmers only one has adopted the use of hermetic bags.

Adoption of liming show that only two farmers are using lime to control soil acidity *Figure 4.13* Further interviews revealed that cost and bulky nature of the lime is a contributing factor.

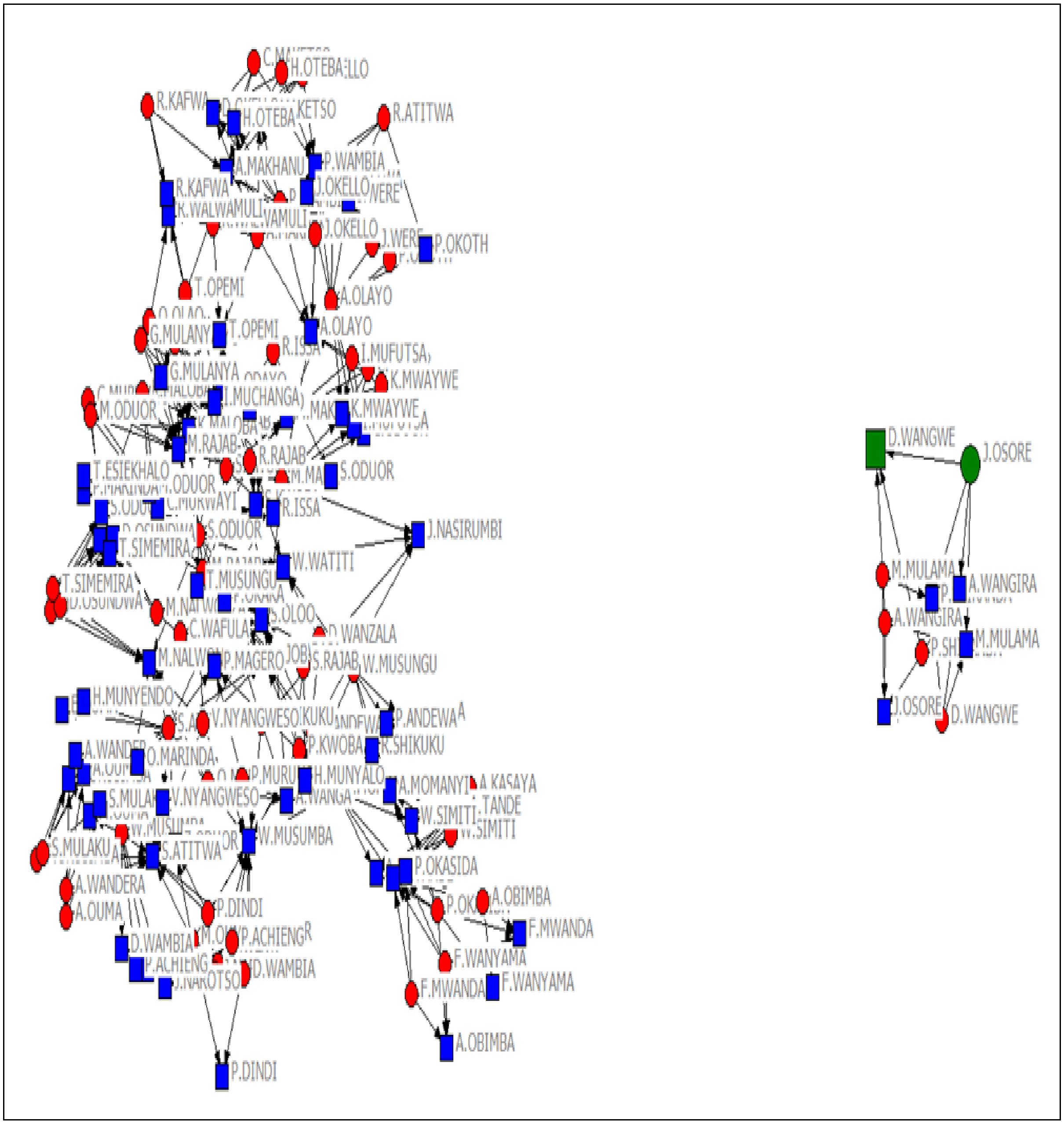


Figure 4. 13 Adoption of Liming

Source: Field data,2016

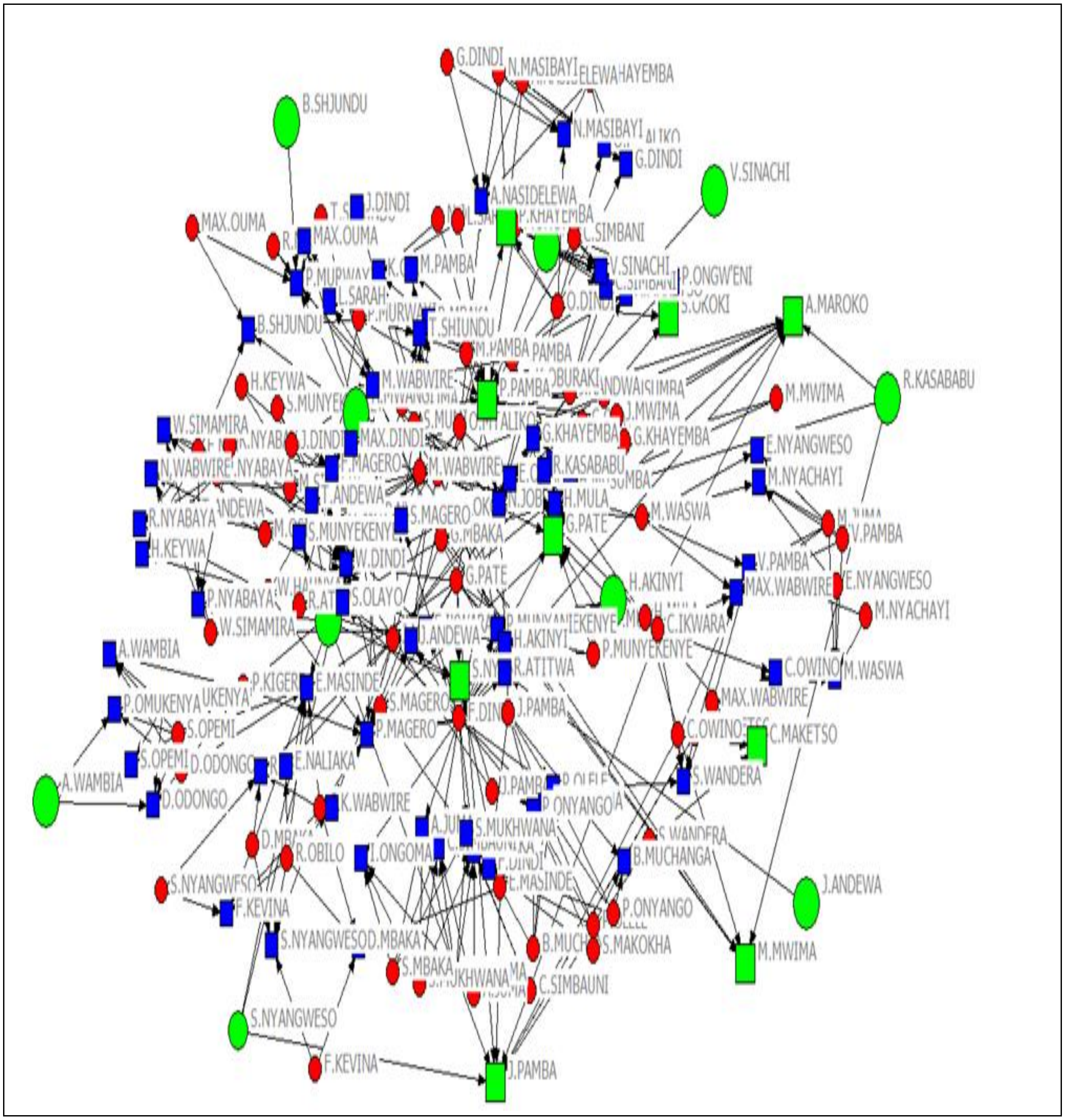


Figure 4. 14 Adoption of hermetic bags in Ibanda village

Source: Field data, 2016

Figure 4.14 illustrates the adoption of hermetic bags in Ibanda village (green nodes). Only a few farmers are adopting the technology despite a dense network showing sharing of agricultural information.

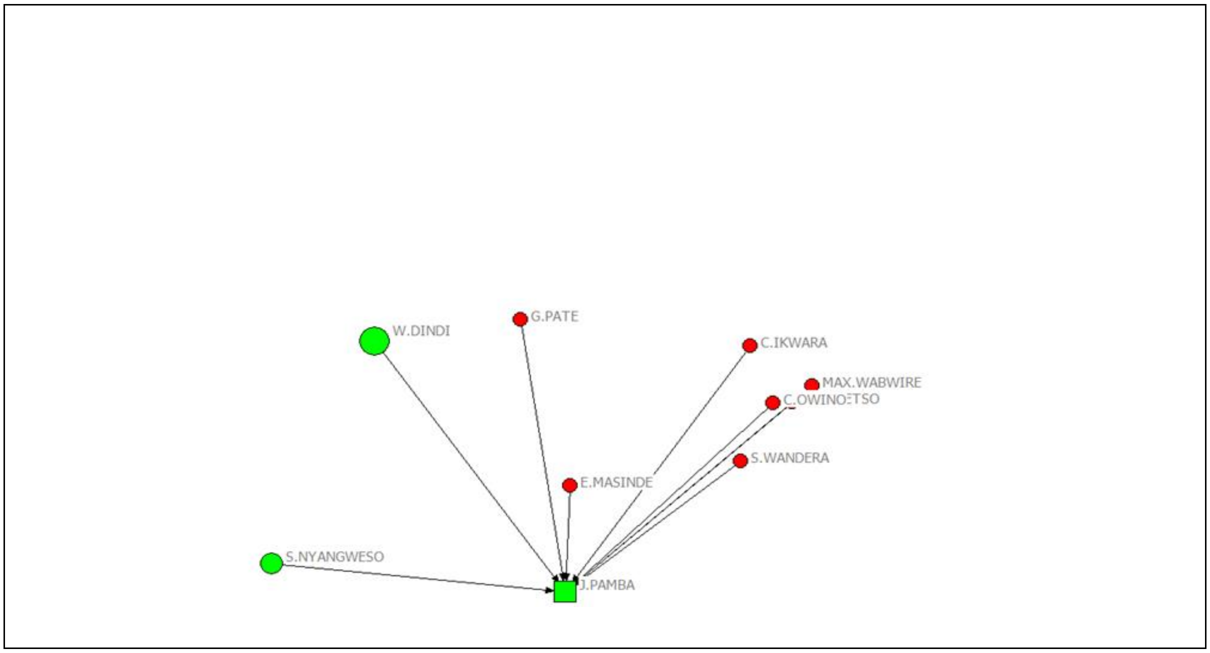


Figure 4. 15 Betweenness centrality in Social networks

Figures 4.15 illustrates the significance of betweenness centrality in adoption of innovations in Ibanda village. The Farmer **P. Pamba** is linked to eight other farmers who share and exchange agricultural information. This farmer (***P. Pamba***), identified by the by the square green node has the high betweenness centrality in this social map. Despite the fact that this farmer interactes with sixteen other farmers, only two have adopted.

4.5.4. Low adoption of Desmodium (*Desmodium uncinatum)* in Ibanda village

Figure 4.16 shows low adoption of Desmodium (*Desmodium uncinatum)* in Ibanda village Even though farmers agreed to having information about use of Desmodium (*Desmodium uncinatum)* to control Striga weed (*Striga hermonthica)*, further analysis revealed factors that have discouraged farmers from adopting. Lack of seeds was mentioned as one factor. Desmodium (*Desmodium uncinatum)* seeds were not easily available. Farmers perceived the innovation as too ‘scientific’, and a ‘demonstration’ which is managed and owned by outsiders. Farmers also viewed the innovation as incompatible with maize-legume intercropping system.

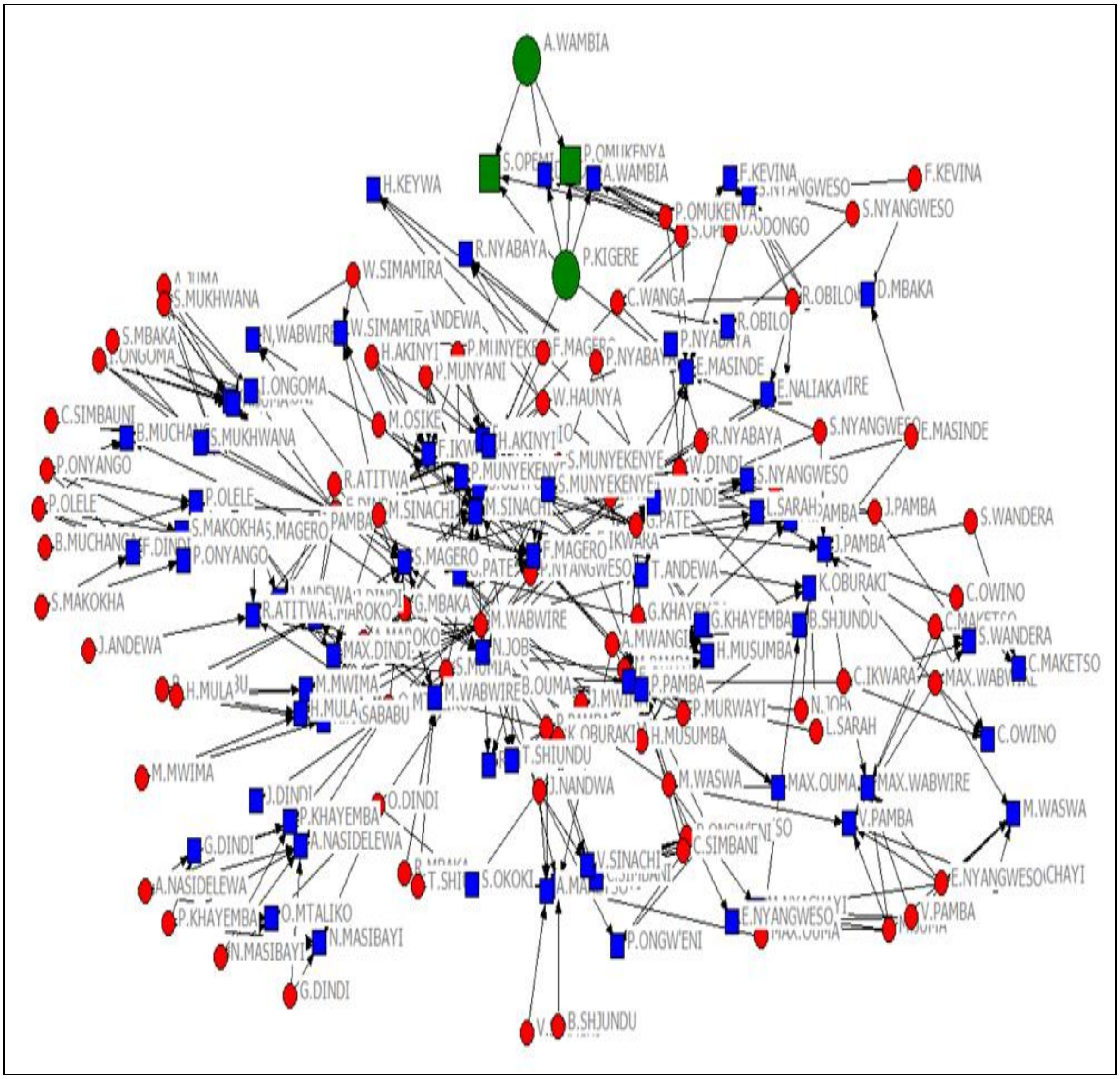


Figure 4. 16 Adoption of Striga weed (*Striga hermonthica)* in Ibanda

Source: Field data, 2016

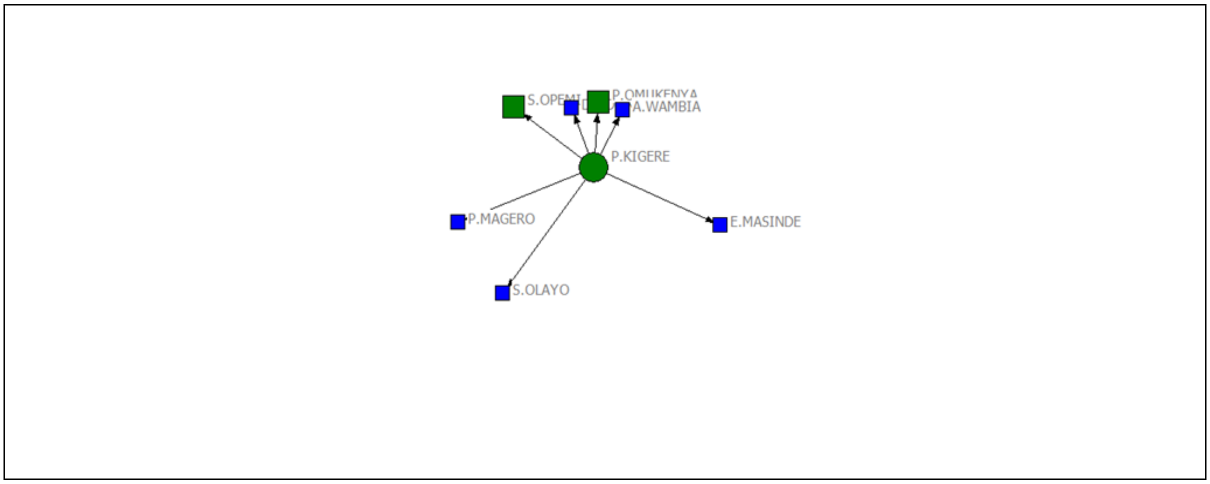


Figure 4. 17 Adoption of Desmodium (*Desmodium uncinatum)* in Ibanda village

Source: Field data, 2016

Figure 4.17 The central farmer receives information from 7 farmers. Out of the 7 farmers two have adopted Striga weed (*Striga hermonthica)* control innovations.

4.5.5. Adoption of liming

Farmers have not adopted use of lime (*Figure 4.18*) due to; cost and transportation difficulties preclude lime from being accessible to smallholder farmers. For lime to be effective at mitigating soil acidity, large quantities of it are required, and it is practically impossible to smallholder farmers to access one or more metric tons of lime.

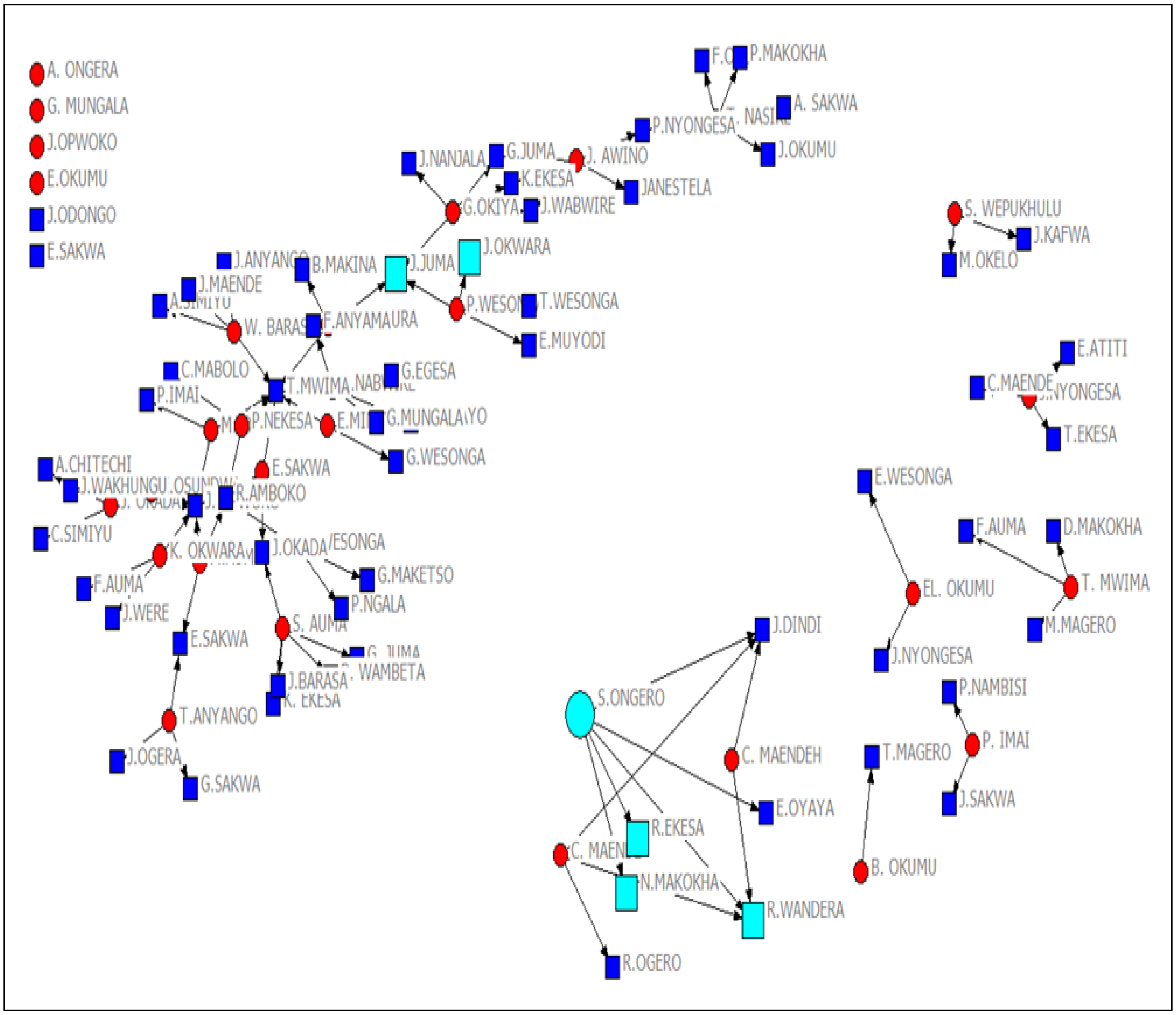


Figure 4. 18 Adoption of Liming Elwanikha Village

Source: Field data, 2016

4.5.6. Low adoption of agricultural innovations

The results suggest that the extension service providers are not keen on making use of the social networks that exist in the villages to stimulate adoption of innovations. This confirms the deficiencies that exist in the current extension approaches that is linear and top-down in operation. Extension staff both at the County and National government operate in a rigid top-down manner. The sharing of information has led to marginalization of large group of farmers.

The results also indicate that communication about the agricultural innovations only involves local leaders and few elites in the community. Extension staff who were interviewed revealed that because of their limited number and constrained transportation means they frequently use chiefs as entry points in the villages and as contact agents for dissemination of agricultural information. But, using the chiefs and other local leaders do not reach the marginalized and vulnerable farmers who are not part of their social networks. The results confirm that the top-down model of information sharing used by the extension service providers could be the reason for low adoption of agricultural innovations.

The study finds that, adoption of agricultural is more than just being aware the innovation exists. It involves information an individual has on benefits and costs associated with the innovation. Being exposed to an innovation does not necessarily result into adoption because social networks have different influence. Farmers who receive information from a social network with great influence would lead to change of behavior and adoption of innovations

The study also established that adoption hermetic bags occurred among the peers. The results tie well with previous studies by that have documented the effects of peers on adoption. A study carried out in China on adoption of agricultural insurance (Cai, 2015) established that respondents who had a substantial number of friends who were trained on agricultural insurance adopted the scheme easily. In another study, (Oster & Thornton, 2012), studied the influence of peers-friends and acquaintances on the adoption of menstrual cups among school going girls in Nepal. The study established that, the girls who had many of their friends who were using menstrual cups were likely to adopt the use of menstrual cups too. The study recommends that individuals within the network should be identified as contact persons for introduction of innovations to avoid marginalization of farmers who are isolated from the social network.

4.5. Leveraging on social networks to improve agricultural extension.

The results of this study points to considerable flow of agricultural information which can stimulate adoption of agricultural innovations. This is because farmers learnt about agricultural innovations in an informal extension setting. By leveraging on the power of social ties, the interventions provide a low cost alternative to the traditional extension services. The results of this study are important as they can inform policy direction especially in Western Kenya where adoption of agricultural innovations is still low and agricultural productivity is also low.

The results demonstrate the importance of social networks in communicating information about agricultural innovations. The advantage of social networks is that it identifies farmers whom other farmers approach for agricultural information within the network. This is done by identifying the most influential member within the network. The influential farmers would form the first line of entry into the villages for introduction of agricultural innovations. The study proposes steps that can be taken to hasten information sharing and the adoption of agricultural innovations and reduce information deficiencies frequently observed among agricultural service providers.

4.6.1. Formal networks

Farmers were asked to name formal sources of agricultural information. 53% of the respondents named government extension as sources of information. 39 % named private extension services as their main source of agricultural information. 8 % named agro-chemicals as their main source of information. For the farmers who named government extension as sources of information, only 11 % reported that the extension staff had visited them twice in 6 months. The area chiefs are key ‘‘information brokers’’ between extension workers and the farmers. They provide farmers with information from official sources. when an agricultural event/activity is organized, the extension staff informs the chiefs who would mobilize farmers to attend. It is assumed that, the farmers who have attended would share the information with their neighbors and friends.

4.6.2. Integrating Social Networks in Agricultural Extension system

Identification of farmers who are influential can help in acceleration flow of agricultural information and adoption of innovations. These farmers will link the farmers to other sources of information such as researchers and extension staff. They will also act as a link to farmers who are isolated from the network. the social maps generated from the social networks can be useful in identifying the location of influential farmers and their role in the social network.

The identified influential farmers should be facilitated to participate in agricultural activities that are outside their area. By doing this they will get new information which they will come and share with other farmers within their networks.

Foster interpersonal communication among the farmers. Information sharing takes place in interpersonal networks. Encourage farmers who adopting innovations early to freely share their experience with others. These farmers can be invited in farmers barazas to share their experiences. Making use of farmers who are directly using the innovation to share in formation, respond to questions and proposing better ways of application would be effective compared to experts who are not part of the social network. Finally, farmers who from the social map appear to be on the periphery or otherwise marginalized should be targeted as individuals.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter covers summary of the study findings, conclusions drawn from the findings, recommendations for each of the four research objectives based on the study findings and suggestions for further research.

The study established that information sharing and introduction of innovations occur in group setting which does not catalyze adoption. The groups were seen as the easiest entry points by the extension workers and researchers given their limited numbers. Most of the groups are self-help groups which were formed to address welfare issues of the members.

Social networks of Nambale Sub-county are characterized by weak and strong ties which are traits in a social structure that are important in sharing of information on sustainable agricultural innovations. The strong ties in Nambale Sub-county exist between people in the same social group an indicator of trust. This strong intra-group bond is an indicator of high frequency of interactions. Granoveter (1973) asserts that, the strength of a tie is important in studying the level of trust in the social networks.

Also, the study finds that there are no reciprocated ties between the farmers and extension officers. Of the existing information sharing networks, on average 13% are reciprocated. The reciprocated networks occurred among the farmers. Analysis of the reciprocated relationship among the farmers and the extension service providers revealed a one directional information sharing. The extension service providers were the main source of information and there was no feedback from the farmers.

Adoption of agricultural innovations is low in the villages studied. This confirms the deficiencies that exist in the current extension approaches that is linear and top-down in operation. Communication about the agricultural innovations only involves local leaders and few elites in the community who do not champion the concerns of the marginalized and isolated farmers

The complexity of agricultural problems cannot be solved by the linear model of information transfer currently used by the agricultural extension workers. Farmers who were interviewed, advocated for a more participatory method in generation and dissemination of agricultural innovations. By leveraging on the power of social ties, the interventions provide a low cost alternative to the traditional extension services.

Extension service providers were listed as key information sources (formal) at 53%. However, the area chiefs are key bridges that connect extension worker and the farmers. They provide farmers with information from official sources. For instance, when an agricultural event/activity is organized, the extension staff informs the chiefs who would mobilize farmers to attend.

5.1. Conclusions

5.1.1. Flow of agricultural information among the farmers through social networks

Flow of agricultural information through social networks occurs a mixture of both strong and weak ties. Weak ties are illustrated by sub-groups that are loosely connected to each other. Farmers who act as connectors to other farmers or sub-groups are important as they act as a link in disseminating agricultural information. However, these farmers can also destabilize the network by hoarding information from other farmers. In identifying farmers to disseminate information, extension workers must not rely too much on such farmers.

SNA as a methodology if effective in mapping, measuring and analyzing information flow in networks and can be used to investigate how farmer share and exchange information. For effective information communication, the individuals who control sharing of information and those who are information brokers should be identified.

5.1.2. Relational and structural factors that influence flow of agricultural information within the social networks.

Social networks of Nambale Sub-county are characterized by both weak and strong bonds which structurally are good traits that are significant in sharing of information on sustainable agricultural innovations. Extension workers, researcher and policy makers can take advantage of these networks to disseminate agricultural innovations. Lack of reciprocated networks between extension workers and farmers is an indicator of one directional relationship.

5.1.3. Formal and informal communication and their influence on adoption of agricultural innovations.

Agricultural extension workers are not keen on taking advantage of the existing in the villages to facilitate adoption of innovations. This confirms the deficiencies that exist in the current extension approaches that is linear and top-down in operation. Extension staff both at the County and National government operate in a rigid top-down manner. The sharing of information has led to marginalization of large group of farmers.

5.1.4. Establish how Extension Service Providers can make Use of Social Networks to Increase the Adoption of Agricultural Innovations

The complexity of agricultural problems cannot be solved by the linear model of information transfer commonly used by the extension agents. This calls for alternative method which will focus on information sharing among the farmers' social networks rather than linear transfer. By leveraging on the power of social ties, the interventions provide a low cost alternative to the traditional extension services.

5.2. Recommendations

Value of information networks among farmers should not be underestimated. The study concludes that interpersonal relationships are important in generation and dissemination of agricultural information and social networks significantly contributes to this process. It is thus important for extension workers, researchers and policy makers to encourage the use of social networks in dissemination of information and innovations. Analyzing the power of social networks and how they can facilitate information sharing can provide cheaper alternatives to agricultural extension. This can be effective in exchange of agricultural information and catalyze adoption of sustainable agricultural innovations. The results of the study are significant to policy makers in Kenya where agricultural productivity is still low. The results of this study will also, contribute to the academic body of knowledge in relation to social network analysis.

5.3. Further research

Dissemination of agricultural information and adoption of innovations can be affected by many factors. Further research should be conducted to inform policy makers in designing agricultural extension approaches that can leverage on the power of social networks. Also research should be conducted to determine how demographic attributes such as age, gender, literacy level and land tenure affect exchange of information among farmers, researchers and extension service providers.

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Appendix A-Letter of Informed Consent

Participant Informed Consent

1. Research title- Application of Social Network Analysis on information flow for the adoption of agricultural innovations
2. I have been explained to and accepted to participate in the above research voluntarily without conditions
3. I have also agreed that my names can be used in the research document and further inquiries about the information provided can be clarified from me. I understand the results of this study will be used for thesis publication and by researchers who may want to introduce innovations to the community through me.
4. The copy of this consent is signed in duplicate so that each party remains with a copy

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

Respondent ………………………………. Date………………………………………….

Researcher or representative………………. Date………………………………………….

APPENDIX B: OBSERVATION CHECKLIST

Look out for the following parameters in the transect walk in the field.

1) Check the farmers who have adopted the following innovations;

    a. Use of lime to control soil acidity

    b. Use of hermetic bags

    c. Use of Desmodium (*Desmodium uncinatum)*

If the answer is yes interview the farmer to establish;

a. the source of information,
b. how long he has been using the innovation
c. who does he share information with?

APPENDIX C: Questionnaire Administration Protocol

Read the following statement to farmers before you start collection of data.

You have agreed to voluntarily accepted to participate in this study which seeks to establish how farmers share and exchange information in this village. To collect data, we are going to ask questions which you are expected to give honest answers. The interview session will take between 30 to 40 minutes.

APPENDIX D: Questionnaire (adopted from (Othieno, 2014)

Questionnaire no. ....

Section A: Bio-data Data

Q.1 The name of the household head (At least 2 names)..

Name of the village..

GPS coordinates..

Q.2 The age of the household head?

Q.3 what is the marital status of the respondent?

a) Married { }

b) Divorced { }

c) Widowed { }

d) Single { }

Q. 4 what is the education level of the house hold head

a) Primary { }

b) Secondary { }

c) Tertiary { }

d) None...... { }

Q.5. what is the education level of the house hold head's spouse (*if married*)

a) Primary { }

b) Secondary { }

c) Tertiary { }

d) None...... { }

Q.6. what is the occupation of the house hold head's spouse (*if married*)

What is the household size?

Q.7.what is the religious denomination of the household head?

a) Catholic { }

b) Protestant { }

c) Muslim { }

d) Non believer { }

e) Others.................................

Q.8 a) what is the approximate size of your farm in acres?

b) Do you own the farm? (Yes or No)

c) How long have you owned the farm? ________________years.

d) How did you acquire the farm? (1. Inherited from parents 2. Bought 3. Leased 4. Other, specify

Q.9 Do you belong to any local membership group?

a) Yes { } go to Q.9

b) No { } go to Q. 10

Q. 10 on what basis are these groups formed?

a) Religious

b) Family

c) Friendship

d) Others.................................

Q 11. A Do you know anyone from whom you can learn about new crops and farming techniques? List at most five of them. (Write at least 2 names - family & other)

Name	**Q 11.B.**Where does this person reside 1. Neighbor 2. In my village 3.Outside my village (name the village)	**Q11.C**How are you related/ relate to this person? 1. Neighbor 2.Relative 3.Friend 4.Worshop together 5.Same social group 6.In same age Group7. other (specify)
1.		
2.		
3.		
4.		
5.		

Q.12.A. After getting this Information ***(from Q.11A)*** whom do you share it with? List at most four of them. (Write at least 2 names - family & other)

Name	**Q 12.B.**Where does this person reside 2. Neighbor 2. In my village 3.Outside my village (name the village)	**Q12.C** How are you related/ relate to this person? 1. Neighbor 2.Relative 3.Friend 4.Worshop together 5.Same social group 6.In same age Group7. other (specify)
1.		
2.		
3.		
4.		
5.		

Q13. What is the size of the land owned by this person? (1. Bigger than mine 2. Same as mine 3. Smaller than mine)	**Q14.** Approximately how far does this person live from you (in meters)	**Q15.** When did this person adopt the innovation (1: Not yet 2: Before me 3: At the same time as me 4: After me	**Q17.** Do you exchange more than agricultural information with this person (open question; potential answers: borrowing/lending, seasonal labor, seeds, etc.)
1.			
1.			
2.			
3.			
4.			

Q18A: In your opinion, who does person 1 discuss important agricultural matters with?
2. (1: Yes, 2: No)
3. (1: Yes, 2: No)
4 (1: Yes, 2: No)
5 (1: Yes, 2: No)
Q18B: In your opinion, who else among the listed does person 2 discuss important agricultural matters with?
1 (1: Yes, 2: No)
3 (1: Yes, 2: No)
4 (1: Yes, 2: No)
5 (1: Yes, 2: No)
Q18C: In your opinion, who else among the listed does person 3 discuss important agricultural matters with?
1 (1: Yes, 2: No)
2 (1: Yes, 2: No)
4 (1: Yes, 2: No)
5 (1: Yes, 2: No)
Q18D: In your opinion, who else among the listed does person 4 discuss important agricultural matters with?
1 (1: Yes, 2: No)
2 (1: Yes, 2: No)
3 (1: Yes, 2: No)
5 (1: Yes, 2: No)
Q18E: In your opinion, who else among the listed does person 5 discuss important agricultural matters with?
1 (1: Yes, 2: No)
2 (1: Yes, 2: No)
3 (1: Yes, 2: No)
4 (1: Yes, 2: No)

Q19. Which of these innovations and techniques have you learned from these friends? and have you adopted the technique if yes mark (√) or (x) if not Adopted	**Q20.** Why did you adopt this Technique (s)/innovations you have mentioned? 1.To increase production 2.Because my friend did 3. Others (specify).............................
1. Use of desmodium to control Striga/ use of Striga tolerant maize varieties	
2. Use of lime	
3. Use of hermetic bags	
4. Pit planting	
5. Use of compost	

Formal networks

Q. 21 Name the formal sources of information on these innovations or techniques 1. Govt. Extension agents, 2.Private extension agent (NGOs) 3. Agro-Chemical Companies 4. Para-professionals 5. Community Based Organizations 6.Others....................................(specify)	**Q.22**How frequently do you communicate with these source(s) in a single growing season? 1. Ones 2. Twice 3. Three times 4. More than three times	**Q 23**Which of these source(s) of information do you prefer	**Q24** How satisfied were you with the information provided by these sources? 1. Very satisfied 2. Somewhat satisfied 3. Not satisfied 4. Totally unsatisfied
1.			
2.			
3.			
4.			
5.			

Q11 list types of crops and livestock found on your farm (*Use the table below to answer the question)*

Crops/livestock	Proportion of Land Occupied	No. of Years Grown/ kept