SOCIAL NETWORK ANALYSIS OF CLIMATE CHANGE ADAPTATION COMMUNICATION IN MAKUENICOUNTY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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DEDICATIONS

This thesis is dedicated to my entire family headed by Simon, Elizabeth and Marciana, my son Hope daughter Pendo and wife Irene and to God who granted me the spiritual and physical strength during this study.

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Acronyms

ASAL	Arid and Semi-Arid Lands
BCC	Behaviour Change Communication
CBOs	Community Based Organizations
CSTI	Centre for Science and Technology Innovation
DoI	Diffusion of Innovations
GDP	Gross Domestic Product
GoK	Government of Kenya
ICRAF	World Agroforestry Center
ICTs	Information and Communication Technologies
IECs	Information Education and Communication materials
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IPM	Integrated Pest Management
IRDP	Integrated Rural Development Project
KARI	Kenya Agricultural Research Institute
MoA	Ministry of Agriculture
NCCRS	Kenya National Climate Change Response Strategy
NGOs	Non-governmental Organizations
PPP	People's Participation Programme
SCAO	Sub County Agricultural Officer
SN	Social Networks
SNA	Social Network Analysis

Abstract

Climate change is already negatively affecting communities who depend on rain fed agriculture for their livelihoods. Adaptation through the adoption of appropriate agricultural technologies is crucial for the survival of the affected communities. The awareness among farmers of the existence of the phenomenon is perhaps the first step in the adaptation process. Awareness occurs through information sharing both horizontally and vertically channels.

The growing of drought resistant, drought avoiding (early maturing) crop varieties, and irrigation are among innovations adopted by crop farmers adapting to climate change. The adoption of these techniques occurs within a social setting and is initiated by awareness of the existence of the technique through the process of information exchange. These actors in the information exchange process play different roles which determine the flow of such information and resultant communication patterns. An understanding of how this information flows through a social system is crucial in the development of agricultural communication approaches.

There is limited literature on the study of information flow in agricultural field using a methodology that integrates communication, statistics and graph theory. Social Network Analysis (SNA) enhances the understanding of how information flows through social system in the context of climate change adaptation.

SNA is a relatively new methodology that has gained currency due to its ability to combine graph theory, statistics and computer programmes to produce visual socio-grams and indices that assign values to relationships in a network. This study used social network analysis (SNA) using NodeXL

version 1.0.1.245 computer programme to generate socio-grams that showed the patterns of information flow. Correlation and regression analyses were used to show if there were any significant relationship among the study variables.

Sakai sub-location in Makueni County, Kenya is an area that is already experiencing climate change. The Kenyan government in collaboration with Centre for Science and Technology Innovation (CSTI) agency has stepped in to assist the farmers to adapt to climate change through introduction of appropriate agricultural techniques. The aim was to support the farmers in Sakai sub-location to adapt to climate change phenomenon.

A social network analysis was carried out among farmers in five villages in Sakai sub-location in Makueni County in Kenya. The villages were namely:-Nthongoni, Kiteani, Kathamba, Linga and Muiu to assess the effects of social network structures on climate change adaptation communication. Questionnaires were administered to 165 farmers and this yielded 485 nodes and 747 edges.

The socio-grams showed dense clustering of actors at the centre that are well but weakly connected to the peripheral actors who most likely acted as links to neighbouring villages. Low eigenvector centrality of 0.002 implies a lower number of opinion leaders who influence information flow but the high average in-degree and out-degree of 1.5 shows a structure which supports flow of information with every farmer at least being a source of information for two farmers and as well as being a receiver from another two farmers. The existence of both weak and strong ties as shown by the wide variation in the clustering co-efficient (maximum 0.5 and average of 0.025) and visual observation of the socio-grams show structural features which supports information flow.

The results of the study show that homophily in this social network enhanced horizontal flow of climate change adaptation information within groups and showed that the structure of a social network affects how information on climate change flows through the social system.

A correlation analysis shows that there is a statistically significant relation at 0.05 co-efficient between age (0.238), education level (0.624), size of the farm (0.509) and group membership (0.173) access to information on climate change. A probit regression analysis showed that even though some variables such as household marital status and land size positively affect information flow on climate change there is no variable statistically which influences information flow on climate change and adaptation strategies.

This study shows that SNA can be used to study agricultural communications. The socio-grams can be used to identify opinion leaders and map out information flow and therefore inform the best agricultural extension approach to be used in creating awareness on climate change adaptation.

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CHAPTER ONE

1.0 Introduction

Agricultural production remains the main source of livelihoods for rural communities in Africa, providing employment to more than 60% of the population and contributing about 30% of the GDP (Nhemachena & Hassan 2007 and Quiggin *et al*. 2010). Globalization, changing consumption patterns, climate change and emerging diseases are shaping the development in agricultural production (ILRI, 2008). Although man has been adapting to other changes in his environment; for example economic development and globalization, climate change presents the greatest challenge to human endeavors, key among them being agricultural production (Smit & Pilifosova, 2001 and, Global Humanitarian Forum, 2009).

Climate change refers to any change in climate over time, whether due to natural variability or anthropogenic forces resulting in significant shift in the average weather condition especially average temperature and precipitation of an area (IPCC, 1998; 2007).Studies shows that the globe has over the years experienced increase in temperatures and reduction in precipitation and agriculture in Africa will be negatively affected by climate change (Fancherean *et al*., 2003, Deressa *et al*., 2008). However; this strong scientific consensus on causes and risks of climate change is in contrast to widespread confusion among the lay public (Leiserowitz, 2007). In Kenya, the level of understanding climate change and its impacts is low among the lay public (NCCRS, GoK 2010). This therefore calls for awareness creation on climate change phenomenon especially among the farming communities.

Climate change directly affects agricultural production in developing countries due to the sector's sensitivity to the risks and Africa's socio-economic, demographic and policy trends that limit their capacity to adapt to climate change (Fankhauser, 1995, Parry *et al*. 1999; and Morton, 2007). In the developing countries climate change is a silent enemy that will affect high risk and stressed agro-ecosystems as its effects are not immediately visible (Kgakatsi, 2006). Kenya is among countries that will bear the brunt of climate change since rain-fed agriculture is the largest contributor to the GDP (GoK, 2010).

Adaptation is an important approach in coping with the climate change for smallholder farmers to increase their production through adoption of appropriate techniques. Adoption begins with sharing information with potential users through interpersonal communication channels (Gailhard, 2012). Communication of the agricultural adaptive measures between the scientists, extension agents and farmers play a crucial role in the process of adaptation. Smallholder farmers have been adapting to changing climate since time immemorial using information shared within their local social networks (McDowell, 2012). Strengthening of such adaptive capacities is essential for future sustainable and equitable development particularly for livelihoods sensitive to climate change and which must adapt to the changes for them to survive (Osbahr, 2010).

Information is power; and access to relevant information on climate change offers a firm foundation for adaptation to climate change and its effects. The discussion on the usefulness and applicability of such information occurs within a social context whose understanding can inform future participatory agricultural extension approaches targeting food production and natural resources management. Individuals when faced with climatic risks; prioritize between elements of production, consumption and ecological systems (Osbahr *et al*., 2010). Such decisions are arrived at through formal and informal interactive processes among the farmers and other actors. Study by Ostrom *et al*. (2007) showed that the process of adaptation depends on natural, social, human and financial capital; and that scarcity in the above factors limits actions. Ostrom *et al* (2007) recommended the need for an in-depth study of these factors.

New mechanisms to foster the development and diffusion of innovations are needed to strengthen ways in which information; knowledge and technologies development and dissemination are done in light of emerging phenomenon like climate change (ILRI, 2008). Maponya & Mpandeli (2012) in a study on impacts and adaptation options in South Africa found out that farmers need adequate information about the importance of climate change in order for them to adapt.

Everret Roger's (1983) theory of diffusion of innovation has been applied in the study and application of diffusion of innovations in agriculture. This theory has been criticized as being top-down, linear and foreign to the African continent (Chambers *et al.* 1989, White 2008, Ansu-Kyeremeh 2005and Tarawalie 2008). Ansu-Kyeremeh (2005) and Tarawalie (2008) developed centripetal and blending theories of communication respectively which they proposed to be appropriate for the African continent; both theories are bottom up and acknowledge the importance of participatory approaches, indigenous knowledge and cultural practices.

The communication process can be studied at the farmers' (horizontal) level using research methodologies that define the role of different actors in climate adaptation in farming communities. An understanding of these characteristics can inform agricultural extension approaches to be applied in assisting farmers adapt to climate change. Social networks have been shown to affect the adaptive capacity of local communities (Crona & Bodin, 2006). "Lousie (2011) acknowledges the complexity of innovation as a social process, involving relationships between a range of actors, institutions and technological and organizational opportunities. It is the interactions between these elements which can help us to understand how diverse actors generate, exchange and use knowledge (information)”.

The pattern of flow of information through social networks and the factors that facilitate or impede the flow and utilization of such information are among areas that need to be studied in technology adoption in adaptation to climate change context (Matuschke, 2008 and Demiryurek, 2010). Social networks structure are among the factors determining the flow of information within communities and are important in the successful implementation of community based initiatives (Foster and Rosenzweigh, 1995, Conley & Udry 2003, Tompkins & Adger, 2004, Crona & Bodin, 2006). The influence of social structures on innovation processes was recognized in the work of Everett Rogers on the “Diffusion of Innovations” (1983) which brought to light the importance of communication networks in innovation processes. Rogers (1983) was informed by earlier works of Katz (1961) who, through studies on diffusion of innovation noted that gaining knowledge on social structures is critical to understanding diffusion process just like knowledge of the structure of blood veins and arteries is to the study of circulatory system.

Community social networks have been shown to build resilience based on the composition and demographic traits of their members and thus adaptation to unexpected environmental changes (Tompkins & Adger, 2004). Networks are complex and form spontaneously or organically among communities and sub groups within communities to bridge information gaps and reduce uncertainties about the application or local appropriateness of an innovation their ability to form spontaneously lends them the social capital that can be exploited in agricultural extension (Goyal, 2005). These relationships result in social interactions from which innovations emerge and are shared and adopted by farmers. The networks’ ability to initiate adaptive behaviour largely depends on the structures and dynamics of networks which either facilitates or hinder the ability to access information and innovate (Newman & Dale, 2005). The role of social networks and their impact on the current demand driven extension approaches that aim at accelerating adoption of innovative techniques by smallholder farmers in developing countries needs to be understood (IFPRI, 2008). In agricultural extension similar links exist among researchers, extension agents and farmers and promote the adoption of new technologies Bandiera & Rasul (2006). Farmers in social networks learn how to cultivate new crops from the choices of other farmers cultivating the same crop (Foster & Rosenzweigh, 1995, Conley & Udry 2003).

Social Network Analysis (SNA) is the study of relationships among agents, groups and entities that provide channels for the transfer of information (Matuschke, 2008). When combined with computer programmes it can be used to model, visualize and analyze interactions between individuals within groups and organizations (Springer & de Steiguer, 2011).

SNA can measure the relation between extension, farmers and adoption of better practices, improved decision making by the farmer and performance which are influenced by the kind and sources of information (Anderson & Feder, 2004). A Social networks approach assists in establishing which network characteristics have the greatest persuasive impact and thus technology uptake and hence improve on the design of extension approaches (Matuschke, 2008). Since the adoption of agricultural technologies is through social learning it is important to understand social networks among smallholder farmers that are adapting to climate change (Foster & Rosenzweig, 2010).

SNA has been applied in the mapping of networks and identifying the patterns of a group/organization's information and knowledge flow. There is a growing interest on the formation of such networks and their effect on communications (Monge & Contractor, 2003). Raini *et al.*

(2005) noted that SNA is an understudied area especially in agriculture. Evidence on social network construction and impact on adoption are warranted since only few studies have dwelt on identifying important and useful network characteristics (Raini *et al*. 2005 and Matuschke, 2008).

1.2 Statement of the Problem

Studies on adoption behaviour have investigated farmer's decision making process by focusing on innovation and adoption of technology (Gialhard, 2012); while the process of adoption begins with the sharing of information among the potential users of the technology (Rogers 2003, Feder & Slade, 1984) and the facilitating agents. Most of this information is shared through interpersonal channels within social networks (Conley & Udry 2001) and innovation studies need to be focused at this level. There is need to research on how this information flow using a methodology that can map out the information flow patterns and social network characteristics that affect this process within the context of a current agricultural extension model within a social network context.

Social networks have characteristics which are a sum total of the individual traits that can either facilitate or hinder the flow of climate change adaptation information and thus adoption of the agricultural innovations.

1.3 General Objective of the study

To assess effects of social networks characteristics on the flow of climate change adaptation information in selected villages in Makueni County.

1.4 Specific Objectives of the study

I. To describe social networks through which information on adaptation to climate change flows.

II. To describe relational and structural factors that facilitate or hinder the flow of climate change adaptation information within social networks.

III. To identify effective pathways of disseminating climate change adaptation information in social networks.

1.5 Research Questions

I. What are the characteristics of social networks through which information on climate change adaptation flows?

II. What are the relational and structural factors that facilitate or hinder the flow of climate change adaptation information within social networks?

III. What are the patterns of climate change information flow within a social network?

1.6 Assumption of the Study

The study assumes that:-

I. Farmers in the study areas are rational human beings and will therefore make decisions that will enable them avoid adverse effects of climate variability if offered relevant information.

II. Extension agents have created awareness on agricultural climate change adaptation measures in the study site.

III. Farmers will cooperate and give their full identity (at least two names) to enable SNA.

1.7 Justification and Significance of the Study

The social aspect of Climate change adaptation warrants more of research to better understand the climate change as a problem among farmers and subsequent intervention measures. The government of Kenya through its National Climate Change Response Strategy (NCCRS) notes the importance of information and communication management to ensure different stakeholders take appropriate actions to respond to the challenges.

Social networks are important to smallholder and resource poor farmers who mostly rely on more informal than formal sources of information. These groups are also vulnerable to climate change and need to be linked to appropriate channels of communication; hence the need to better understand how their social networks function and how they can be exploited as entry points for adaptive interventions. Such an understanding can contribute towards the development of better extension approaches in the emerging area of climate change. There is need to have a novel and local climate change adaptation communication model to describe how local farming communities interact about the impact of climate change on agricultural production.

The study results inform on the aspects of novel agricultural extension models especially on climate variability and change that can even identify opinion leaders in a social system. The research results can benefit policy makers and the development agencies working in rural development through agriculture.

1.8 Limitation of the Study

Owing to the unique socio-cultural settings within which social networks exist, the relational and structural aspects that were studied may not necessarily be the same elsewhere as such this may limit the replication of the findings in another socio-cultural setting. To overcome this limitation the study has tried to compare its findings with other studies and explain any differences and how this can be taken care off during application of the research findings; in the execution of agricultural extension activities in climate change adaptation.

1.9 Definition of Key SNA terminologies

Betweenness	Is the number of shortest paths an actor is on. Betweenness measures the extent to which an actor lies between other nodes in the network. The measure reflects the number of people whom an actor is connecting indirectly through their direct links (Wasserman *et al*.1994)
Degree Centrality	Is simply the number of connections (or edges) a vertex has to other vertices. Is the number of links incident upon a node (i.e., the number of ties that a node has)
Eigenvector Centrality	Is a measure that reflects the facts that not all connections are equal, and in fact, connections to people that are more influential are more important (Newman, 2012).
Social network	Refers to the articulation of a social relationship ascribed or achieved among individuals, families, households, villages, communities or region.
Homophily	Describes the tendency of individuals to associate with those similar to themselves
Heterophily	Refers to sender receiver dissimilarities in communication
Ties	A connection of a pair of actors by one or more relations.

Bridge	An edge is said to be a bridge if deleting it would cause its endpoints to lie in different components of a graph.
Centrality	This measure the social power of a node based on how well they're connected with other actors in a network. There are three measures of centrality betweenness, closeness and degree.
Closeness	Measures the degree to which an individual is near all other individuals in a network both directly and indirectly. Shows how an actor's ability to access information.
Cohesion	The degree to which actors are connected directly to each other by cohesive bonds.
Eigenvector centrality	A measure of the importance of a node in a network. It assigns relative scores to all nodes in the network based on the principle that connections to nodes having a high score contribute more to the score of the node in question.
In-degree	How many directed edges (arcs) are incident on a node
Out-degree	How many directed edges (arcs) originate at a node
Vertex	The fundamental unit of a network also called a node or an actor
Edge	A line connecting two vertices also called a bond, link or a tie.
Directed Socio-gram	Is a socio-gram that has edges which runs in only one direction (arcs) normally have an arrow showing their direction. A directed socio-gram has both an in-degree and an out-degree for each vertex, which are the numbers of in-coming and out-going edges respectively.
Undirected Socio-gram	Is a socio-gram that has edges which runs in both directions (arcs) normally have an no arrow showing their direction
Geodesic Path	is the shortest path through the network from one vertex to another
Network Diameter	is the length (in number of edges) of the longest geodesic path between any two nodes (actors)

CHAPTER TWO

2.0 Literature Review

This section looks at literature relevant to the study. It gives a brief historical overview of the climate change phenomenon and its effects on agricultural production especially on livelihoods dependent on rain fed agriculture, therefore introducing the problem of the research namely climate change and information exchange. This is followed by an analysis of agricultural extension approaches in Kenya with emphasis on challenges faced when disseminating agricultural information and measuring impact of agricultural extension programmes. The agricultural extension models are discussed and the information flow challenges noted as a gap being addressed by this research. While modern agricultural extension models are participatory it is noted that the top-down communication is still a gap and the need for more research in horizontal communication at local level is suggested. To address this gap the Social Network Analysis model is introduced and key aspects described.

2.1 Effects of Climate Change on Agricultural Productivity

Climate is a major determinant of the performance of agricultural sector in Kenya. The sector is a major contributor to the national economy accounting for 26% of GDP. The country is already experiencing high temperatures and relatively low but highly variable rainfall patterns (IFPRI, 2010). The result has been frequent droughts which have decreased the length between famine cycles from 20 years (1964 to 1984), to 12 years (1984-96) to 2 years (2004 to 2006) to yearly (2007, 2008 and 2009)- NCCRS GoK, (2010).

Climate variability and change is more pronounced in the Arid and Semi-Arid Lands (ASALs) which account for 83% of Kenyan land mass; these areas support smallholder farmers that depend on rain-fed agriculture thus making them vulnerable to climate variability and change. The advent of climate change will worsen their situation and therefore have a negative impact on the Kenyan economy. Nonetheless this situation also presents opportunities which can be exploited through adaptive agricultural measures by the affected farmers. For example, in the highlands, the increase in temperatures and rainfall changes may lead to an extension of growing season (IFPRI, 2010). If the affected farmers are not made aware of this and appropriate adaptation measures put in place; crop failures will be on the increase and thus food shortage.

Although there has been public discussion on the effects of climate change in rural areas of developing countries, there has been little discussion that engages science of climate change impact on agriculture and smallholder subsistence systems (Morton, 2007). This may hinder the coping and adaptation process by the smallholders. Response to climate change needs to encompass several levels including crop and farm-level adaptations; collective action at the community level and supporting policies and investments at national levels (IFPRI, 2010).

2.2 Agricultural Extension and Climate Change

The strong scientific consensus on causes and risks of climate change is in contrast to widespread confusion among the lay public (Leiserowitz, 2007). This scenario places the agricultural extension agents at a critical position in assisting farmers to cope and adapt to climate change. The old extension models may not work and this calls for novel extension approaches that are participatory in nature. Tarawalie (2008) asserts that inadequate communication between farmers, technical support staff, policy makers and NGOs is a major problem hindering improvement in agricultural production. The provision of agricultural extension services in Kenya has been done to varying levels of success amid challenges. It is clear that although some level of successes has been registered there are weaknesses that hamper effectiveness of agricultural extension (Anderson & Feder 2004, Rivera *et al*. 2001).

Agricultural extension services after a period of neglect are now back on the development agenda with a sense of excitement about many of the emerging institutional innovations (World Bank 2008). There is still much to do in bringing needed extension services to small holder farmers around the world especially the poorest group (World Bank 2008). The investment in agricultural extension services has the potential to improve agricultural productivity and therefore the farmers' incomes in the developing economies where more than 90% of world's nearly 1 million extension personnel are located (Feder & Anderson 2004). Agricultural extension agents will play a crucial role of awareness creation to the vulnerable farmers on the impacts of climate change.

2.3 The Challenge of Measuring the Impact of Agricultural Extension

Many factors affect the performance of agriculture in complex ways and it is difficult to attribute specific impacts at farm level to extension services (Anderson & Feder, 2004). Nonetheless (Romani, 2003, Muyanga & Jayne 2006 and Demiryurek, 2010) note that productivity of these factors is affected by the quality of information and effectiveness of the communication process.

The difficulty in attributing the impact of extension on agricultural production has resulted in under funding of research activities in the developing economies and therefore hampering their skills and knowledge development (Purcell & Anderson 1997 and Anderson & Feder, 2004).

Extension is a public good; in most countries it is offered by the government using the tax payers' money. It is therefore imperative to measure its impact in order to justify the financial input and therefore establish if its beneficial to the end consumer- the farmer. Although Belli *et al.* (2001) economic analysis of extension projects is similar to that of any investment appraisal; (Anderson & Feder 2004) urge that it is not a straight forward process in agricultural extension and there are challenges of appropriately valuing and attribution of the benefits. Maredia *et al.* (2001) suggest that for projects that deliver knowledge products to producers, effectiveness in productivity is quantified by estimating economic benefits to producers and computing the rate of return to investment. The rate of return can be computed through econometrics by relating productivity changes to investment in research and extension. Even in such cases most studies have focused on impact of research rather than extension (Anderson & Feder 2004). Birkhaeuser *et al.* (1991) used a systematic computational comparison of cost and benefit between areas where extension is used and where it is not.

The performance of research systems is assessed according to the recognitions they receive within scientific community, where research priorities are not necessarily aligned with those of the extension agents or farmers they come in contact with (Anderson & Feder, 2004). In other cases the assessment of effectiveness of extension is done through collecting and reporting on the input indicators which leaves out aspects of the extension agents accountability to the farmers (Anderson & Feder, 2004). In lieu of these challenges in assigning a cost to extension process this study chooses to use a method that analyzes the characters of the individuals who form a network and in defining their roles in the adoption process and suggests cost effective entry points for extension agents. The extension agents' role was also be analyzed to inform further researches into the cost effectiveness of extension approaches.

Agricultural extension services have traditionally focused on dissemination of research and development information to farmers (Roling, 1990). Extension agents provide professional technical advice with the aim of improving their farming methods. Extension services were for many years associated with models of diffusion and adoption of innovations (Rogers, 1971, Rogers & Shoemaker, 1983, Long & Villareal, 1994; Rolings 1990).

The top-down approach in diffusion of innovations theory; has been criticized as being linear, top-down and viewing the farmer as a passive recipient of research findings, inventions and innovations. Climate variability and change is a phenomenon that the local communities have experienced and observed; their resilience attests to the wealth of their indigenous knowledge which must be tapped into by the extension agents.

Drinkwater (1992) in his study on the use of farmer research groups in rapid rural appraisal and on-farm trials found out the importance of local farmers' experimentations on their farms. Acknowledgement of the experiments were successful in the establishment of dialogue between the extension agents and farmers who subsequently communicated easily and learned faster new technologies developed out of their dialogue and also improved their farming systems knowledge.

The importance of involvement of farmers in adaptive experimentation is shown by a study carried out in Mali by Stolzenbach (1999) in which he shows how farmers have a better understanding of the complex factors that influence agricultural production. Stolzenbach (1999) found out that farmers have a wealth of tacit knowledge about their environment and they continually carried out experimentation on their farms using techniques that are akin to modern experimentation but which are focused on agricultural production. Asante *et al*. (2012) measured adaptive capacities of farmers in Ghana to climate change by using the level of traditional knowledge, consultation among other factors to determine the adaptive capacities. In another research; farmers in Ghana were shown to experiment to solve their problems, and to satiate their curiosity (Millar, 1994). By picking some traditional knowledge in climate change adaptation; it is possible to follow information flow among actors; the direction of this flow can also determine the level to which such information was blended into the whole project implementation. These studies illustrate the importance of linkages between various actors as they offer pathways through which information is shared. Davis (2008) notes that; the failure by researchers and extension agents to understand and involve clientele in problem definition and solving through technology development due to weak linkages between research and farmers are among the challenges facing extension in Sub-Saharan Africa.

White (2008) argues that the lack of an "African" communication theory to guide extension is a major challenge to Sub-Saharan African Countries in lieu of the importance of communication in agricultural extension. White notes that "The national agricultural research systems in most developing countries consider research as the starting point for disseminating agricultural knowledge. Agricultural programmes are thus planned by national offices and passed down through extension agents to farmers".

2.5 Participatory Approaches and Agricultural Information Flow

Swanson & Claar (1984) definition of agricultural extension as an ongoing process of getting useful information to people and then assisting those people to acquire the necessary knowledge, skills and attitude to utilize effectively this information and technology concurs with (Demiryurek, 2000) assertion that communication is a major concern for agricultural extension services. Chambers *et al*. (1989) in farmer first approach emphasize information and knowledge exchange between different actors in its generation, dissemination and utilization. The various actors in the agricultural extension system can be viewed as audience groups that act as sources, channels or targets of agricultural information and technologies.

Grothman & Patt (2003) argue that decisions on climate change are socially constructed and negotiated; to exploit such a system it is important to understand how information flows through these social systems. Risbey *et al*. (1999) differentiated adaptation process into four stages namely; - information collection (awareness), planning, design, implementation (decision making), monitoring and evaluation of the outcomes of such decisions. This compares well with Hovland *et al*. (1953) stages of a communication process which they enumerated as attention/ reception of the message, comprehension, yielding and action.

Participatory models increase interactivity and therefore diffusion of information which is a prerequisite for the adaptation process. Farmers are rational human beings that make choices and decisions that best suit their needs (decision making theory); they will thus learn from sources that offer relevant information to their local farming systems needs. Farmers are not passive listeners but they actively select messages that best meet their needs as posited by the uses and gratification theory. According to Nitsch (1991) farmers apply adaptive rationality which is a product of continuous interaction among visions and experiences. Adaptation to climate change can be enhanced through a participatory learning process to increase rural agricultural productivity by using assisted self-reliance and appropriate learning modes Uphoff *et al*. (2000). This process needs to be anchored on information needs which must be objectively mapped out.

2.6 Social Networks and Agricultural Information Flow

Social capital in the form of groups is used in communities worldwide, especially in the rural areas as safety nets to cope with risks and for mutual assistance (ILRI, 2008.). Rural communities interact within and across social levels on various risks and this form a crucial component in their resilience to uncertainties. Studies show that social networks have a significant influence on the adoption decision of individual farmers (Conley & Udry 2001, Baerenklau 2005, Matuschke *et al.* 2008). Adaptation occurs in a physical, ecological and human system and involves changes in social and environmental processes, perceptions of climate risks and thus practices that serve to lessen the resultant adverse effects while exploiting the new opportunities.

Interpersonal communications channels and frequency of interaction between individuals influence attitude change (Kadushin, 1966). Individuals are likely to be influenced by the members whom they interact with most and have some similarity. These networks are important in collective community actions (Granovetter1973, Crona & Bodin 2006). The characteristics of the social networks in a community influence successful Natural Resource Management (NRM) due to their profound effect on the diffusion of information and knowledge (Crona & Bodin, 2006).

The linkages that connect actors in agricultural extension system facilitate the exchange of information, transfer, uptake and utilization of research findings and technology (Chema *et al.* 2003). In most developing economies information on which extension advice is based, is not generated within the extension organizations but in separate systems (national agricultural research institutes, universities, private research firms) and such management systems give little weight to extension agents and farmers' opinions and priorities (Anderson & Feder 2004). The weak linkages challenge, traces back to the initial agricultural extension efforts in Kenya; for example the World

Bank sponsored Integrated Rural Development Project (IRDP) in 1970s did little to link farmers to researchers and the private sector (Davis, 2008). Chema *et al*. (2003) in their evaluation of concepts and practices of agricultural extension in developing countries found out that many organizations dealing with research and development in developing countries are faced with poor participation and cooperation by end users in research activities. Smit & Pilifosova (2001) acknowledge that there is very little empirical research literature on the process of adaptation in decision making by farming communities on climate change.

Chambers *et al*. (1998), Ansu-Kyeremeh (2005), White (2008) and Tarawalie (2008) have noted that the top-down introduction of agricultural technologies with little input from the farmer are a main barrier to the blending process which is vital in the adoption of such technologies. Kenya has several local and international agricultural research institutions like ILRI, KARI, ICRAF and therefore a critical mass of agricultural experts and subsequently agricultural innovations. Agricultural research outputs are a fundamental element for science and technology planning in developing countries (Bertin, 2010). These outputs need to address the farmers' needs and blend with their indigenous knowledge for them to be adopted.

Participatory research between the farmers, researchers and extension agents can be strengthened through continuous dialogue that supports the farmers to identify their problems and solutions which best fit into the local farming systems (Nairs & White 1993). Chambers *et al*. (1994) in the farmer-first model note that the starting point of development is the active and equitable partnership between rural people, researchers and extension agents through a participatory research communication process. Social Network Analysis offers a framework within which such participatory approaches can be accessed.

2.7 Social Networks Analysis (SNA)

Social Network Analysis (SNA) is the analysis of relationships among agents, groups or entities in a social setting in relation to exchange of a given resource. SNA studies the patterns of relations among individuals, organizations and other social groups such as states (Wasserman & Faust, 1994). Social Network Analysis focuses on the relational aspects of social behaviour and views social structures as arising from patterns of interaction between individuals (Wasserman & Faust 1994). The SNA methodology has been used in disciplines like sociology, business management and public health but remains underutilized in agriculture and natural resource management (Springer & de Steiguer, 2011).

The relationships provide channels for resource transfer for example money and information; they also present opportunities and barriers to an individual's actions (Wasserman & Faust, 2005).SNA is focused on uncovering the patterning of people's interactions by answering the questions; who is the main actor in a network?, who is most influential member?, who acts on the periphery?, who offers the most important connections? And which kind of information is shared through the network?

SNA is an interdisciplinary methodology that incorporates anthropology, communication, mathematics, statistics and computing disciplines into a very versatile research method used in a wide array of disciplines (Scott 2000). Statistical methods have been applied to SNA for example correlation analysis have been introduced to identify the determinants of network positions or to estimate the likelihood that a relation exists between two or more actors within a network (Brieger 2004).

The actors in social networks are linked together by relationships called ties; the nodes represent the actors involved in the relationship. Socio-centric networks are composed of all the actors within a population while ego-networks are composed of a selected group of actors. This research analyzed ego-networks. There are numerical and graphical techniques used in the description and measure of networks to assess the flow of resources which this research also utilized (Matuschke 2010).

Social Network Analysis (SNA) when applied to communication about agriculture in rural communities reveals regularly used sources of advice on agriculture and conversely those who are not well connected to established networks (Garforth, 1993). William *et al*. (2006) used SNA to evaluate educational programmes; they found out from their research that SNA is an effective tool for evaluating school programmes that foster greater collaboration between actors. Zack, (2000) applied SNA to measure effects of organizational systems on social communication structures. Zack (2000) demonstrated that SNA can be used to understand information flow and communication patterns in organizations. Bartholomay *et al*. (2011) used SNA to map out the University of Minnesota department of agricultural extension outreach. In their study they found out that SNA offers a unique method for describing and measuring extension outreach to the internal and external actors and can inform better knowledge management approaches. Zack (2000) and Bartholomay (2011) recommended SNA as a strategic approach that can be used in developing internal collaboration, communication and in conducting system-wide impact evaluations.

2.5 Previous Studies on Social Networks Analysis

Few studies explore the nature of social networks in the diffusion of climate variability and change; we look at three examples that applied SNA in studying farmer's adoption. Three studies described in this sub-section applied social network analysis to study natural resource management along the Kenyan coastal region, the uptake of integrated pest management among tomato farmer groups in Kiambu and diffusion of innovation among farmer groups in Kenya and Ethiopia. The studies analyzed social networks at the group level and social network characteristics at the individual level. They provide more information on the roles of actors in the diffusion process.

Darr & Pretzsch (2006) used social network analysis to study the spread of innovations within formal and informal farmers groups in rural communities in Kenya and Ethiopia. They studied group characteristics that affect the diffusion of innovations in a group setting. The study areas just like Sakai- sub location, had received previous support from development donors in support of tree planting. The findings revealed cohesive groups with intensive information exchange and collaborations among members facilitated the spread of innovation. It also found out that the spread of farming practices was effective through interpersonal interactions and communication among the rural communities. The study recommended a study to be done at the individual level using a qualitative approach to get more insight into the diffusion process. A study done in India by Matuschke & Qaim (2006) showed that individual networks as opposed to village networks played a significant role in the adoption of hybrid wheat.

Raini *et al*. (2005) carried out a study on the Integrated Pest Management (IPM) information flow using SNA combined with descriptive statistics. Their research specific objectives were to:- Asses how the density of selected social networks shape tomato IPM stakeholders interaction and to examine the structural patterns of connections as induced by social relations and the role they play in IPM information flow. This was the first study to apply SNA in the study of information flow among the tomato stakeholders using IPM. The study was done in central Kenya in 2004 and mainly characterized social networks in terms of size and density. They found out that the density of social relations influence IPM stakeholder's interaction behaviors and induce various structural patterns of connection.

Crona & Bodin (2006) carried out a study among the coastal communities on how occupational (defined by the fishing gear) and relational social networks affected the diffusion of information and knowledge on natural resource extractions. They used knowledge as the dependent variable and its distribution among resource users was qualitatively compared to map out the group relations. They found out how influential groups of non-fishermen who had limited communication with the various fisher groups but were key in creating bridges through which information flowed. The type of fishing gear influenced social network formation and provided channels of communication. Groups with strong intergroup relations and same pattern of relations had strong influence on the other with the same occupations; this is in tandem with Wasserman and Faust (1994) assertion. It should be noted this study was at the group level and the resultant social network. No study has been done in climate change adaptation communication hence the need to carry out SNA in this area.

2.6 Theoretical Framework

This sub section briefly describes the theories that guided this research; starting with the Diffusion of Innovations theory which laid the foundation for modern diffusion theories is included to give the historical background to the study. Blending and Centripetal models are also discussed to complement the current participatory approaches in agricultural extension. Because climate change adaptation has components of behavior change, the decision making theory is included to emphasize that fact that the rational trait of audiences in a communication process.

2.6.1 Diffusion of Innovations

Early approaches to research in the diffusion of innovations emerged from the fields of anthropology, geography, sociology, health and communication but were consolidated into a single research tradition in the 1960s (Rogers, 1983).The adoption of new technology is a central feature in the transformation of farming systems in economic development.

The Everett Rogers theory of diffusion of innovations describes the process by which an innovation is communicated through a certain channel over time among the members of a social system (Rogers, 1983). According to this theory innovation refers to any new idea to a group of individuals. Information about research outcomes can therefore be considered as new. The theory posits that an innovation attains a "tipping off point" over some time upon its introduction and communication at which it spreads through a social system through a domino effect (Greg, 2003).

The theory lists five procedural steps through which information goes through once it reaches the targeted audiences as follows; knowledge, persuasion, decision, implementation and confirmation. Among the factors that influence the adoption of new ideas and practices are communication channels and the efforts of the practitioners (Lamble, 1984). This attempts to illustrate the preferred channels of information exchange and also describes the role played by agricultural extension agents in government and NGOs, opinion leaders and religious groups.

The theory is still in use but it is seen to be largely top-down with very little analysis of the needs of the end consumer of innovations and largely congruent with the modernizing theory (Servaes, 2003). The theory assumes that scientists originate/develop innovations which are transferred by communication workers and other intermediaries and applied by agricultural practitioners through a linear model (Kline & Rosenberge, 1986).

Chambers *et al*. (1989) in their farmer-first paradigm challenge the modernization paradigm of this theory in agricultural extension as a straight forward process that diffuses modern techniques with the aim of attaining economic development among the target groups. This approach still forms a strong component of development initiatives that ride on technology. Understanding the farmers' perspective has been a major influence in the development of participatory research methodologies Shah, (1993) which are largely driven by demand and not the supply of the technology as diffusion of innovations theory posits. The Diffusion of Innovation theory though top-down in nature acknowledges the important role played by horizontal channels of communication. This is implied in the factors that it outlines that support diffusion of innovation namely: - Relative advantage compatibility, complexity and trialability; all these factors are constructed through interpersonal interaction.

2.6.2 Blending Theory

The study by Tarawalie (2008) on People's Participation Programme (PPP) in several African countries introduced the concept of blending in agricultural extension realms. The concept refers to the incorporation of indigenous culture within new agricultural technologies inventions and innovations through stage-by-stage participatory approaches in rural development programmes. The main focus of this concept; is that the targeted individuals are not passive consumers of technologies since they are continually engaged in local experimentations in agriculture on their farms. The importance of indigenous knowledge and cultural practices of the local communities must be considered and integrated in the development initiatives.

The concept of this approach of extension communication is best illustrated in Uphoff (2000) study on Gal Oya irrigation scheme in Sri Lanka. In this case the already existing groups of local farmers were aided by catalysts (extension agents through participatory communication) to revive a local agricultural irrigation scheme. The catalysts assisted the local communities by training them on how to carry out problem identification and solving and how the lessons learned can be shared through horizontal channels. The local groups had representatives who sat with the district level committees this enhanced bottom-up communication (Uphoff, 2000). The success of this initiative was tied on rural community participation in the identification of the problem and active solution seeking and the sharing of information among the farmer groups. This theory is relevant in this research in that it puts emphasis on indigenous knowledge which is embedded in social networks.

2.6.3 Centripetal Communication Model

Ansu-Kyeremeh (2005) in his theory of grassroots participatory communication points at the flaws of the current extension model which was imposed on African countries by their colonial masters. The model referred to as centripetal development communication structure, is in contrast to centrifugal model where innovations and inventions are formulated from the centre and then transferred to the periphery without considering the views and knowledge of people at the periphery who are considered passive and helpless. In centripetal research and innovation is driven from the periphery to the centre.

Centripetal development communication structure is proposed by the Ansu-Kyremeh as a model that can correct the traditional dysfunctional structure of communication. The model recognizes and incorporates local organizations and forms of communication for decision making and adapting improved forms of education, agriculture and other forms to African values, motivations and forms of communication.

This is corroborated by Melkote (2001) definition of development communication in which he asserts that it should not only be based on exchange of messages but should aim to emancipate people so that they can determine their own future by exploiting their innate powers. Ascroft *et al*. (1973) pointed out the lack of knowledge and skills about an innovation and not being involved in the development planning process as the major bottlenecks to adoption of innovations in Kenya.

This theory underscores the importance of bottom-up communication in agricultural research and guided this study in understanding interpersonal channels that serve to inform farmers on appropriateness of innovations based on on-farm trials.

2.6.4 Decision Making Theory

This theory has been applied in the study of adaptive capacity of people to climate change by Grothmann & Patt (2003). According to the authors the decisions by people acting either to avoid negative impact of climate change to things they value or to benefit from the opportunities associated with climate change; partly drives the process of adaptation to climate change and its impacts.

According to the theory the higher the perceived probability of being exposed to an event that causes harm (in our case climate change) the higher the appraisal of such impacts and thus the resultant in an action, the theory refers to this as risk perception and perceived severity respectively. Smallholder farmers aware of the climate variability and change effects are better placed to respond to the information on adaptation and are more likely to adapt. This theory explains the rationality of audiences and why this is important in attitude change.

2.7 Conceptual Framework

Climate variability and change phenomenon is already affecting agricultural production in Kenya. Farming communities in the Arid and Semi Arid Lands (ASALs) are among the most affected with this climatic phenomenon. This presents a new challenge to agricultural extension which calls for new approaches of diffusing information. This study looked at the climate variability and change information and communication management aspect within a social network setting.

The research is conceptualized around a scenario of two major audience groups namely the farmers residing in Sakai sub-location, an area that is experiencing climate change and variability which is affecting their agricultural activities and on the other hand and the agricultural extension agents together with the development partners. In order to adopt, these farmers need information on appropriate agricultural techniques, this is information which resides with the extension/agricultural experts and also with the farmers in the form of traditional/indigenous knowledge.

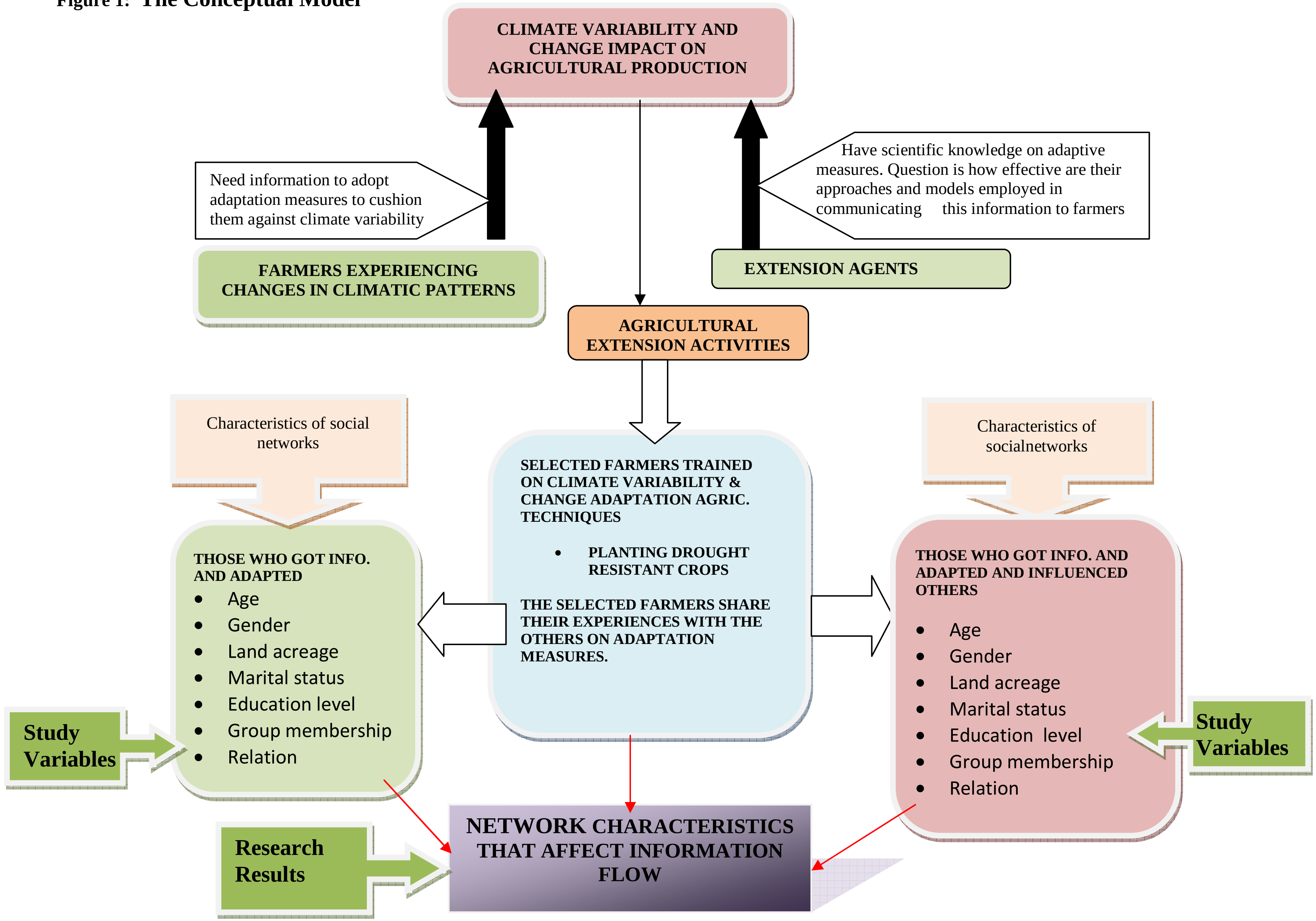
The dependent variable was the information on climate change; with the independent variables being the audience groups' characteristics like the level of education, gender, income, group membership (religious and social). The Audience groups have been classified into the following three groups:-

1. Agricultural extension agents
    a. In government
    b. NGOs
    c. Faith based organizations
2. Farmers who have adapted to climate change by planting drought resistant cropsand practicing conservation agriculture (mulching).
    a. After getting information on climate change
        - From fellow farmers
        - From extension agents
3. Membership to groups:-
    a. Those who belong to a social network
    b. Those who marginally belong to a social network

Adaptation is indicated by the implementation of at least one of the climate change adaptation agricultural techniques.

The agricultural extension agents are important in the adaptation process since they have the relevant information on how the farmers can adapt to climate changes through the adoption of innovation in their farming practices. These innovations include growing of drought resistant crops, conservation farming, use of irrigation, natural resource management, rain water harvesting among others. Farmers on the other hand have indigenous knowledge on coping with adverse climatic conditions and therefore are not passive recipients of such information. The two groups therefore need to blend their knowledge through participatory extension approaches. Figure 1. presents the conceptual model that guided the research.

Figure 1: The Conceptual Model



CHAPTER THREE

3.0 Methodology and Research Design

3.1 Variables in the Study

The flow of information on the agricultural adaptive measures was the dependent variable in the study. The independent variables were the land acreage owned by each household, age of the household head, level of education, marital status and group membership. These variables were determined through interviews and observation (Appendix A).The respondents were classified categorically for example on land acreage into small, medium or large scale farmers, the other variables are illustrated in Figure 2.

Purposive sampling was done among respondents who were household heads; either male or female, residents in the study area and have either benefited from the drought resilience project, or have been in contact with beneficiaries and have implemented climate change agricultural adaptive measures. This was followed by snowballing which identified the subsequent respondents based on the exchange of information on climate change adaptation within and across five villages in Sakai sub-location.

Age	Gender	Education Level	Group membership	Relation	Land Acreage	Marital Status
1. 18-35 2. 35-50 3. >50	1. Male 2. Female	1. Primary 2. Secondary 3. Tertiary	1. Social 2. Religious 3. None	1. Neighbor 2. Relative 3. Friend 4. Same age group	1. Small (<3 acres) 2. Medium (3-5acres) 3. Large >6 acres	1. Married 2. Not Married 3. Divorced 4. Widowed

Figure 2: Study variables

These variables were used in the description of network characteristics and their effect on information flow by showing:-The sources of information on climate change adaptation, the strength of ties between actors and the direction of information flow (into or from an individual and a group)

3.2 Study Site

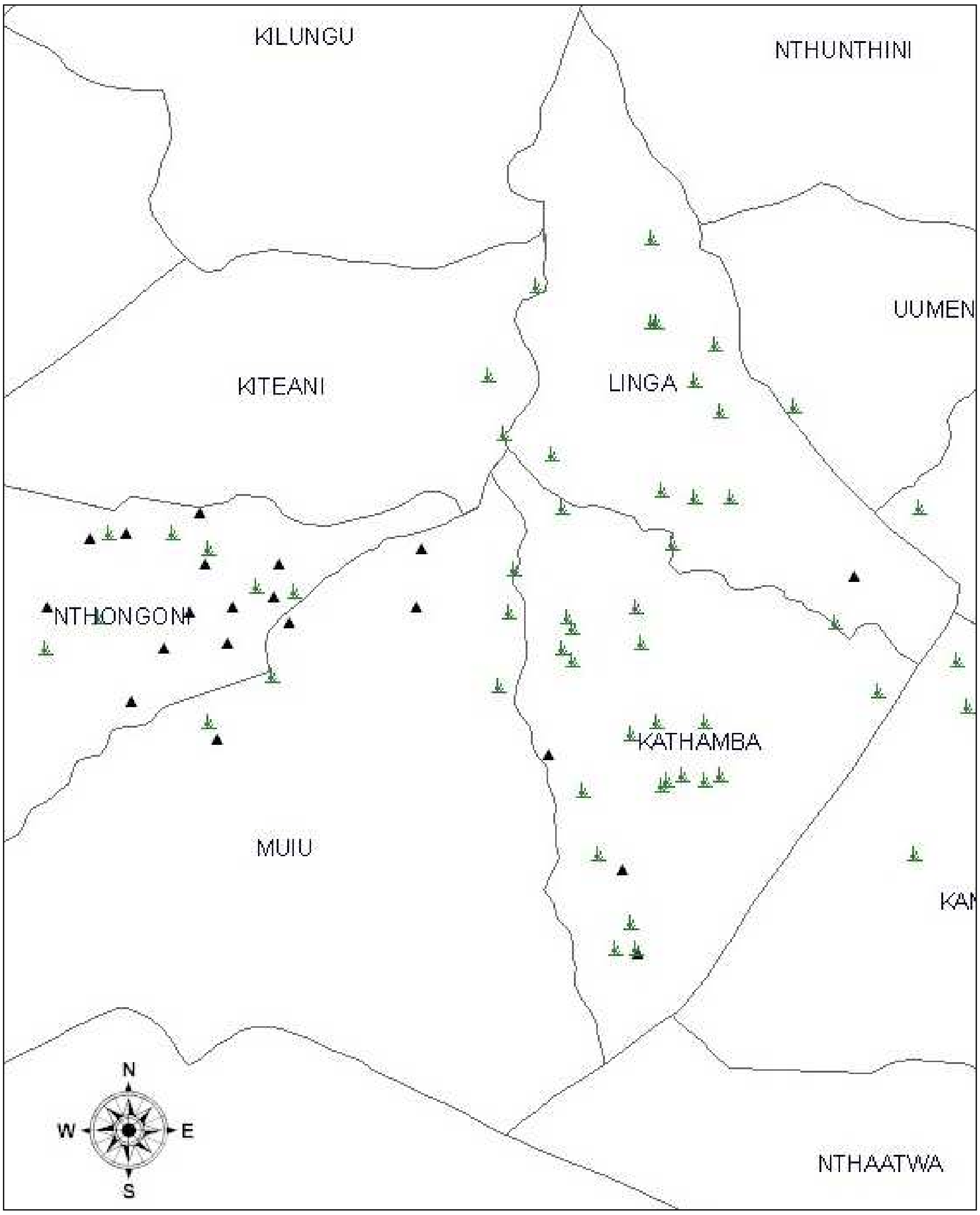


Figure 3: Map of Sakai sub-location showing the five villages
(Source CSTI, 2009)

Sakai Sub location is approximately 24.5 km square, covers five villages of Kathamba, Muiu, Kiteani, Linga and Nthongoni (see Figure 3) with a population of 4,866 and composed of about

520 households (CSTI, 2009). Sakai sub-location is located in Waia location, Kisau division and Mbooni East District, Makueni County. The framers in this sub-location have since time immemorial depended on rain fed agriculture but this has increasingly come under threat from the climate variability and change phenomenon which has hit the area. Farmers interviewed gave accounts of how rainfall patterns were regular and how they used to harvest a lot of crops. Over time the rainfall patterns have become erratic and crop production has dwindled.

Source: Othieno Joseph

Figure 4. Cowpeas plantation in Kathamba village

A drought resistant crop being grown by farmers in Sakai, notice the mulching between the rows

The average land holding size is about 3 acres per household for 64% of the households; 6-10 acres per household for 18%; 11-15 acres per household for 7.9 % of households while 1.3% own over 40 acres (CSTI, 2009). The rains in Sakai used to come in two seasons; the long rains in March/May; and the short rains in November/December. According to the baseline survey done prior to the project implementation, 97.3% of the residents were aware that there were changes in the climatic patterns since the 1980s (CSTI, 2009).The change in rainfall patterns, frequent and prolonged droughts resulted in a water shortage and subsequent food insecurity, conflict over natural resources, inadequate fodder and pasture among other livelihood problems (CSTI, 2009).

Sakai sub-location was selected for this research because there have been efforts to train local communities on climate variability and change adaptation through appropriate agricultural practices by the Ministry of Agriculture in collaboration with NGOs and other donors. The villages setting offer unique social networks build around information on climate change adaptation and therefore one can generate information networks. The adoption of agricultural innovations and adaptation to climate change is thus happening in this population hence the reason for choosing it.

Figure 5. Cassava plantation in Muiu village,

A drought resistant food crop that is being grown by farmers in Sakai sub-location.

3.3 Study Population

The study was undertaken in five villages in Sakai sub-location in Makueni County. All the villages are situated in an area that has received support from the government and development partners and are experiencing climate change.

3.4 Sample Size

Sakai sub-location has approximately 520 households according to a baseline survey done prior to the drought resilience project (CSTI, 2009).The sample size to calculated using this formula by Doho *et al* (2003).

$$n = \frac{\sum^2 \alpha pq}{d^2}$$

Where

n –The desired sample size

$\sum^2$- the standard normal deviate at the required confidence level

p - The proportion in the target population estimated to have characteristics being measured

q - 1-p

d - Level of statistical significance

Because there was no estimate available for the proportion in the target population assumed to have the characteristics of interest 50% was used according to Fisher *et a.l* (1935) recommendations.

$$n = \frac{(1.96)^2 (0.50)\,(0.50)}{(0.05)^2} = 384$$

The study population being less than 10,000, a final sample estimates (n_f) was be calculated using the formula below:-

$$n_f = \frac{n}{1+n/N} = \frac{384}{1+384/520} = 220$$

This sample size was rounded down to 220 households; this was divided equally among the five villages in Sakai sub-location to yield 44 respondents per village (the assumption was that the variation in village populations wasn't significantly different). The initial respondents were identified through purposive sampling (based on their farming characteristics that showed adoption of agricultural techniques for climate change adaptation) and snowballing was used to identify the other subsequent actors in the social networks.

3.5 Instrumentation

Primary data was collected using semi-structured questionnaires (see Appendix A) developed using Tailored Design Method (Dillman *et al*. 2000), from household heads in five villages. The questionnaires were pre-tested for reliability and validity in the study population by the recruited research assistants. Observations were also used to collect data using a check list (see appendix D). The questionnaires were administered using an interview protocol. The initial households in each group were purposively identified based on a set criterion (see appendix D) this was followed by snowballing to generate subsequent respondents in order to establish the patterns of information flow. Secondary data was collected from reports on the project that also included gray literature.

3.6 Data Collection

Six research assistants were recruited with the assistance of the Sub-County Agricultural Officer (SCAO), who was closely involved in the Sakai climate change adaptation project. The research assistants were sourced from the respective villages for ease of identification of the farmers by names as listed during the interview. The research assistants were trained on how to administer the questionnaires (Appendix C) and a pre-test done to ensure they were conversant with the filling of the questionnaire and they participated in the pretesting of the questionnaires (Appendix A).

The data was entered into NodeXL from where socio-metric values and graphical representations (socio-grams) were derived. In the socio-grams the individuals and organizations are shown by nodes (shaded circles), their links (ties/edges) are illustrated by a line in joining the nodes. The ties show the direction of information flow which is either one or two way; the socio-grams also show the position of the different nodes in relation to their importance in the sharing of information. The study uses two formats of socio-gram presentation namely: - Harel-Koren Fast Multiscale and Fruchterman-Reingold. They were used to illustrate visual attributes of the social networks.

Data was collected concurrently from the five villages in Sakai sub-location. To start off the process of data collection a farmer implementing climate change adaptation agricultural technique(s) was identified by observing their farms and brief interview from where snowball sampling technique was used to identify subsequent farmers based on information exchange on climate change adaptation agricultural techniques.

Recall of names by respondents was used to generate a minimum of one name to a maximum of four names of fellow actors who either act as a source or receiver of information on climate change adaptation. This limitation in the number was to enable the respondent to name only the strongest network partners.

The household heads (either male or female) were asked to indicate their sources of information and whom they subsequently share it thereafter with as regards to climate variability and change adaptation in agricultural production and the relationship between them and those with whom they shared the information.

3.7 Data Analysis

3.7.1 Illustration of Relational Links among Actors

Binary measures were used to illustrate the existence of relationships as shown by whether or not two actors are related based on information on climate change adaptation sharing. The direction of the relation was also showed by the arrows on the edges and measured using in-degree and out-degree centrality measures. For example, if two farmers A and B in Sakai sub-location have a relation based on the information they share on climate variability and change adaptation agricultural practices; this was expressed as an adjacency matrices as follows:-

$X_{AB}=X_{BA=}1$ if they share information between them. In which case the adjacency matrices are symmetrical in that $X_{AB=}\ X_{BA}$

Visually in the socio-gram was illustrated by the edge joining two nodes and the direction by the arrows.

On the other hand if only farmer A relates to farmer B and Farmer B doesn't relate to farmer A then this is expressed as:-

$X_{AB}=1$ *and* $X_{BA=}0$

SNA is derived from the graph theory; the set of vertices is what is referred to as nodes(A and B) and the lines (edges) connecting them are called ties which can be directed or undirected, in this study they were all directed.

The strength of the tie between farmers A and B can also be measured on ordinal scales (Hanneman & Riddle 2005). Matuschke (2010) added the interval scale and ratios in measuring the nature of the relationship between actors. For example, it can be measured that farmer A likes farmer B, two times more than farmer C. The scope of this study didn't cover the two scales of measuring relationships in the studied networks; they are mentioned in this literature for information sake.

Measures of centrality namely network density, betweenness, closeness and reachability were used in this study to show how actors control information, the power they possess and the number of intermediary contacts between any two individuals (Bodin *et al*. 2006;Valante, 2003). This described the network characteristics both at the individual and group levels. Conceptually, each centrality measures represented a different process by which key players influence the flow of information through a network (Valante, 2003). Centrality measures indicated who occupied the critical positions in the network. Central positions were equated with opinion leadership or popularity of these traits which are associated with adoption behavior (Rogers, 2003) and in agricultural extension these are indicative of the entry points for agricultural extension agents, during awareness creation/advocacy campaigns.

Additional questions were asked to show the frequency of interaction between the actors based on a single adaptive measure which were the growing of drought resistant/avoiding crops (maize, millet, soya beans, cowpeas, green grams, pigeon peas and beans).This information was analyzed using NodeXL computer programme to determine which actors were involved in dissemination of information on climate change adaptation activities and the frequency of interaction with the other actors within and across villages.

3.7.2 Network density

Network density refers to number of ties in a network expressed as a proportion of the number of all possible ties. Network density is therefore the ratio of actual numbers of relationships between people observed in the network and the total number of relationships that are possible within the network (Wasserman, 1994). It is the ratio of all actual ties within a network to all possible ties; it is calculated by dividing actual ties in the network with the number of all possible ties (Newman, 2003). In an undirected network, the number of possible ties is defined as n*(n-1)/2 and in a directed network, it is the number of possible ties is n*(n-1).

Using the example above it is the number of other farmers that farmer A communicates with compared to the total possible number farmer A can actually pass information on climate change adaptation to in the social network. So if a network of size g contains L relationships then the network density will be calculated as follows.

$$\Delta = \frac{L}{g(g-1)}$$

When L= zero then no relationships exist between any actors in the network. When all nodes are connected to all other actors L= g (g-1) and density equals to a maximum of one.

This centrality measure contributed towards the achievement of the first and second research objective which were on the identification and characterization of social networks through which information on climate change and adaptation takes place.

Density represented pathways rather than volume of communication; hence this was used to inform the utility value of a given path; it illustrated the speed of information diffusion among actors, since a dense network will also have many pathways of information flow. Therefore in dense network actors interact with each other frequently and thus information spreads faster compared to a less dense network (Valente, 1995). A closely knit network or a perfectly connected network is called a clique and will have a network density of 1.

3.7.3 Degree Centrality

Degree centrality is the number of ties a node has; it measures the likelihood of getting any resource flowing through a network in our case information on climate change adaptation. In cases where the ties are directed (originate from a source and reaches a target audience, can be reciprocated) two measures of degree centrality are used in this study namely:-

I. In degree

II. Out degree

Degree centrality measures the position of a given node as a mediator for geodesic paths between other nodes in the graph (Freeman, 1978).

3.7.3.1 In degree

Is the number of actors/edges pointing to a given node (Freeman, 1978, Degenne & Forse, 1999).In collaborative networks in-degree may mean a form of popularity and potential for influence and leadership.

It is the count of the number of ties directed to the node. In degree is often interpreted as a form of popularity of an actor in a network (Freeman, 1973).The number of ties ei coming into a node and is expressed as.

$$= \frac{ei}{n-1}$$

3.7.3.2 Out Degree

Out degree is the number of ties that a node directs to others within the network. It is calculated by dividing the number of ties di going out of a node.

$$= \frac{di}{n-1}$$

It shows the capacity for sociability and extent of dependency.

A value of zero for both in-degree and out degree shows that a node is isolated and without interaction on one hand and on the other may also indicate situation of self reliance or resourcefulness.

3.7.4 Betweenness Centrality

Betweenness measures the extent to which a particular node lies between other nodes in a given network. Betweenness measures how actors under study can function as point of control in the communication process. Actors with a high betweenness were deemed to play important intermediary role and therefore could act as brokers in their networks (Coulon, 2005).Such actors influence the flow of information through a network by facilitating, hindering or altering communication (Freeman, 1979 and Newman, 2003). The deletion of actors with high betweenness from a network can impact negatively or positively on the network depending on the role such information was serving; examples of such actors are visually illustrated in the socio-grams. Betweenness is a centrality measure that quantifies the number of times a node acts as a link along the shortest path between two nodes.

Betweenness centrality is therefore the sum of times a farmer i, needs farmers k (the subject of the measurement) to reach another farmer j in a geodesic path. If gij is defined as the number of geodesic paths between farmers i and j and gikj is the number of these geodesics that pass through farmer k, then farmer k's betweeness centrality can be calculated as:-

$$C_B(n_i) = \sum_{j<k} g_{jk}(n_i) / g_{jk}$$

Where g_{jk} = the number of geodesics connecting *jk*, and

$g_{jk}(n_i)$ = the number that actor *i* is on.

3.7.5 Closeness Centrality

This measure is based on efficiency and independence (Freidkin, 1991). According to (Freeman, 1978) - Closeness centrality (Ci) for a given node is defined as the sum of the geodesics (ties) between that node (i) and all other nodes in the graph (j). This is an inverse measure and so the higher the closeness centrality measure, the less central is the node (Valante, 2003). Actors with high closeness centrality are positioned close to others and in the network and can therefore efficiently transmit information (ibid).Closeness is based on the inverse of the distance of each actor to every other actor in the network.

It was calculated using this formula:-

$$C_c(n_i) = \left[\sum_{j=1}^{g} d(n_i, n_j) \right]^{-1}$$

Where d (ni, nj) indicates the smallest number of lines linking nodes ni and nj (the geodesic distance).

Closeness Centrality is a measure of reach and is applied to show the speed of information flow.

3.7.5 Eigenvector Centrality

Is a measure of the influence a node has in a network. This measure illustrates the fact that not all connections are equal, and the fact that connections to people that are more influential is more important (Newman, 2012).The actors with high eigenvector value are linked to well connect actors and may influence many others in the network either directly or indirectly through their connections.

3.8 Pearson's Product Moment Correlation

Social networks analysis is mainly descriptive in nature giving the similarities, centralities and positional measures. This was the reason why a statistical analysis to show the relationship between the dependent and independent variables was done. Pearson's Correlation test was carried out to show if there is any correlation between the dependent and independent variables.

CHAPTER FOUR

4.0 Results Presentation and Analysis

A total of 165 questionnaires were administered in Sakai sub-location after cleaning a total of 164 questionnaires out of the 165 administered was analyzed (see Table 12). The study had targeted to have 220 respondents and therefore the response rate was 75% which is within the acceptable limit (Yamarino *et al.* 1991).

In Muiu village 34 questionnaires were administered and upon analysis yielded 120 vertices and 147 (Figure 7 and Table 10) edges. In Nthongoni Village 30 questionnaires and 84 vertices and 98 edges generated (Table 11). In Kiteani village 24 questionnaires were administered and 93 vertices and 120 edges recorded (Table 8). A total of 36 questionnaires were administered in Linga village and they yield 109 vertices and 137 edges (Table 9). In Kathamba village a total of 40 questionnaires were administered out of which 144 vertices and 245 edges were registered (Table 7).

Photographs (Figures 6, 10, 11 and 13) were taken to show the various farming innovations in the Sakai sub-location and are presented in various sections of this chapter.

Figure 6. Tomatoes grown through irrigation and grafted mango tree and mulching in Nthogoni village. Irrigation is among the innovations adopted by farmers in Sakai sub-location as an adaptive measure

The analyzed data is presented per village; a breakdown is also offered to show the socio-metric values of individual nodes, followed by a summary of the whole Sakai sub-location. Emphasis is put on the centrality measures and socio-grams for the whole village. All the socio-grams are directed (direction of information flow is given) and two layouts of visualization are used for this study namely Fruchterman-Reingold and Harel – Koren Fast Multiscale (for example Figures 32 and 33) for comparison purposes. Personal network socio-grams have also been used to visualize individual level connections.

Emphasis is placed on measures of centrality namely degree centrality (in-degree, out-degree) betweenness and closeness, clustering and reciprocity which describe the actor and network characteristic and how they affect the flow of information among the actors.

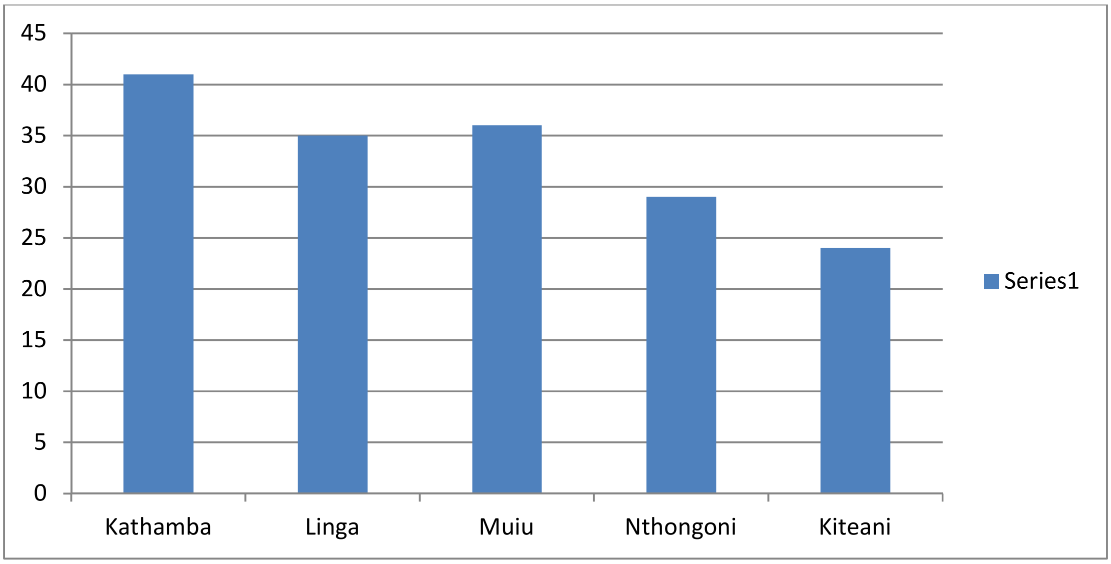


Figure 7. Distribution of the respondents in the five villages of Sakai sub-location.

4.2. Population Demographics of the Five Villages

Out of the 165 respondents 60 were male and 105 were female translating to 36.4% and 63.6% respectively. The farmers in Sakai sub-location are almost equally distributed across age groups ranging from 18 to over 60 years (see Figure 7 and pie chart in Figure 8). In terms of levels of education 18.2% didn't attend school while 42.4% of the repsondents had atleast attended primary school, 30.9% secondary and only 8.5% had gone upto tertiary level (see pie charts in Figure 9).

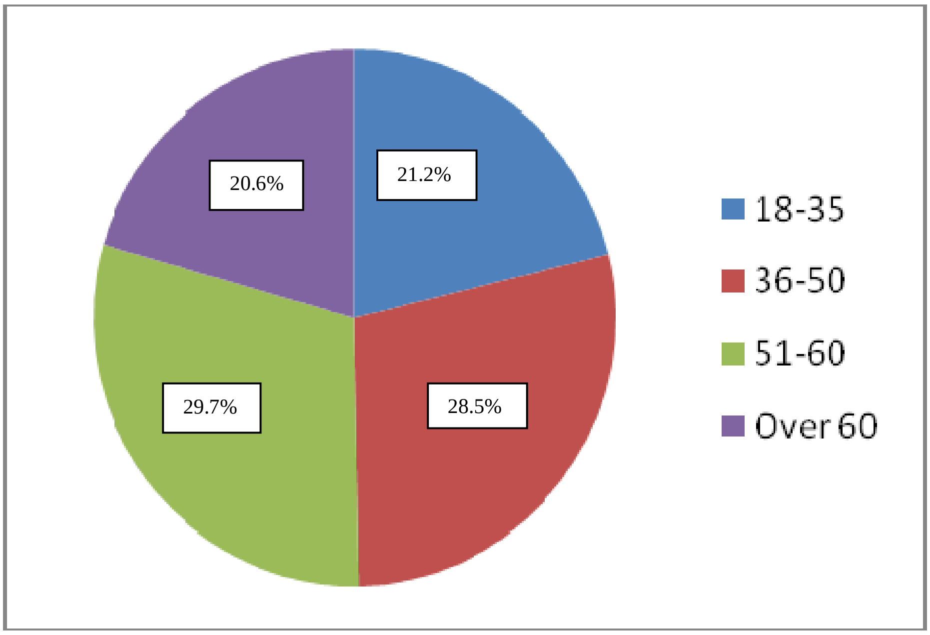


Figure 8. Pie chart of the respondents according to age brackets

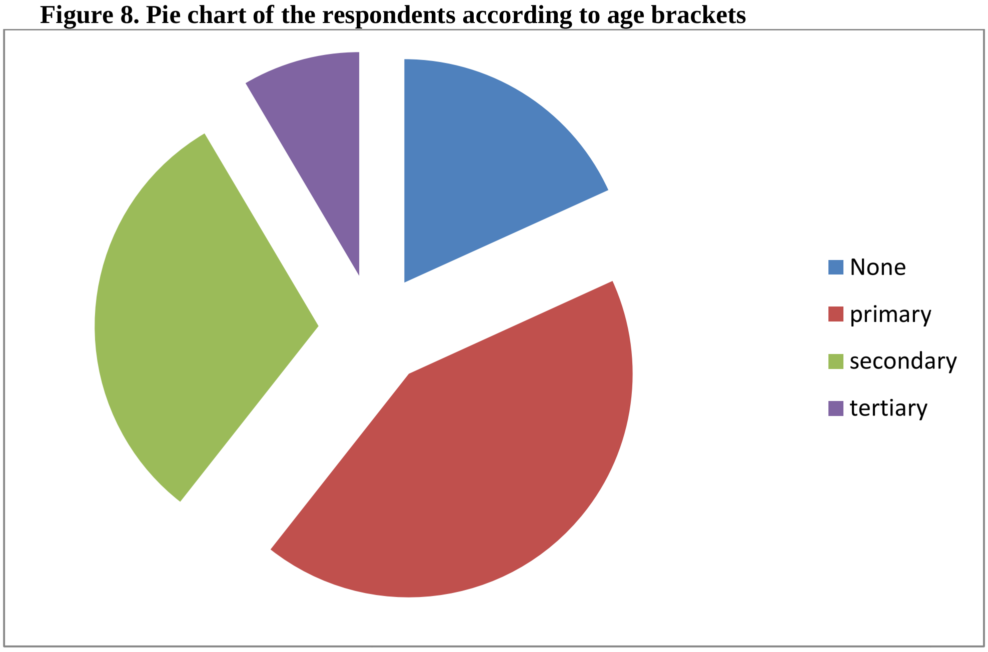


Figure 9. Pie chart showing the level of education of the respondents

4.3 Farm Sizes and Membership to Farmers Groups

Most of the respondents were small scale farmers only 10.3% owned more than 6 acres with 46.7 % and 43.0% owning 3-6 acres and less than 3 acres respectively (see Table 1). Most respondents belonged to a membership group; only 22.4% didn't belong to any membership group (see Table 2). The membership groups were social, economic or religious in nature. In these social groups members shared information on farming techniques, markets and agricultural innovations. In economic membership groups members contributed money that members borrowed and repaid with some little interest. The religious groups were tied to church membership, which created opportunities for information sharing on adaptation to climate change.

Farm size	Frequency	Percentage %
<3	71	43.0
3-6	77	46.7
>6	17	10.3
Total	165	100.0

Table 1. Land acreage owned by the respondents

Type of group	Frequency	Percentage %
Social	55	33.3
Economic	57	34.5
Religious	17	10.3
Others	1	.6
N/A	35	21.2
Total	165	100.0

Table 2. Types of groups that respondents belong to in Sakai sub-location

4.4 Crops being grown following information from friends

In the five villages sampled farmers were growing drought avoiding or early maturing crop varieties like beans and drought resistant crop varieties like millet, cowpeas, sorghum and pearl millet as shown in the Table 4 and Figure 14. Hybrid maize (Figure 10) and certified beans seeds, grafted mango trees (see Figure 14), cowpeas, pearl millet and green grams were the most adopted innovation following information from fellow farmers (Table 3).

Source: Othieno Joseph

Figure 10. hybrid maize on one of the farms in Nthongoni village,

This shows the adoption of scientific research outcomes by farmers to adapt to climate change.

Crop Grown	Percentage
Tomato	0.6
Onion	3.0
Hybrid maize	28.5
Sorghum	3.0
Green grams	5.5
Pearl Millet	6.1
Cow peas	8.5
Beans certified seeds	23.0
Mango trees	9.7
Pawpaw	0.6
Banana	1.2
Oranges	0.6
Napier grass	0.6
Avocado trees	1.2
Yams/Arrow roots	1.2
N/A	6.7

Table 3. Table of crops grown following advice from fellow farmers

Figure 11 Cowpeas intercropped with maize

There was a relatively low percentage (6.7%) of farmers who were not planting any drought resistance or avoiding crops (Table 4 and Figure 14).

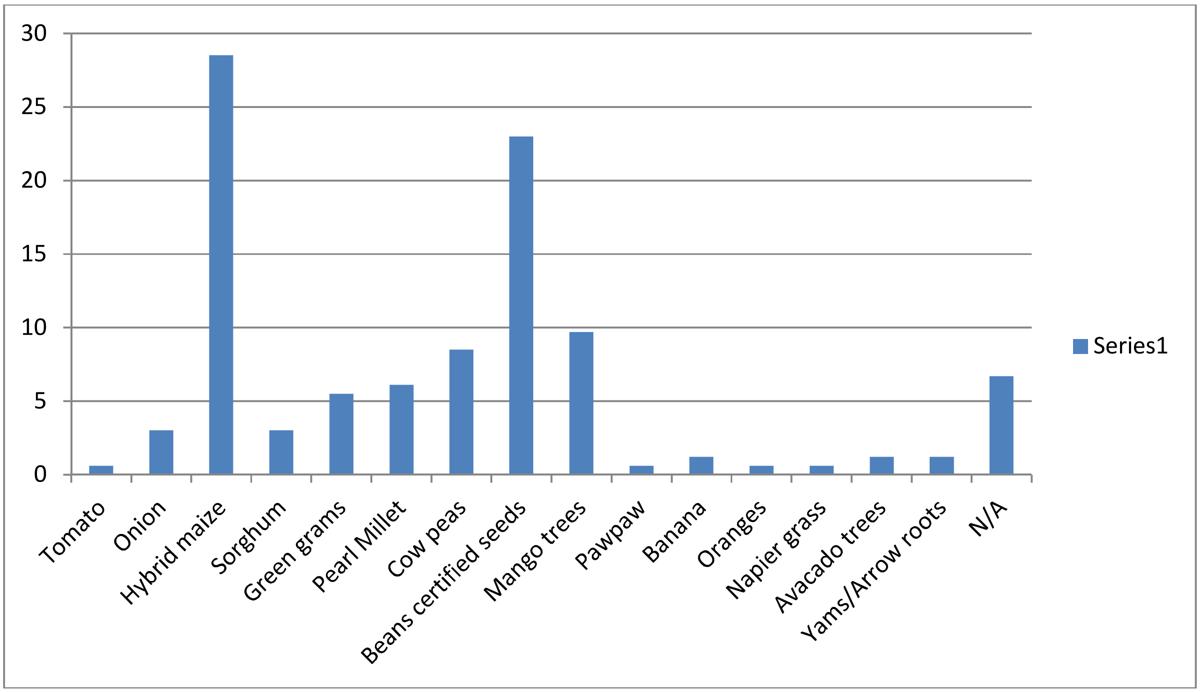


Figure 12 Bar graph of the crops planted following information from friends

4.5 Farming Innovations Adopted Following Information from Friends

Mulching, irrigation early planting, use of organic manure, planting of certified seeds and terracing were adopted by the farmers as a means of coping with the climate change (see Fi),. There was a relatively high percentage (21.8%) of farmers that didn't adopt any of these innovations (Table 4). The grafting technology was also being used in Sakai sub-location and especially with mangoes (Table 4 and Figure 13).

Figure 13 Grafted mangoes in Linga village.

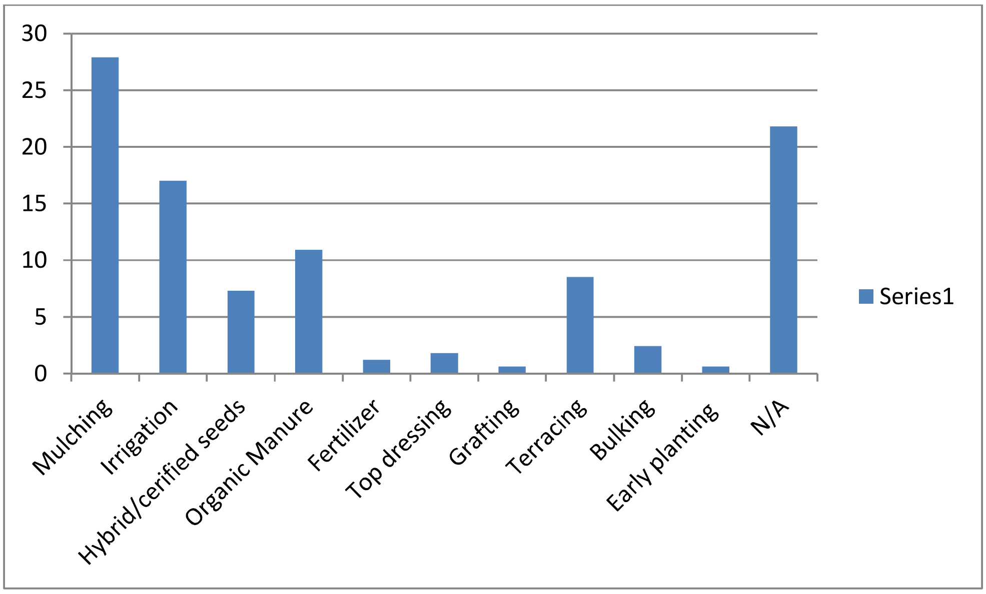


Figure 14. Farming technologies and innovation adopted by farmers.

4.6 Reasons for Adoption of Innovations

The need to increase yields and to cope with prolonged dry conditions were the main reasons given for adopting modern farming techniques and growing drought resistant or drought avoiding crops. A small percentage (2.4%) of famers adopted the farming techniques purely because their friends did (see Table 4).

Reason for Innovation Adoption	Frequency	Percentage %
To increase production	76	46.1
Because my friend did	4	2.4
To cope with climate Change	63	38.2
Others	18	10.9
N/A	4	2.4
Total	165	100.0

Table 4. Reasons given for adopting the agricultural technologies and innovations

4.7 Formal Agricultural Information Sources

Agro-chemical companies were the most popular formal source of information for farmers in Sakai sub-location; followed by government extension agents and NGOs respectively. Community Based Organization and para-professionals also served as sources of information for the farmers (Figure 15). In terms of preference the Community Based Organizations were the most preferred sources of information followed by NGOs and government extension agents in that order. Despite the agro-chemical companies being the most popular sources of information they ranked very low in terms of preference by the farmers (Figures 15 and 16).

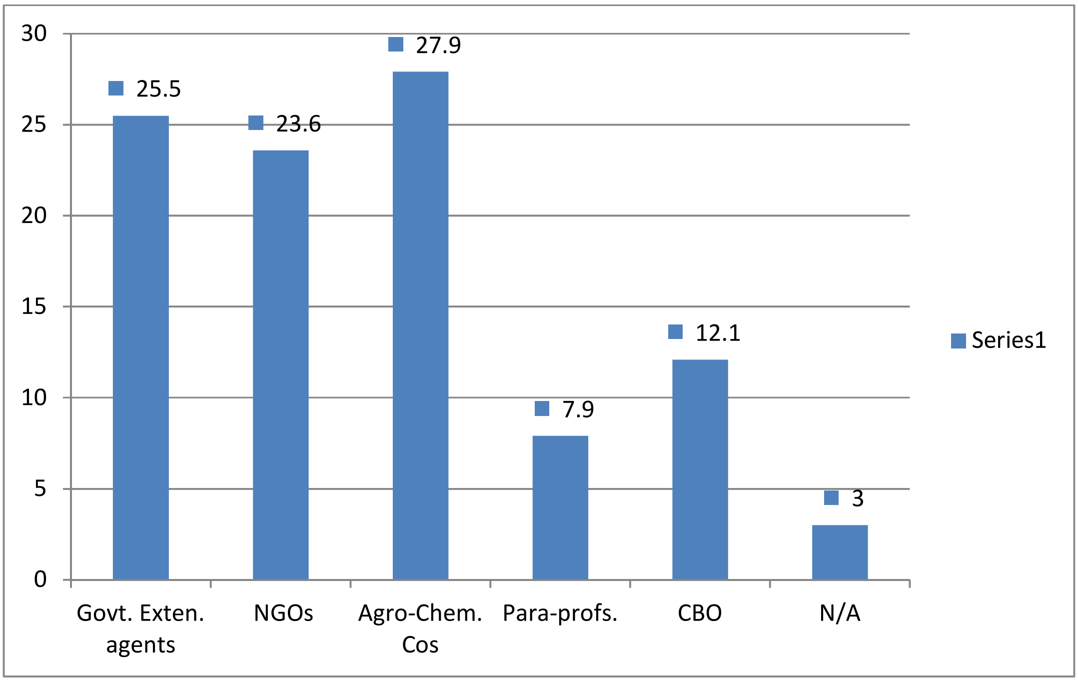


Figure 15. Formal Sources of information for farmers

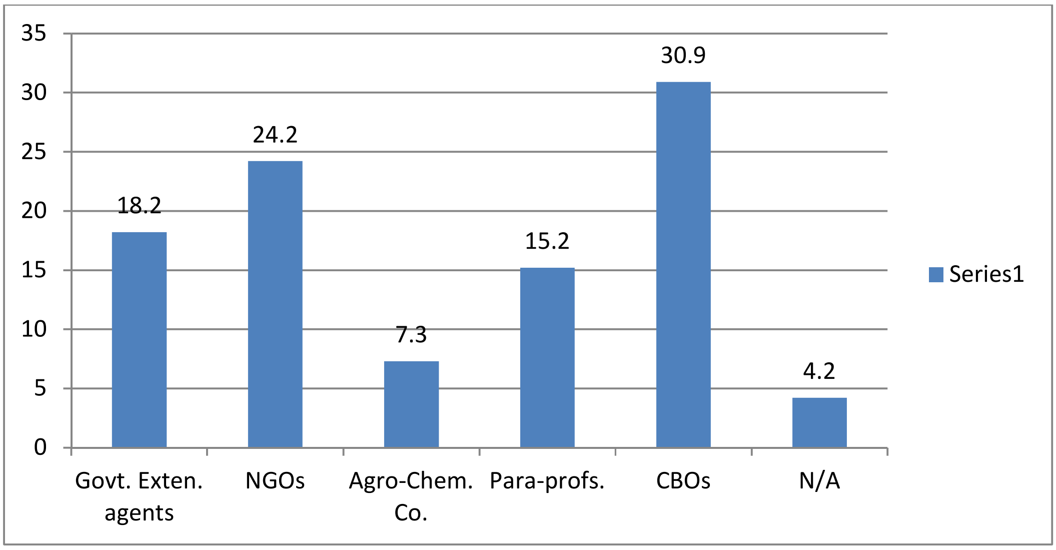


Figure 16. Formal sources of information preferred by the farmers

4.8 Frequency of Communication with Formal Sources

Most (44.8%) respondents said they communicated with a formal source only once in whole planting season while 23.6% communicated twice and only 4.2% three times (see Figures 15,16, 17). Interestingly 10.3% didn't have any communication with formal sources of agricultural information (Figure 17). This shows how important horizontal channels of communication are important in the dissemination of information and influencing behavior change. The vertical sources role is to inform the opinion leaders on novel information.

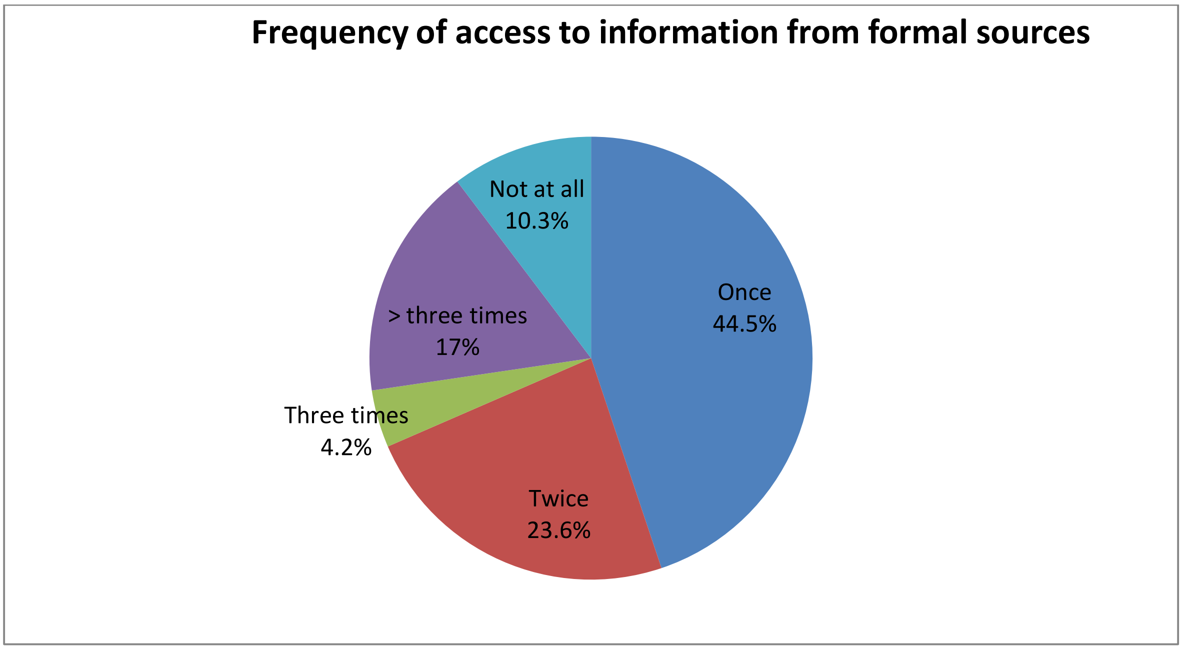


Figure 17. Frequency of access to information from formal sources

4.9 Farmers Awareness of Climate Change

Most farmers agreed that rainfall patterns have changed over time and atmospheric temperatures had risen in Sakai sub-location; alluding to the fact that the sub-location was experiencing climate change and that there were high level of awareness about climate change among the farmers. A majority (67.3%) strongly agreed that climate change was taking place in the area and only 0.6% disagree that climate had indeed changed. This strong agreement that indeed climate is changing was confirmed by the fact that 45.5% of those interviewed knew the scientific name of this phenomenon as climate change this was closely followed by the local name *Munyao* 38.2% (Table 7). All the other names (*Kungetya, Uvindukuwanzeve)*described drought or famine like phenomenon in the local dialect.

Names	Frequency	Percentage%
Munyao	63	38.2
Drought	8	4.8
Climate change	75	45.5
Kungetya	3	1.8
Uvindukuwanzeve	13	7.9
Disaster	3	1.8
Total	165	100.0

Table 5. Various names given to climate change by respondents

4.10.0 Socio-metric Data Presentation and Analysis

4.10.1 Kathamba Village

In Kathamba village 41 questionnaires were administered. The average clustering coefficient for Kathamba village is 0.030 while the maximum clustering co-efficient was 0.5 (see Table 7) this shows a wide variation in the measure of how individual actors are connected to their neighbours (see Figure 18, 19 and 23). There are many sub-groups within the Kathamba village that are loosely connected to other groups hence Social network in Kathamba village are less cohesive as shown by a low graph density of 0.011460761 examples are shown in Figures, 20 and 21.

The village has an average in-degree and out-degrees of 1.653 (Table 7); the maximum in-degree is 7. This means that most farmers in this village have at least two interpersonal source of information and also acts a source of information for approximately two farmers. The node with the highest number of incident nodes (in-degree) has seven which means that the node receives information from seven interpersonal connections in the sub-locations.

The average geodesic distance for Kathamba 3.990877 (Table 7) which means that on average a farmer in this village has to go through four encounters on to gain access to information on climate change adaptation.

Measure	Value
Graph Type	Directed
Vertices	144
Total Edges	245
Self-Loops	2
Reciprocated Vertex Pair Ratio	0.021645022
Reciprocated Edge Ratio	0.042372881
Maximum Geodesic Distance (Diameter)	8
Average Geodesic Distance	3.990877
Graph Density	0.011460761
Modularity	0.050246
Average closeness centrality	0.016
Maximum clustering coefficient	0.500
Average clustering coefficient	0.030
Median closeness centrality	0.002
Maximum eigenvector centrality	0.036
Average eigenvector centrality	0.007
Median eigenvector centrality	0.004

Table 5. Table of socio-metric values of Kathamba village

Kathamba Socio-gram shows a network with many central farmers and many peripheral vertices (Figure 18 and 22). In this village with vertex pairs having a low probability of forming pairs as shown by the reciprocated vertex pair ratio of 0.021645022 (Table 7), the mix of weak links/ties and strong bonds may explain this pattern (see Figures 19 and 20).

In general Kathamba village socio-grams show a social structure characterized by many central actors and many peripheral actors connected by a mix of strong bonds and weak ties. According to Granovetter (1973) this mix is good for flow of novel information.

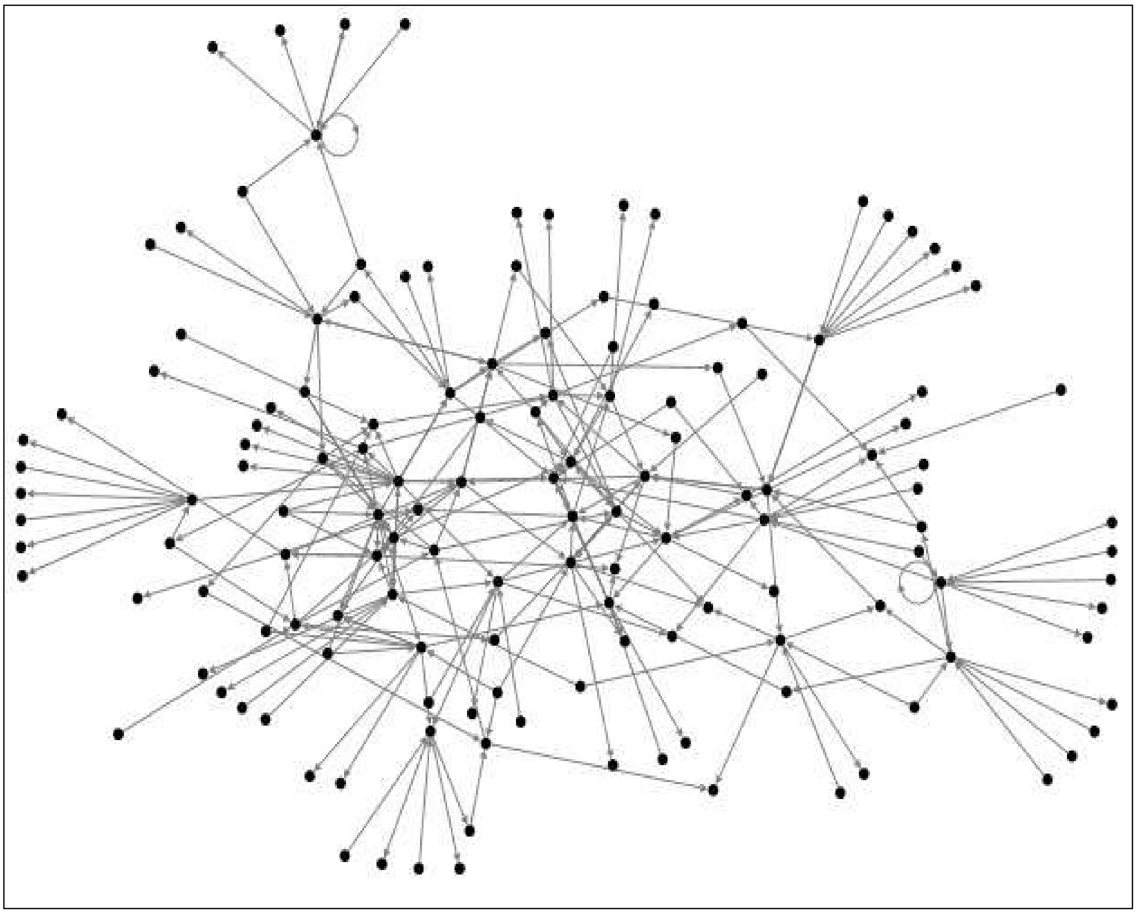


Figure 18.Kathamba socio-gram showing all the vertices and edges

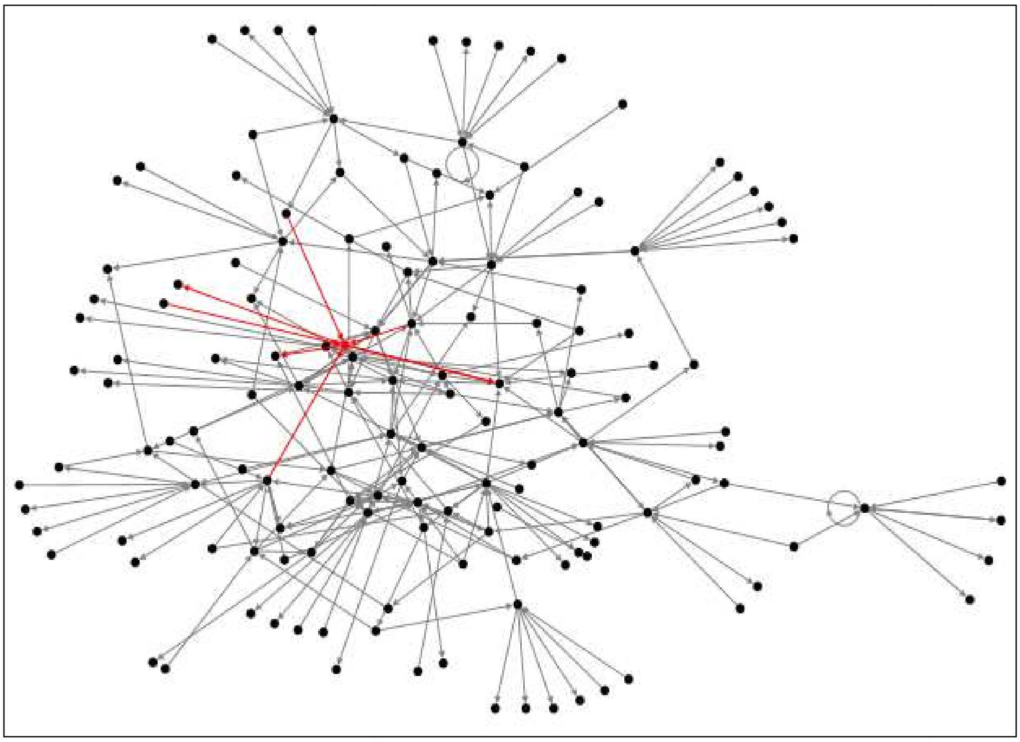


Figure 19 Socio-gram showing a central node (Philip)

The red edges in Figure 19 shows an actor (Philip) who is central in this network and who serves a centre for the diffusion of information, such an actor can act as a broker or a gatekeeper in the communication process. This actor acts a link that can disseminate information through the whole network because he/she is positioned on a shorter geodesic path or is well positioned to reach all the other nodes. However such an actor can also hoard information and therefore deny many actors vital information since he plays a bridging role in the network when it comes to the flow of information.

Below are Kathamba ego-centric networks socio-grams (Figures 20, 21 and 23) showing connections around selected nodes drawn from the network. The selected socio-grams show the individual characteristics of the various farmers in Kathamba.

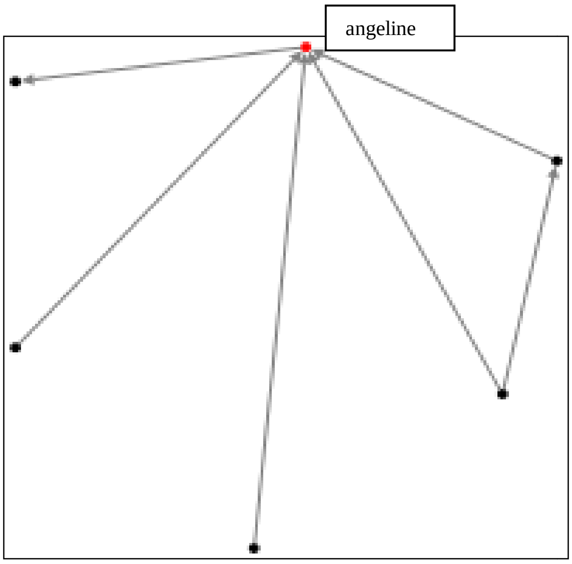


Figure 20. Angeline, a bridging actor,

To appreciate the linking role played by the above actor (Figure 20); compare this socio-gram with the Figure of 23 showing the same actor is a bigger network.

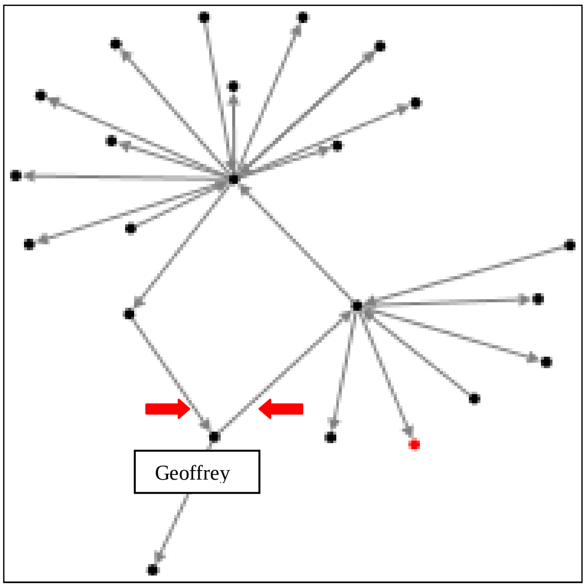


Figure 21. Geoffrey a peripheral actor weakly linked by the two nodes (red arrows)

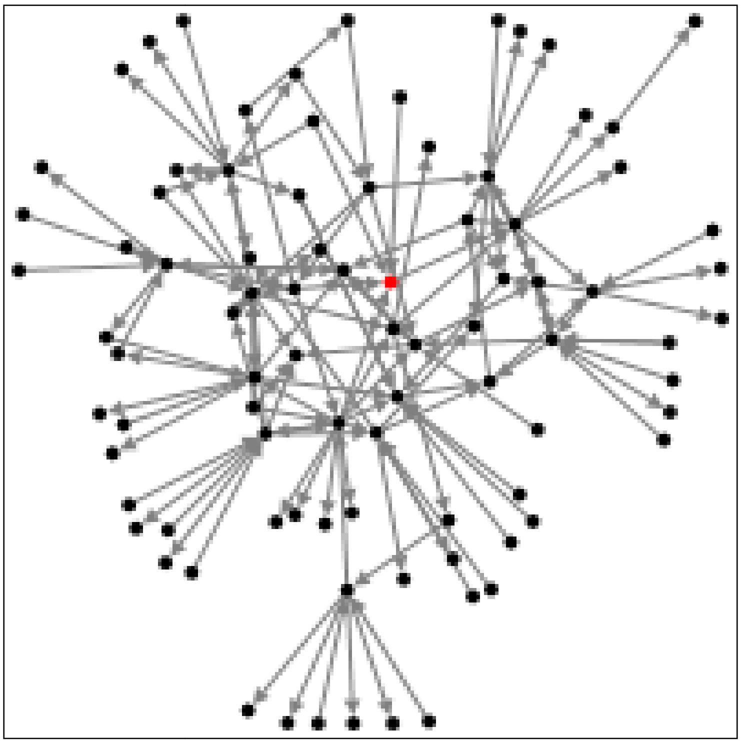


Figure 22 Daniel (red node) a centrally positioned actor

Daniel (Figures 22 red node) in the social network acts as a link to peripheral actors both directly and indirectly.

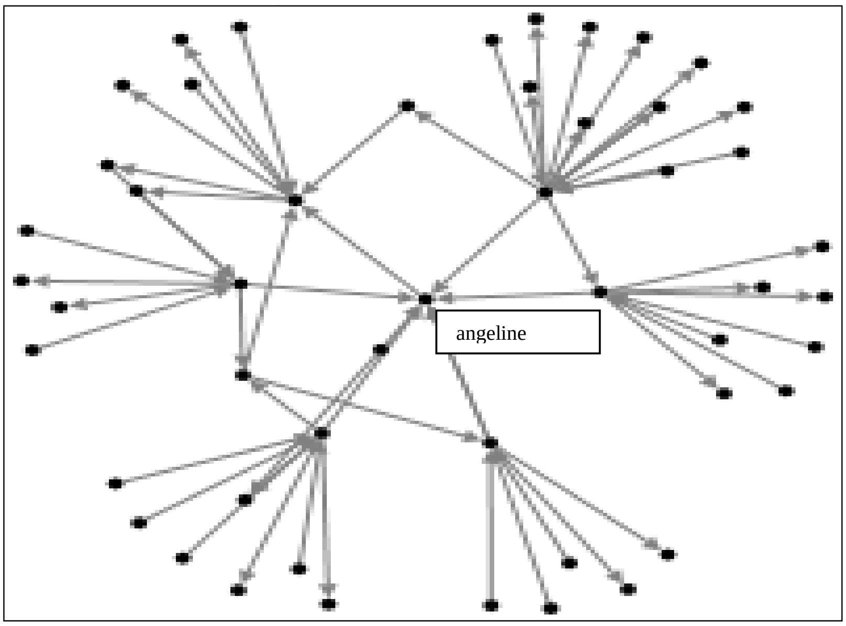


Figure 23.Angeline in a wider socio network, compare with figure 20.

Two self loops (see Figures 18 and 19) were recorded in Kathamba, while this isn't possible as no farmer can nominate his/herself as a source or receiver of information; this could be due to an error arising from entering of same names because some farmers shared similar names.

4.10.2 Socio-metric analysis of Kiteani Village

Kiteani village recorded a total of 93 vertices and a total of 120 edges and a graph density of 0.014 and the average social distance (Geodesic distance) between nodes being 4.4 (see Table 8). This means that on average a farmer will need a minimum of 4 edges to access information on climate change adaptation. The reciprocated vertex pair ratio is 0.017 (see Table 8) and reciprocated edge ratio of 0.034, pointing to a social network where actors have a low probability of forming mutual pairs between each other; the weak structural linkages in Figure 24 corroborates this Each actor has at least one source of information and actors as a source for another actor as shown by the in-degree and out-degrees of 1.28 (see Table 8).

Kiteani village like Kathamba has high centralization (see Figures 24, 25, 26 and 27) with many actors at the centre and many at the periphery many occurring in groups. However unlike Kathamba the Kiteani village has some periphery actors with zero betweenness centrality. Isolated sub-groups cannot access information from the social networks around them and in the diffusion of innovations will most likely constitute the laggard group. This is because such peripheral actors don't mediate with other vertices and therefore don't disseminate information to other actors neither do they get information from other actors. This is supported by an equally low centrality which measures how well positioned a node is to get information earlier. The closeness centrality is only 0.011 and a high geodesic distance of about 4.5 (Table 8). Since closeness centrality is important for availability of novel knowledge, the low value shows the low number of sources of such information, this is true as such people are normally few in any social system and are normally weakly linked to their groups though they have great influence on the behaviours of their followers Granovetter (1973) Strength of weak ties principle.

The actors with low out and in-degrees could be positive social deviants experimenting/practicing novel farming techniques and will therefore not need information from the social system. This was supported by follow-up interview calls made to such actors; three out of the five interviewed were keeping exotic dairy animals; this was a rare observation and one who had refused to adopt by adapting appropriate agricultural technologies claiming that climate change was an act of God and wouldn’t be countered by agricultural techniques. The farmers keeping exotic dairy animals were cosmopolites from a higher social class and this may explain their appearance as isolated nodes in the socio-grams. They most likely interact with other farmers from a higher social class or from other parts.

Graph type	Directed
Vertices	93
Edges with duplicates	2
Total edges	120
Reciprocated vertex pair ratio	0.017094017
Reciprocated Edge ratio	0.033613445
Maximum Geodesic Distance (Diameter)	9
Average Geodesic Distance	4.398507
Graph Density	0.013908368
Maximum Eigenvector Centrality	0.063
Average Eigenvector Centrality	0.011
Median Eigenvector Centrality	0.007
Minimum Closeness Centrality	0.002
Maximum Closeness Centrality	0.250
Average Closeness Centrality	0.011
Median Closeness Centrality	0.003
Maximum Clustering Coefficient	0.500
Average Clustering Coefficient	0.030

Table 6 Graph metrics for Kiteani village

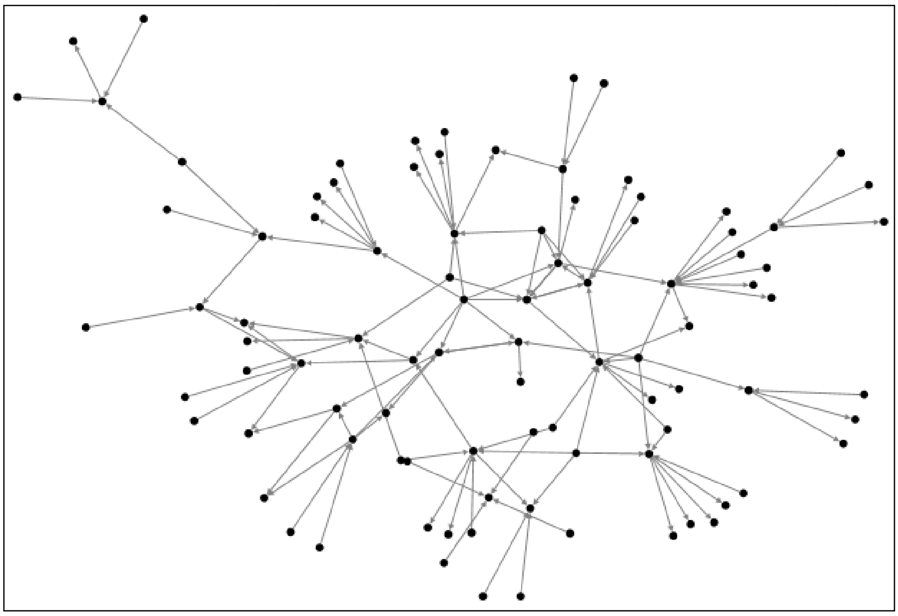


Figure 24.Kiteani Socio-gram showing subgroups linked by weak links

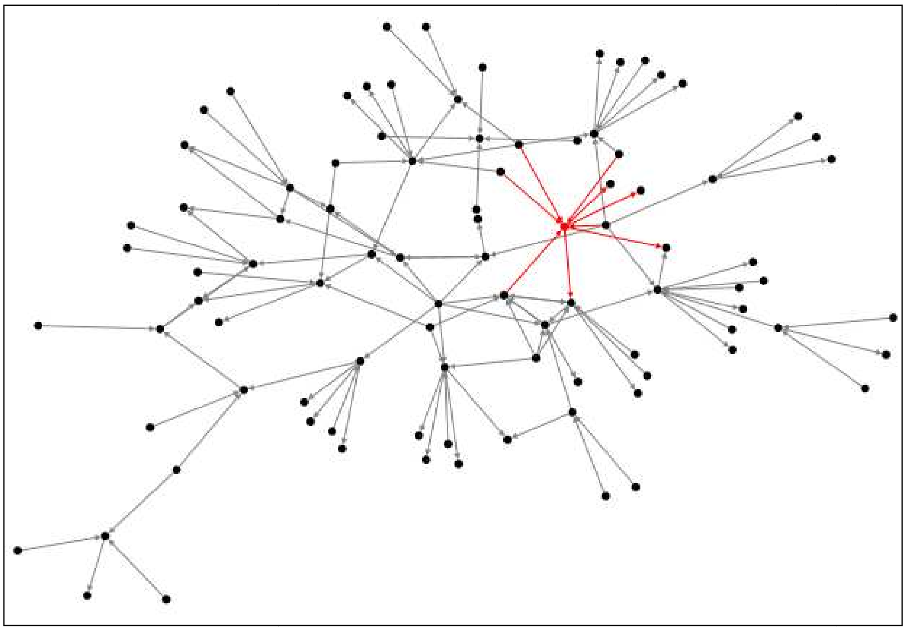


Figure 25. Kiteani socio-gram (Harel-Koren Fast Multiscale format)

This node (marked red in Figure 25) is centrally positioned and exchanges information across the network.

Below are socio-grams (Figures 25 and 26) drawn in Fruchterman-Reingold format for visual comparison with the Harel-Koren Fast Multiscale format, the former best illustartes clustering.

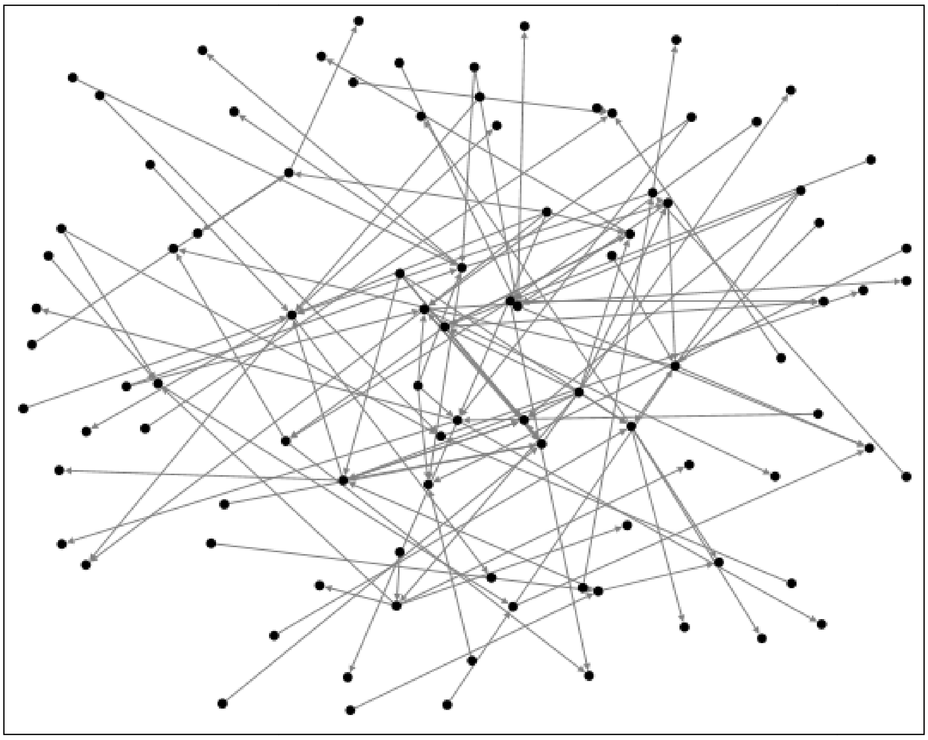


Figure 26.Kiteani Village Socio-gram in Fruchterman-Reingold format

Below are some of the individual socio-grams (Figure 27, 28,29 and 30) for farmers in Kiteani village showing their individual characteristics that subsequently form the information exchange patterns. The socio-grams have brief descriptions. While in this village Christine (Figure 30) is peripheral in this socio-gram in the Linga village socio-gram she is actually a central actor (Figure 31).

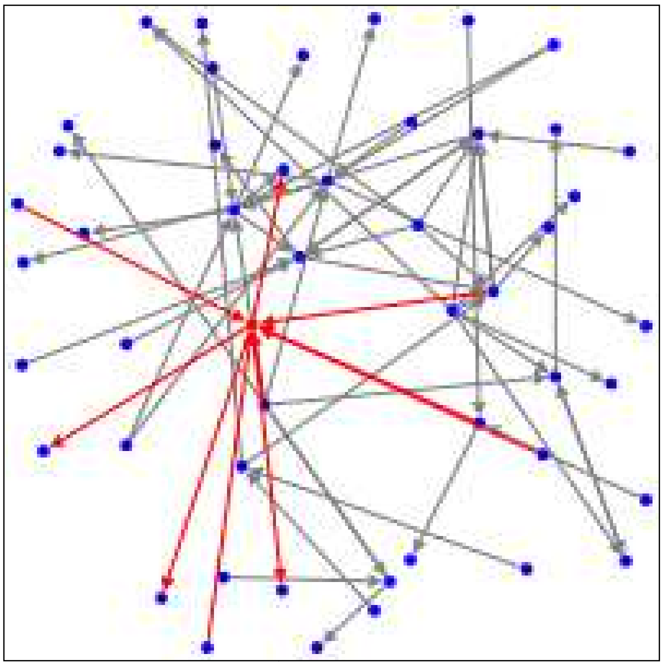


Figure 27. A socio gram showing Damaris, a central actor

Damaris is centrally position and has the potential to receive and disseminate the information throughout the network

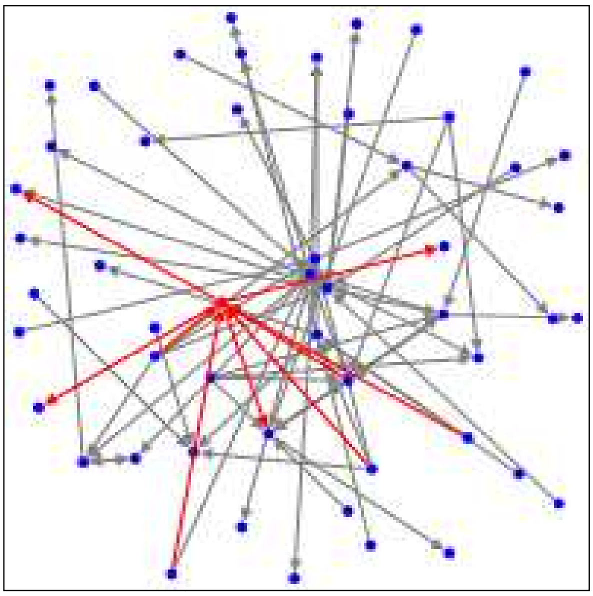


Figure 28. Mbaika node in the socio-gram

This socio-gram (Figure 28) shows Mbaika's bridging function throughout the network

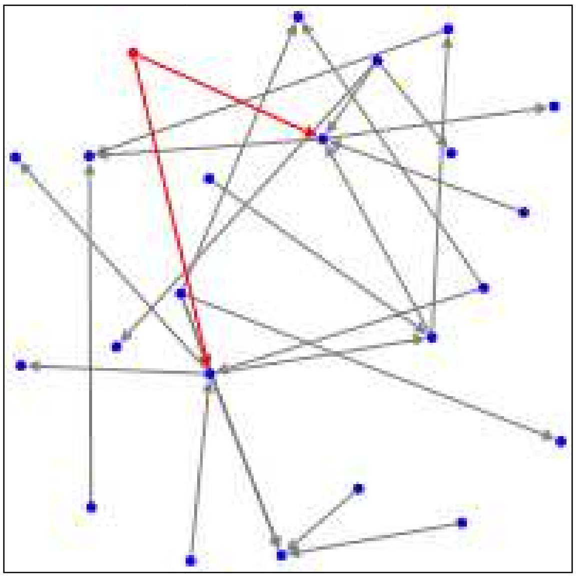


Figure 29.Socio-gram showing Mr. Mutindi

Though peripheral, Mr. Mutindi is connected to central actors and can therefore still access information despite his peripheral position which might have been disadvantageous, if he was not linked to central actors..

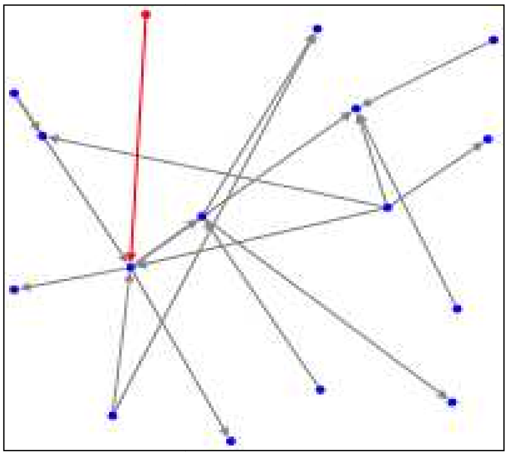


Figure 30 Christine Socio-gram

Christine is peripheral (Figure 30) and only connected to a peripheral actor, she therefore has little access to information from this network. Though Christine (Figure 30) appears to be at the periphery but she is from a neigbouring village (Linga). Christine therefore acts as a link between the two villages; below is her individual socio-gram as generated from Linga village socio-gram, where she is a central actor (see Figure 31).

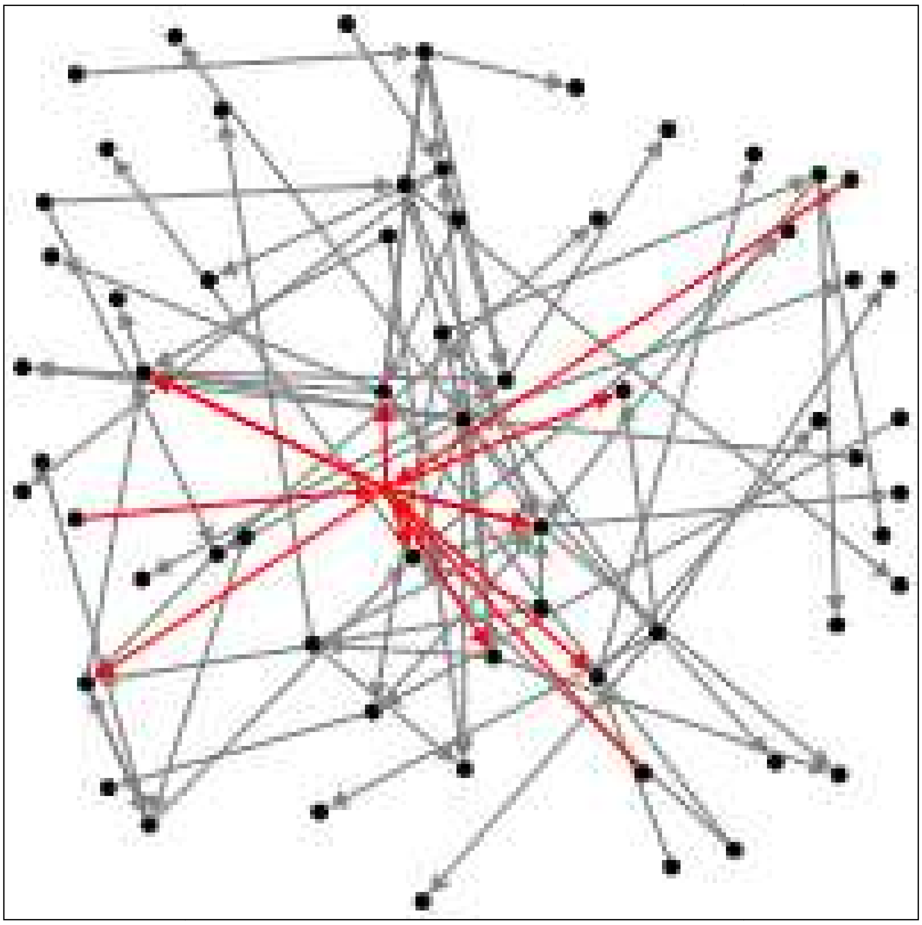


Figure 31. Christine socio gram now showing her at the centre

4.10.3 Socio-Metrics for Linga Village

Linga village generated 109 vertices and 137 edges from the 36 questionnaires. In-degree and out degree for Linga village is 1.229 and the graph density is 0.0114 (Table 9). Linga village network is characterized by centrally strongly bonded groups and weakly linked peripheral actors (Figure 32). Linga village recorded the highest vertex out degree at 11 (Table 9) meaning that it had an actor who has disseminated information to the greatest number of people (see Figure 32 and 33). The village also had the lowest values for reciprocated vertex and edge ratios at 0.008 and 0.015 (Table 9) respectively illustrating low levels of positive feedback among the actors as they had a relatively low potential to form mutual pairs. But the Linga village recorded the highest maximum closeness centrality at 0.333 and the out-degree at 11 (Table 9), this is supported by the closely knit structure (Figures 31, 32 and 36).

Like in the previous graph metrics for Kathamba and Kiteani villages the average Eigenvector centrality value is low at 0.0063 (Table 9). This value measures the importance of a node as a source of information by measuring how well it is connected to other well connected nodes Bonacich (1972) and therefore the notion of power among the actors in social networks. The low Eigenvector figure indicates few nodes that are connected other important nodes in the social network as it favours nodes that have high correlations with many other nodes (Bonacich, 1972).

The maximum and average clustering coefficients for Linga were 0.167 and 0.008 respectively (Table 9). Clustering coefficient is not a centrality measure since it gives the densities of the ego-networks for every node. A farmer with a high clustering co-efficient is connected to other farmers who are likely connected to each other.

Graph Metrics	Value
Graph Type	Directed
Vertices	109
Total Edges	137
Reciprocated Vertex Pair Ratio	0.007518797
Reciprocated Edge Ratio	0.014925373
Maximum In-Degree	7
Average In-Degree	1.229
Median In-Degree	1.000
Maximum Geodesic Distance (Diameter)	9
Average Geodesic Distance	4.209438
Graph Density	0.011382943
Maximum Out-Degree	11
Average Out-Degree	1.229
Median Out-Degree	1.000
Minimum Closeness Centrality	0.002
Maximum Closeness Centrality	0.333
Average Closeness Centrality	0.026
Maximum Eigenvector Centrality	0.069
Average Eigenvector Centrality	0.009
Median Eigenvector Centrality	0.004
Maximum Clustering Coefficient	0.167
Average Clustering Coefficient	0.008

Table 7. Graph metrics for Linga village

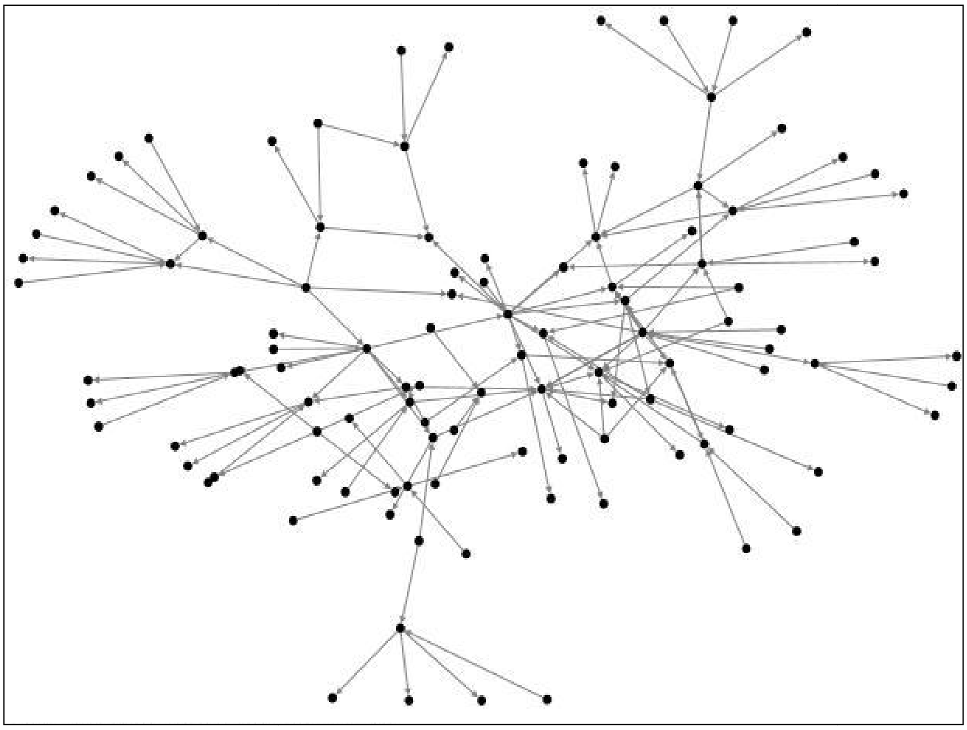


Figure 32. Linga village socio-gram Harel-Koren Fast multiscale format

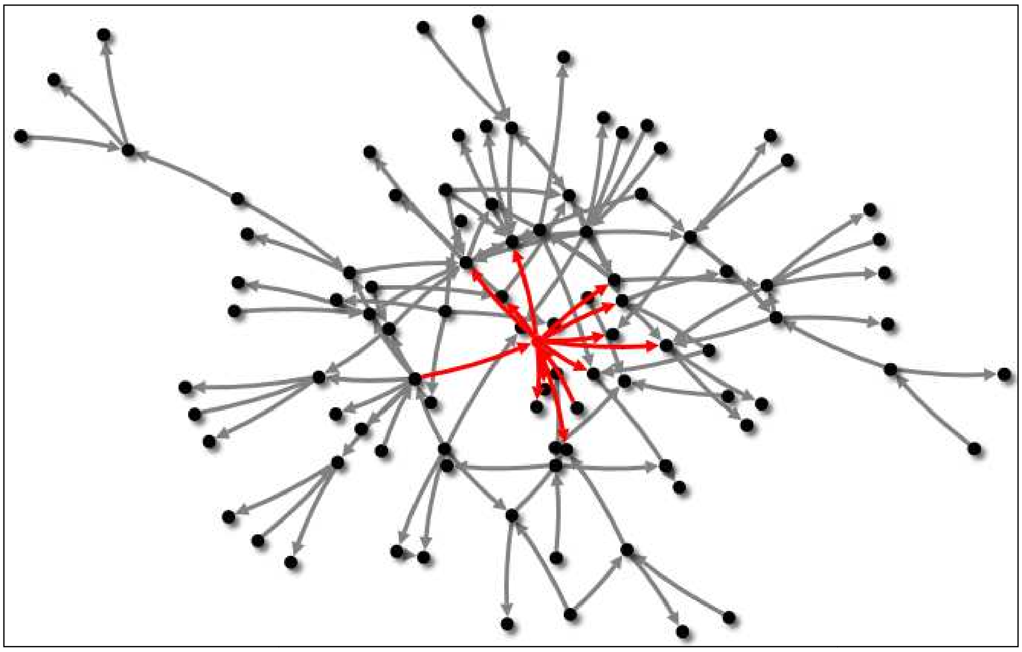


Figure 33. Linga Socio-gram showing a central node

The node acts a link to virtually every actor in the network.

The red colored edges and anode (Figure 33) show the connectivity in Linga socio-gram, this structure supports the flow of information through the social network. Figure 34 is a socio-gram showing the relational basis upon which information is shared among the actors in this network.

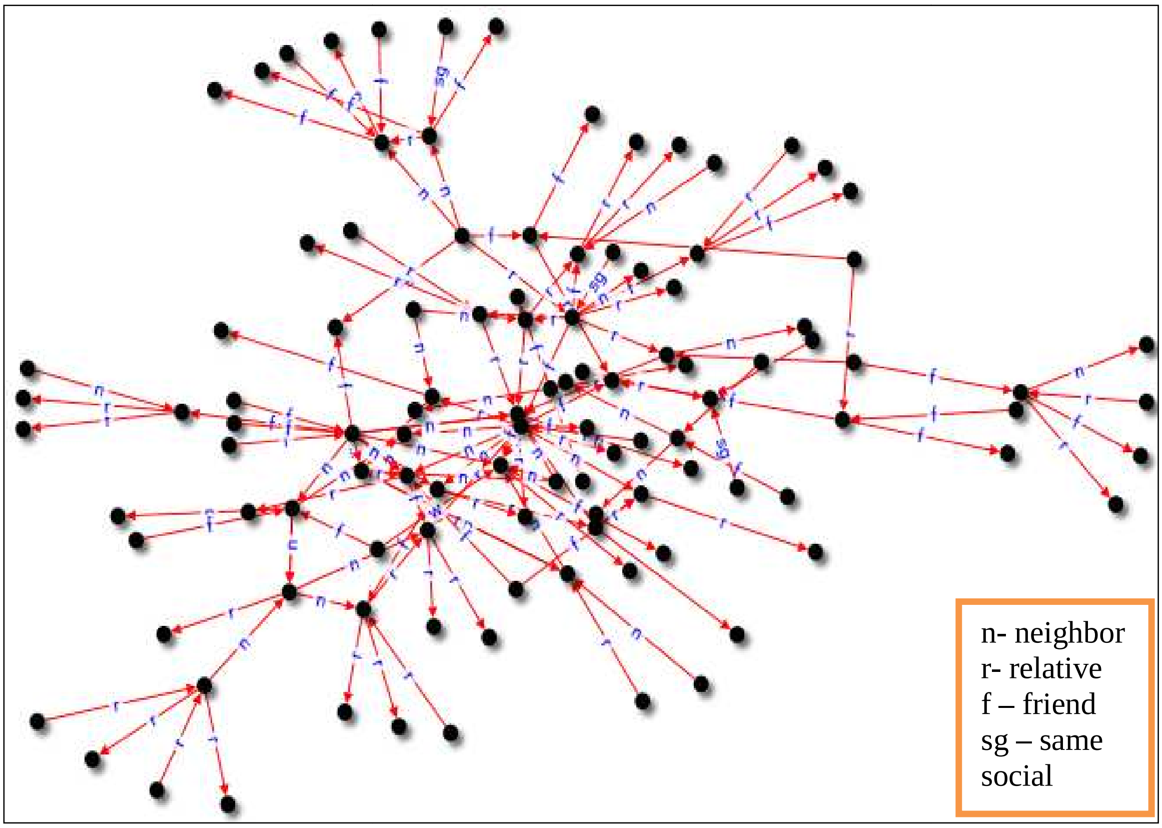


Figure 34.Linga Village Socio-gram showing the type of the relation

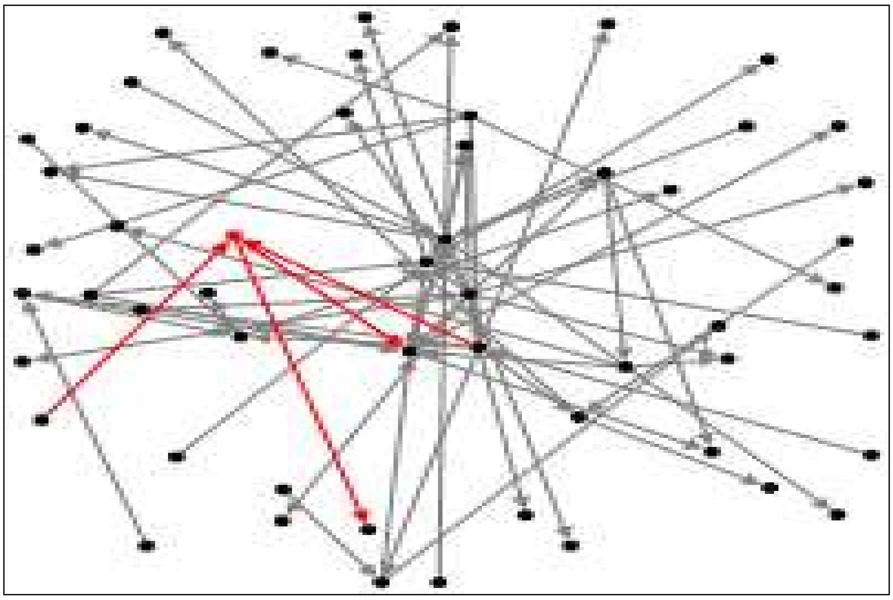


Figure 35. Socio-gram showing how Fitrisia connection to both peripheral and central actors

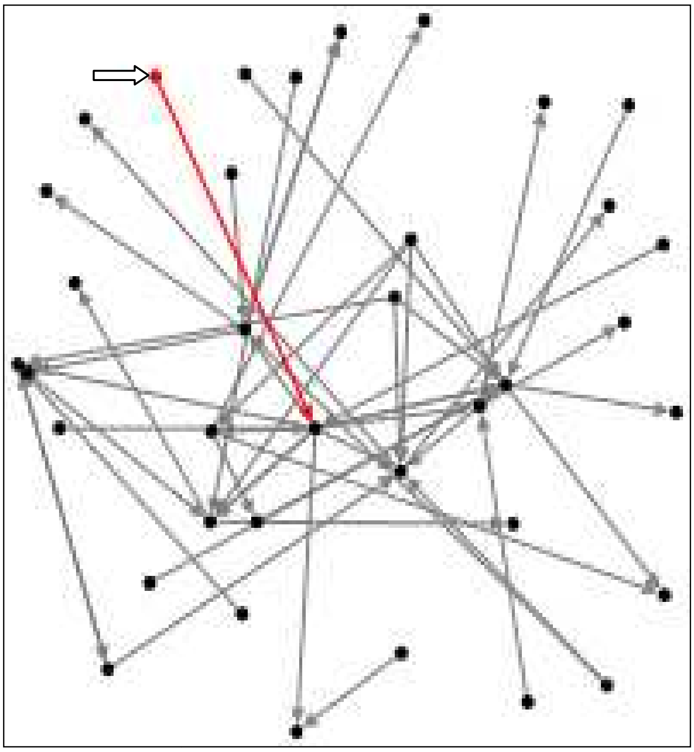


Figure 36. Fransis, (arrow) a peripheral actor linked to a central actor

Fransis (Figure 36) can therefore access information despite his peripheral position

4.10.4 Muiu Village Socio-Metric Analysis

Like networks in Kathamba, Kiteani and Linga villages; Muiu village has structures composed of many groups that are connected to other groups through weak ties but strongly clustered within groups. This village recorded the lowest value for maximum in-degree and out-degree at 6 and 8 (Table 10) respectively but had the highest geodesic distance at 13 among the five villages sampled. These two values are congruent as a low inflow and out flow of information through a node are proportionate with the high geodesic distance in the social network the structure of the socio-grams also support this fact (Figures 37 and 38). But Muiu socio-grams also show the importance of bridging actors in a network (Figure 39).

The wide variation between the maximum and minimum clustering coefficients 0.5 to 0.001 with an average of 0.03 once again shows a mix of strength of ties throughout the network (Table 10).

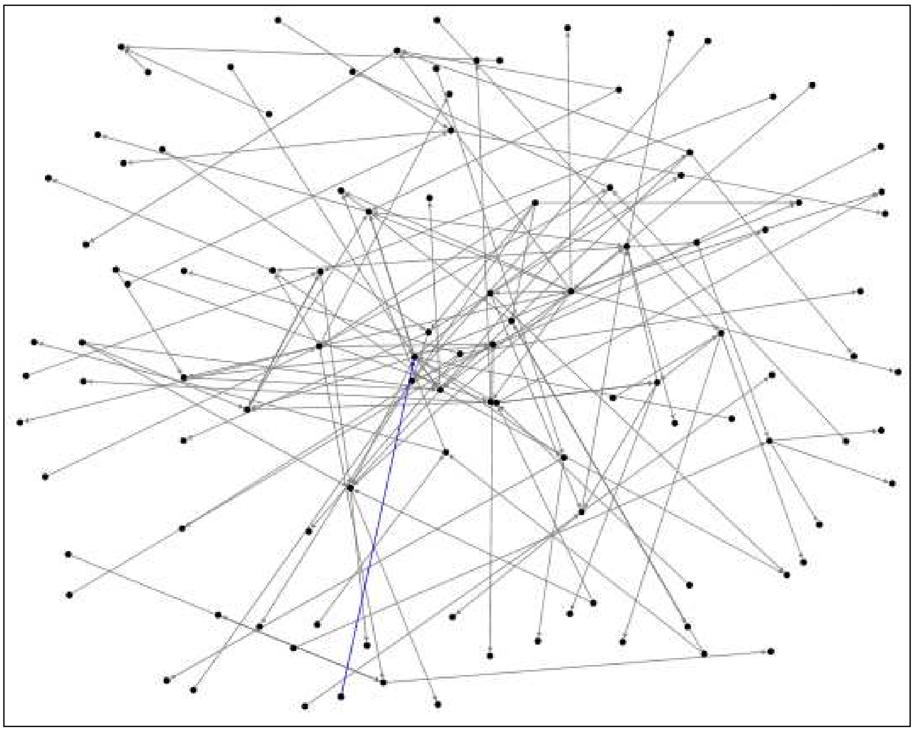


Figure 37.Muiu Socio-gram (Fruchterman-Reingold format

The edge in (Figure 37 blue edge) shows how a peripheral actor is connected to a central actor in the network.

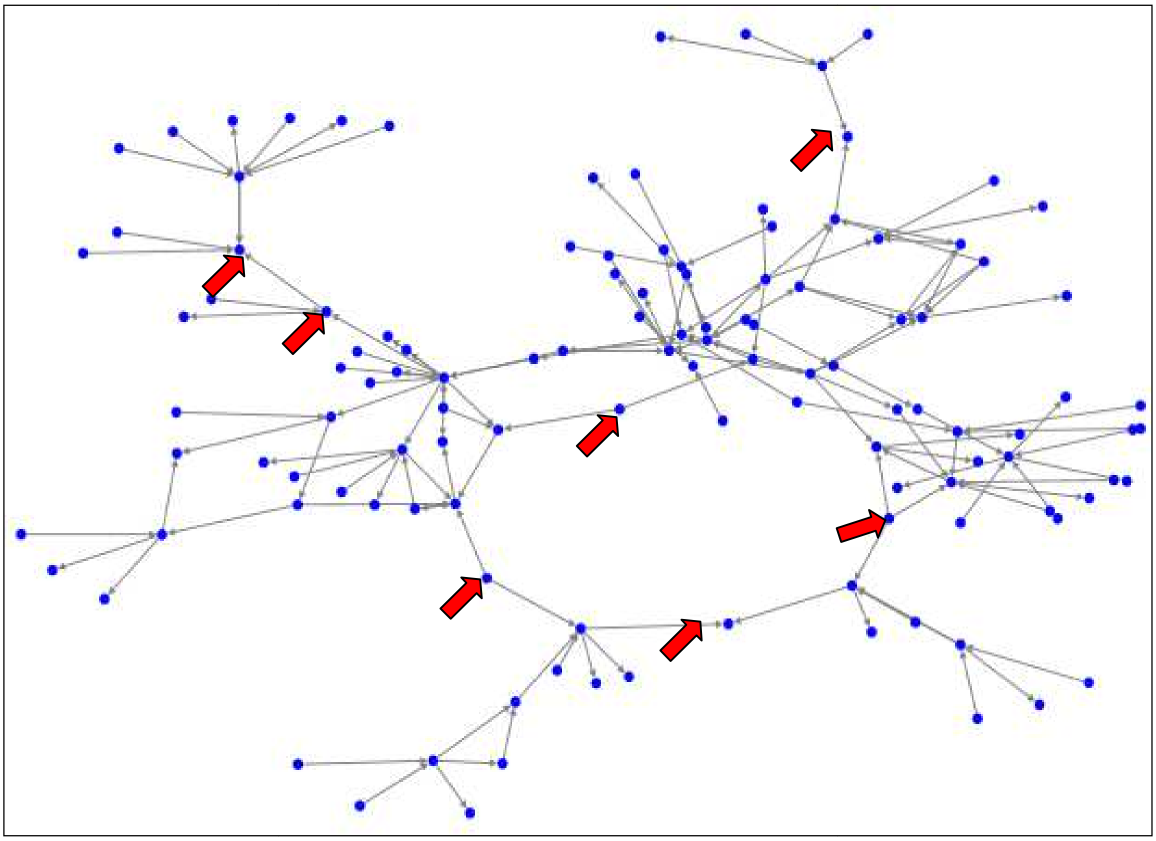


Figure 38. Muiu socio-gram (Harel-Koren Fast multiscale format)

Note the many weak links (bridges marked with red arrows in Figure 38) between sub-groups.

The above socio-gram (Figure 38) shows many sub-groups which are strongly bonded to each other but loosely linked to other subgroups through weak linkages most composed of one or two bridging edges.

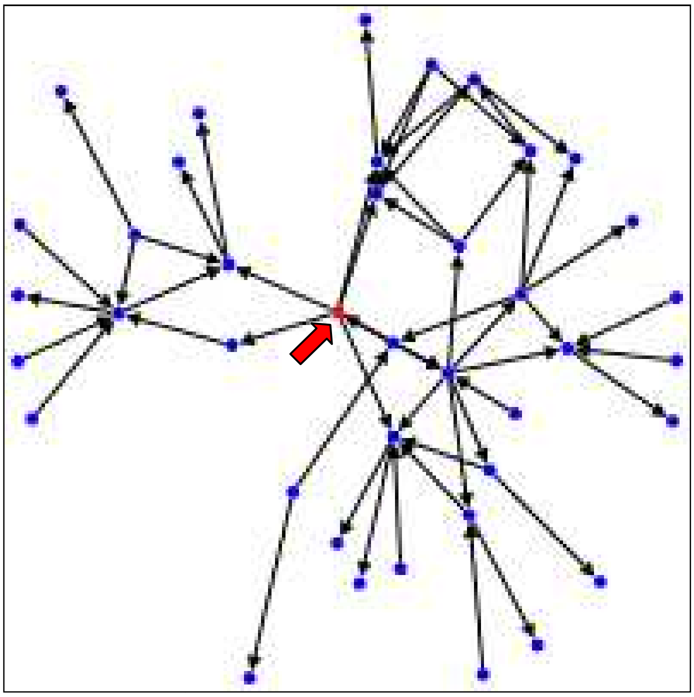


Figure 39. John of Muiu village Socio-gram, showing a bridging role

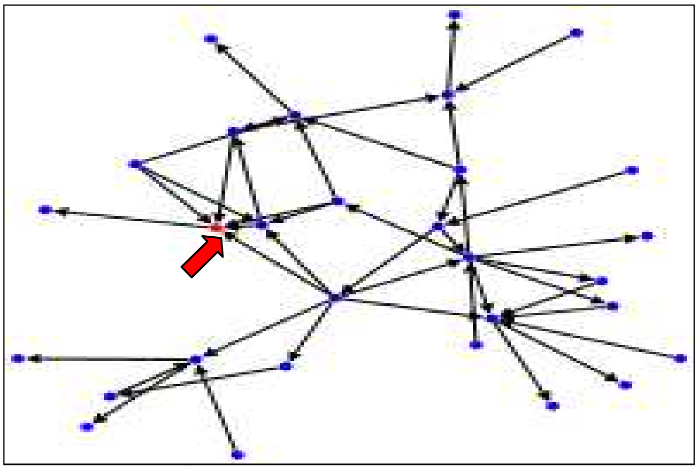


Figure 40.Fransica; a central actor and therefore offering a nexus for bonding.

The red edges (Figures 39 and 40) show how a central node acts as a link between the centre and periphery. The single connecting node is very crucial for a group of farmers' access to information. Its deletion of this network will lock out the group from access to information a network with many bridges mayn't support effective flow of information as deletion of bridges block flow of information.

Graph metric	Value
Vertices	120
Edges With Duplicates	4
Total Edges	147
Reciprocated Vertex Pair Ratio	0.006944444
Reciprocated Edge Ratio	0.013793103
Connected Components	4
Maximum Vertices in a Connected Component	103
Graph density	0.010154062
Maximum Edges in a Connected Component	133
Maximum Geodesic Distance (Diameter)	13
Average Geodesic Distance	5.541643
Maximum In-Degree	6
Average In-Degree	1.208
Median In-Degree	1.000
Maximum Out-Degree	8
Average Out-Degree	1.208
Median Out-Degree	1.000
Minimum Closeness Centrality	0.001
Maximum Closeness Centrality	0.500
Average Closeness Centrality	0.023
Median Closeness Centrality	0.002
Maximum Eigenvector Centrality	0.075
Average Eigenvector Centrality	0.008
Median Eigenvector Centrality	0.002
Maximum Clustering Coefficient	0.500
Average Clustering Coefficient	0.030

Table 8. Graph metrics for Muiu village

4.10.5 Socio-Metric Analysis of Nthongoni Village Network

In Nthongoni village a total of 84 vertices and 98 (Table 11) edges were generated from the questionnaires. The visual observation of the socio-grams show a sparsely connected network of farmers with a closeness centrality of 0.018 (Table 11), this means that farmers have relatively long path lengths to cover in order to reach other farmers or they aren't easily reachable by fellow farmers. The high geodesic distance 5.54 (Table 11) is congruent with the low closeness centrality. Nthongoni farmers' social networks therefore present a structural disadvantage to access to agricultural information (see Figure 41, 42 and 43).The socio-grams also illustrate the existence of several sub-groups at the periphery that are connected central actors (Figures 44). The socio-gram like those for Muiu village have many bridges (Figure 41, 43 and 44).

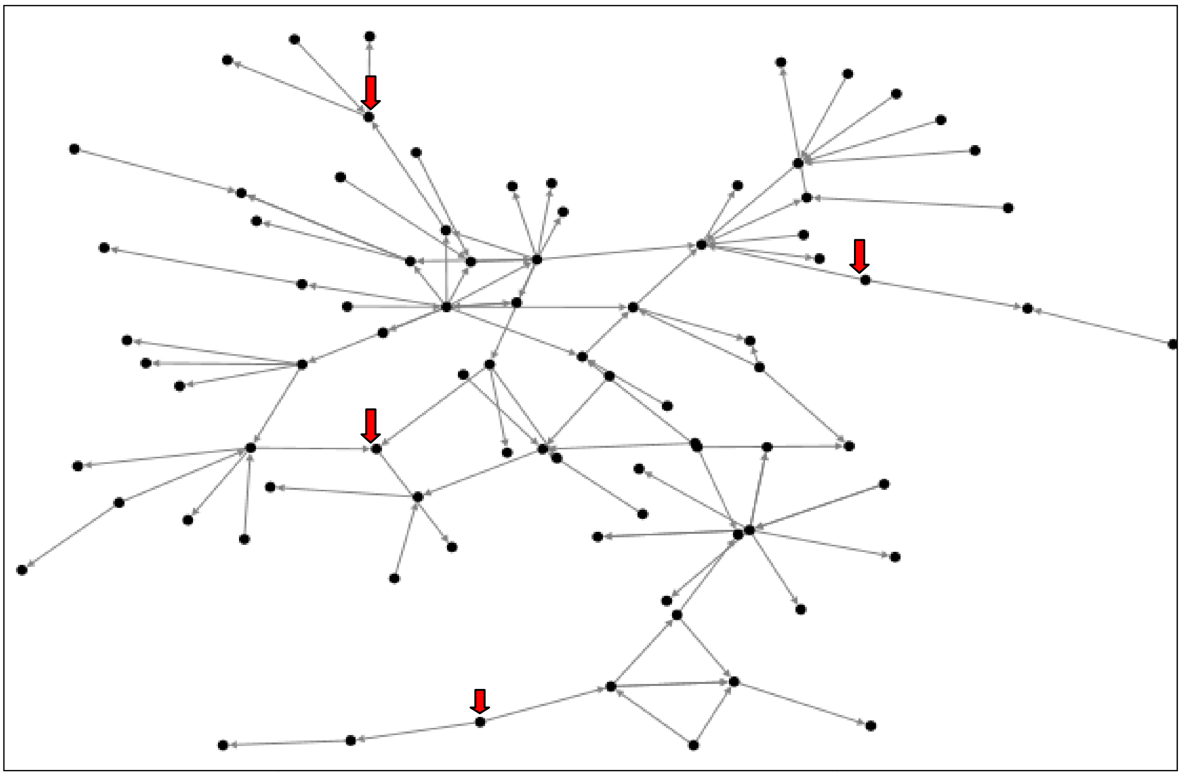


Figure 41.Nthongoni socio-gram, the arrows show the bridging nodes

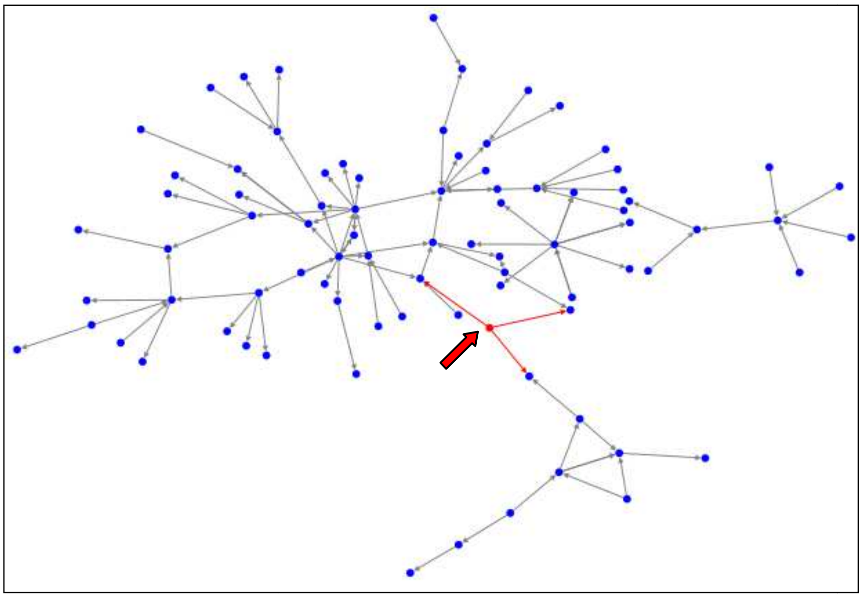


Figure 42.Nthongoni socio-gram showing a bridging actor

The deletion of such actor figure 42 (bridge- marked with arrows) will completely lock out a section of the network from access to information.

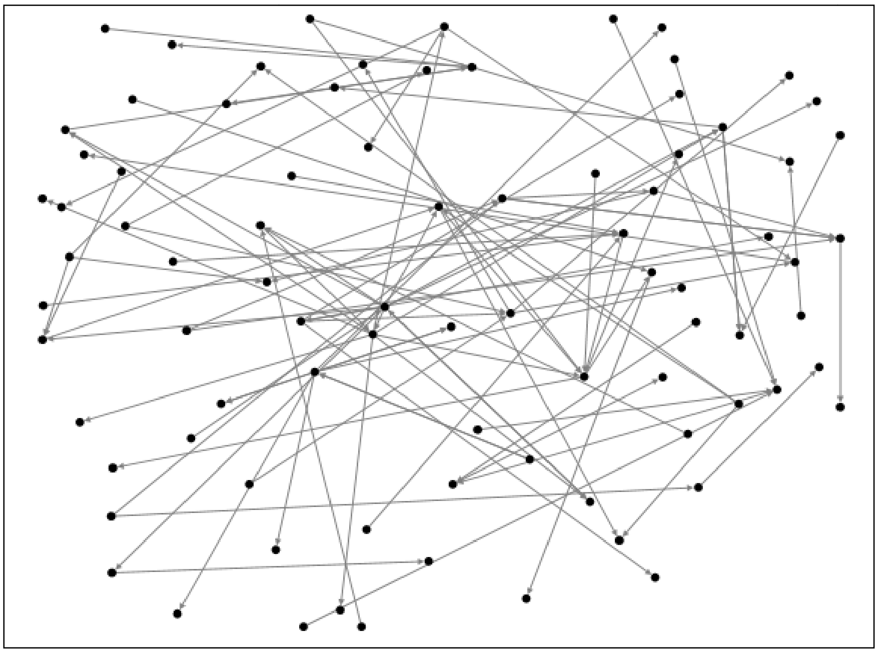


Figure 43.Nthongoni Socio-gram showing the whole network

Graph Metric	**Values**
Graph Type	Directed
Vertices	84
Edges With Duplicates	10
Total Edges	98
Reciprocated Vertex Pair Ratio	0.010869565
Reciprocated Edge Ratio	0.021505376
Maximum Vertices in a Connected Component	68
Maximum Edges in a Connected Component	81
Maximum Geodesic Distance (Diameter)	12
Average Geodesic Distance	4.587542
Graph Density	0.013339071
Maximum In-Degree	5
Average In-Degree	1.107
Maximum Out-Degree	10
Average Out-Degree	1.107
Median Out-Degree	1.000
Minimum Closeness Centrality	0.002
Maximum Closeness Centrality	0.143
Average Closeness Centrality	0.018
Median Closeness Centrality	0.004
Maximum Eigenvector Centrality	0.106
Average Eigenvector Centrality	0.012
Median Eigenvector Centrality	0.003
Maximum Clustering Coefficient	0.500
Average Clustering Coefficient	0.033

Table 9. Graph Metric values for Nthongoni village

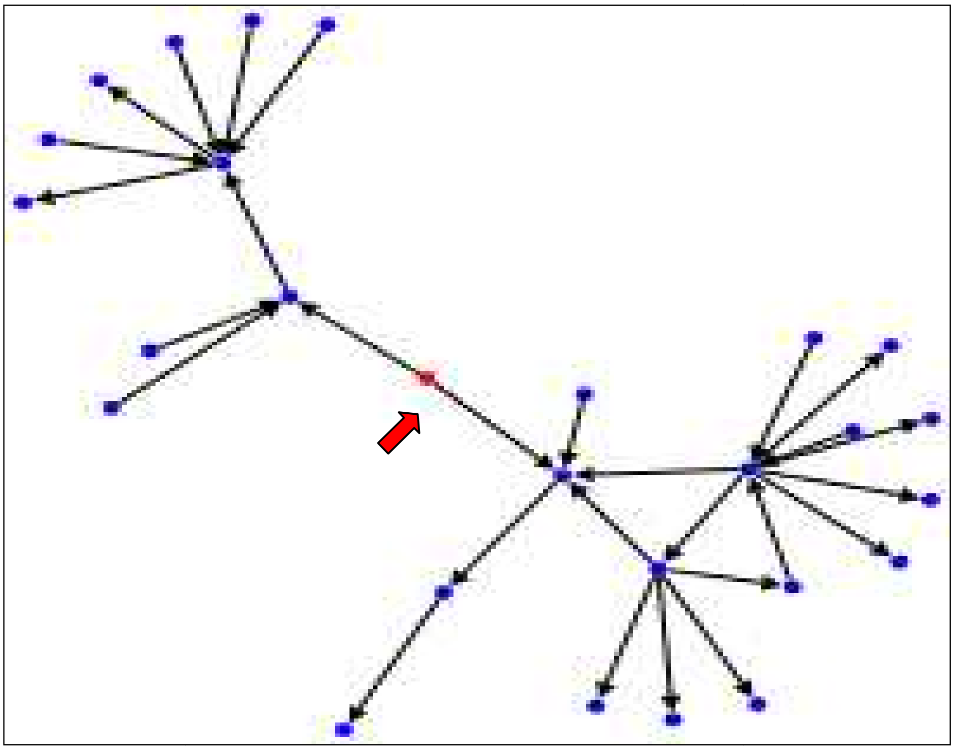


Figure 44. Bridging actor linking sub groups

4.11.0 Sakai Sub-Location

A total of 166 questionnaires were administered out of the planned 200, this translated to 75% response rate. On analysis this data yielded 485 vertices and 747 edges (nodes and edges respectively) – (see Table 12). The names are omitted from the socio-grams (Figure 45 and 46) to avoid crowding but ego-networks for unique individual actors are provided as examples to illustrate certain attributes like connectedness. To visually illustrate the effect of relation and residence on the edges for Linga village socio-grams (Figures 34 and 49) have been used. The correlation analysis is given at the later in the chapter and discussed further in chapter. It shows that individual characteristics of nodes in a social network affect access to and subsequently the flow of information on climate change adaptation in Sakai sub-location.

The Sakai sub-location networks are characterized by high centralization of actors that form positions around which groups form and are connected to other actors in peripheral groups that are connected through bridging ties as shown by socio-grams below. Most of the peripheral actors have some form of linkage to these central actors although a few groups are completely isolated from the Sakai sub-location social network. However unlike the individual village socio-grams, the Sakai sub-location shows a denser clustering at the centre and well but weakly linked actors at the periphery of the social network; this is as a result of combined socio-grams where peripheral actors are acting as links across villages. These actors when viewed at village level will appear to be weakly linked to the centre when they are actually central actors in their respective villages as seen in the village level socio-grams.

In the whole network two self loops were recorded this was attributed to data entry errors where four actors shared names and therefore on plotting the socio-gram it shows them sharing or getting information from themselves which is not practically possible. This also explains the complexity of SNA which calls for thorough training of research assistants for them to be able to collect good data.

4.11.1 Significant Sakai sub-location Socio-metrics

Sakai sub-location network has a low average Eigenvector centrality of 0.002 (Table 12), this index measures the importance of a node Bonacich (1972) and is connected to the power of the node to influence other actors. The low eigenvector centrality implies a lower number of opinion leaders in this community which is in agreement with normal distribution in community structures (Wasserman & Faust 1994, Scott 2000). The maximum Eigenvector centrality of 0.28 shows how influential the most powerful node in this actor is.

The maximum and average geodesic distance or diameter for Sakai sub-location network was 12 and 5.608 respectively (Table 12). This means that on average the shortest path that a node can take to reach any node in the network is 5.608 (Table 12). Based on this therefore the Sakai Sub-location network is fairly dense. In-degree, out-degree, closeness centrality and Eigenvector centrality measures are used to describe the structural and relational attributes of the Sakai networks. Maximum in-degree and out-degree were 9 and 11 respectively and 1.5 average in-degree and out-degree, the average closeness centrality is 0.009 with a maximum of 1 (Table 12). These measures attempt to answer the question who is the most important person, how well the actors are positioned and how acts as a sender and receiver of information. In the network every actor acts a source of and receives information from at least 2 other actors. The maximum and average clustering coefficients are 0.5 and 0.025 (Table 12) respectively; the wide variation shows the existence of both weak and strong ties since it measures how an actor is connected to the neigbours who are more likely connected to others. The strong ties are embedded in the social networks between homophilic actors while the weak ties reach into different groups in the network Granovetter (1973).

4.11.2 Structural and Relational Implications of the Metrics

Selective linking is seen in the Sakai sub-location social network; the average in-degree and out-degree of 1.15 and closeness centrality of 0.01 (Table 12) support the existence of many groups closely linked within the groups showing homophily. In this study correlation was used to measure if access to information on climate change adaptation is correlated to demographic traits like level of education, age, size of the farm and the marital status; all except marital status showed strong and positive correlation.

Below is a summarized table of some significant socio-gram values from Sakai sub-location.

Graph Metric	**Value**
Graph type	Direct
Vertices	486
Unique edges	711
Total edges	747
Self loops	2
Reciprocated vertex pair ratio	0.015363128
Reciprocated edge ratio	0.030261348
Connected components	4
Maximum vertices in a connected component	476
Maximum edges in a connected component	740
Maximum Geodesic distance (diameter)	12
Average Geodesic distance	5.608294
Graph Density	0.003084299
Maximum in-degree	9
Average in-degree	1.500
Maximum out-degree	11
Average Out-degree	1.500
Maximum Closeness Centrality	1.000
Average Closeness Centrality	0.009
Maximum Eigenvector Centrality	0.28
Average Eigenvector Centrality	0.002
Maximum Clustering Coefficient	0.500
Average Clustering Coefficient	0.025

Table 10 Graph metrics for Sakai sub-location

The Sakai sub-location network structure has strong bonds within the subgroups and weak linkages between sub-groups as shown in the socio-grams at both village and whole network levels. The extent to which people in the Sakai sub-location tent to pair up is fairly high with the highest clustering co-efficient being 0.5 and the average being 0.025 (Table 12). This show a mix of homophilic and heterophilic groups where individuals have a high tendency to connect to other similar individuals while being brought together by an actor isn't similar (heterophilic) to them but who also connects them to other networks. Sakai sub-location has structural advantages that can support flow of information on climate change adaptation techniques as shown by the mix of strong bonds and weak ties facilitates the flow of information on innovations Granovetter, (1973).

The socio-gram metrics also show a closely knit social structure with every farmer being near each other as measured by the whole network closeness centrality at 0.01 (Table 12), this translates to a cohesive community quicker access to resources in our case information.

Below is a visual comparison of two socio-grams drawn using Harel-Koren Multiscale and Fruchterman-Reingol formats (Figure 45 and 46).

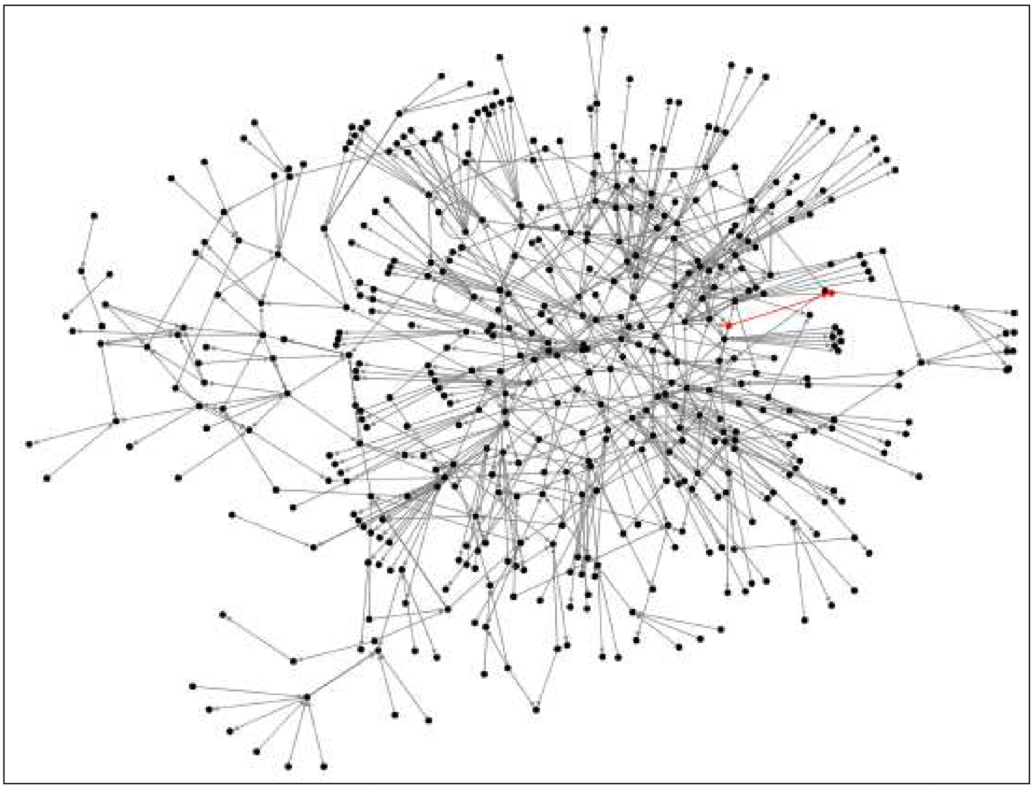


Figure 45. Sakai sub-location socio-gram Harel-KorenMultiscale format

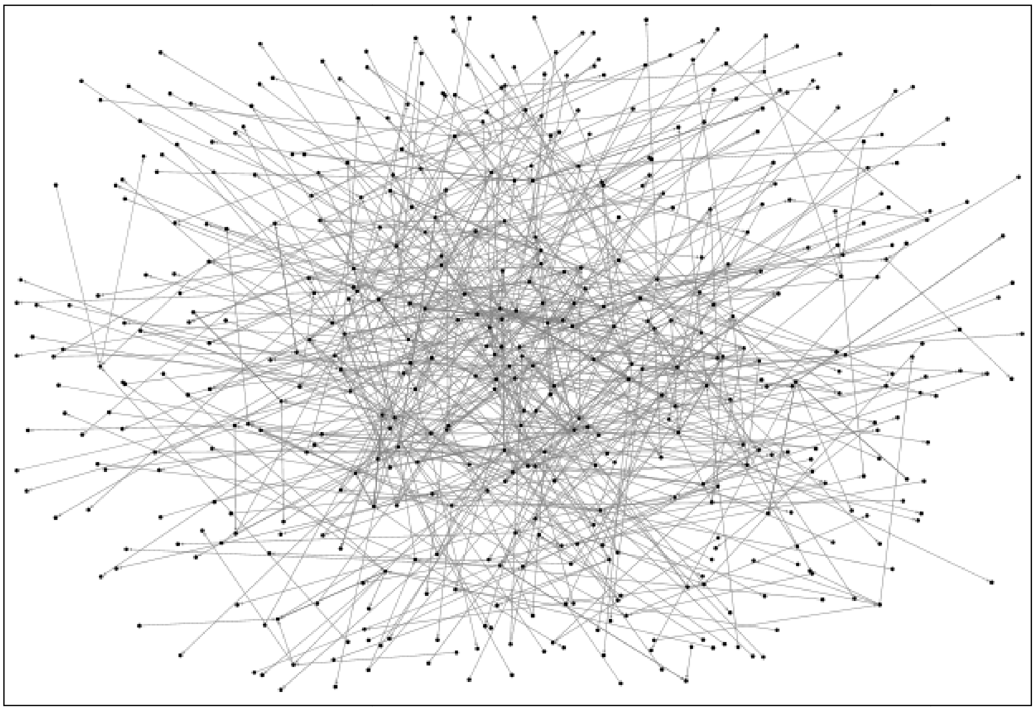


Figure 46. Sakai sub-location socio-gram (Fruchterman-Reingol format)

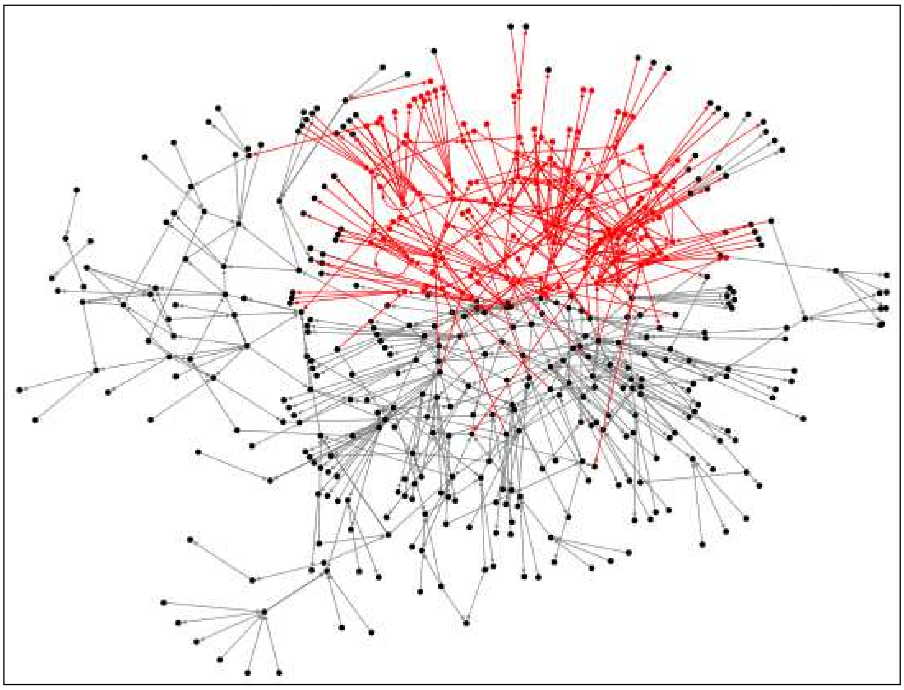


Figure 47.Sakai sub-location socio-gram showing bonding among the actors.

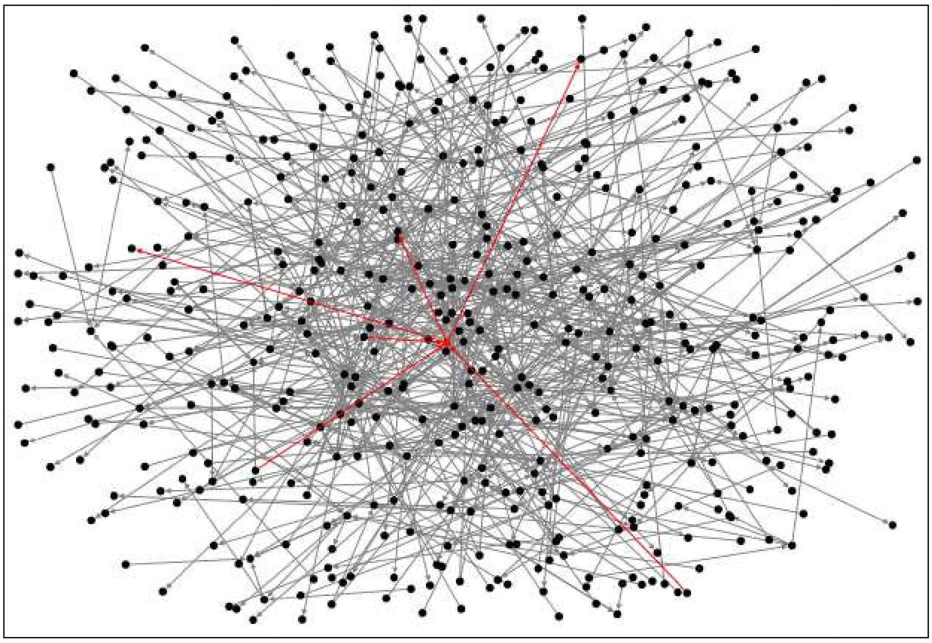


Figure 48. Sakai sub-location socio-gram showing how an actor Titus

The actor (marked red in Figure 48) shows an actor who links with other actors across the villages

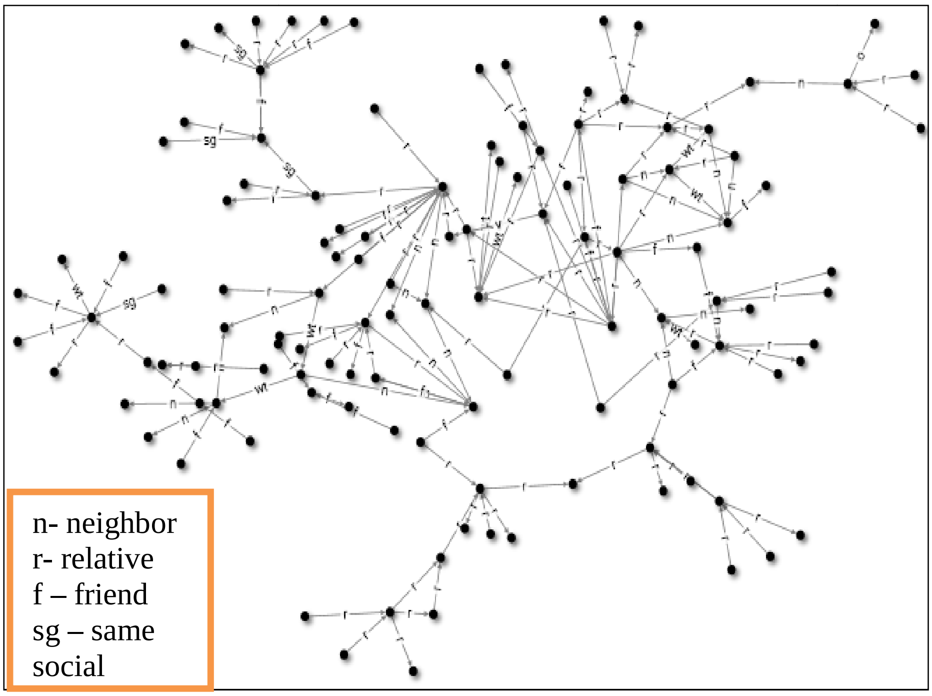


Figure 49.Linga Socio-gram showing relational basis of ties between actors

4.12 Correlation analysis

		Information access	Age of household head	Education level	Marital status	Size of farm in acres	Group membership
Information access	**Pearson Correlation**	1					
	Sig. (2-tailed)						
	N	165					
Age of household head	**Pearson Correlation**	.238	1				
	Sig. (2-tailed)	.026					
	N	165	165				
Education level	**Pearson Correlation**	.624	.326	1			
	Sig. (2-tailed)	.019	.000				
	N	165	165	165			
Marital status	**Pearson Correlation**	.009	.264	.195	1		
	Sig. (2-tailed)	.100	.031	.012			
	N	165	165	165	165		
Size of farm in acres	**Pearson Correlation**	.509	.292	.108	.027	1	
	Sig. (2-tailed)	.016	.000	.167	.732		
	N	165	165	165	165	165	
Group membership	**Pearson Correlation**	.173	.022	.185	.060	.020	1
	Sig. (2-tailed)	.038	.074	.017	.442	.800	
	N	165	165	165	165	165	165
Correlation is significant at the 0.05 level (2-tailed).							

Table 11: Pearson's correlation

From the above Pearson's Correlation (Table 13); the level of education (0.624), farm size (0.509), age of the household (0.238) and group membership are correlated to access to climate change adaptation information.

4.13 Regression Analysis

The model is given by the equation below:-

INFOCCAD = $\beta_{HHGENDER} + \beta_{MARITAL} + \beta_{HHAGE} + \beta_{LANDSIZE}$

Where:-

INFOCCAD = Farmer getting information on climate change and various adaptation strategies
HHGENGER = Household gender
MARITAL = Marital status of the household
HHAGE = Household age
LANDSIZE = Size of land in acres
The data was analyzed as follows:-

First, a simple Ordinary Least Squares (OLS) model was estimated. This was to enable testing whether the variables used did not in any way correlate with each other. This was done by running a variance inflation factor (VIF) values

INFOCCAD, HHGENDER, MARITAL, HHAGE, LANDSIZE

Source	SS	df	MS	
				Number of obs = 165
				F(4, 160) = 0.63
Model	.030404001	4	.007601	Prob> F = 0.6452
Residual	1.94535357	160	.01215846	R-squared = 0.0154
				Adj R-squared = -0.0092
Total	1.97575758	164	.012047302	Root MSE = .11027

INFOCCAD	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
HHGENDER	-.0122843	.0184486	-0.67	0.506	-.0487185	.02415
MARITAL	.0376539	.0250919	1.50	0.135	-.0119002	.087208
HHAGE	-.0029349	.018363	-0.16	0.873	-.0392	.0333301
LANDSIZE	.0024099	.0187806	0.13	0.898	-.03468	.0394998
_cons	.9602545	.0255069	37.65	0.000	.9098808	1.010628

```
Probit regression                                 Number of obs   =        165
                                                  LR chi2(4)      =       2.15
                                                  Prob > chi2     =     0.7073
Log likelihood = -9.7359455                       Pseudo R2       =     0.0996
```

INFOCCAD	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
HHGENDER	-.5102715	.6785894	-0.75	0.452	-1.840282	.8197393
MARITAL	.9416735	.6789756	1.39	0.165	-.3890941	2.272441
HHAGE	-.1217527	.6209151	-0.20	0.845	-1.338724	1.095219
LANDSIZE	.0423939	.6279132	0.07	0.946	-1.188293	1.273081
_cons	1.852047	.5704455	3.25	0.001	.7339946	2.9701

Figure 50 Probit regression analysis

The Figure 50 above shows the results of the probit regression model. Even though some variables such as household marital status and land size positively affect information flow on climate change and adaptation strategies, no variable statistically influenced information flow on climate change and adaptation strategies.

The constant term is significant at one percent suggesting that other variables that were not included in the model have an influence on information flow on climate change and adaptation strategies. This finding calls for a deeper research on the possible factors that could have an influence on information flow on climate change and adaptation strategies.

4.12.Key Finding

This section presents the results of the study as per the objectives:-

4.12.1 Characteristics of Social Networks in Sakai Sub-location

Sakai social network have a community structure (Wasserman and 1994 and Scott 200) composed of groups of nodes that have high density of edges (relations) within them and lower density of relations between the groups. The networks are formed based on similarities in age, levels of education and farm sizes are shown by the strong and moderate correlation co-efficient as relates to access to information as shown by the Pearson's Moment Correlation analysis. This shows that homophily is central to relationship formation based on access to information on climate change adaptation. Two variables level of education age and farm size according to the correlation analysis done were strongly and positively correlated to access to information, while the age of the individual farmers was moderately related to access to information on climate change adaptation. This is in agreement with Nam (2010) and Yila and Bernadette (2013) who found that the level of education and age of the household head had a positive impact on adoption of climate change adaptation techniques.

The social networks in Sakai sub-location that were studied are based on the exchange of information on climate change adaptation among farmers through both informal and formal networks. The farmers in the Sakai sub-location who are adapting to climate change are generally connected by strong bonds within the various sub-groups which are formed and clustered around similarity in socio-economic and demographic traits.

The subgroups are formed and connected to other sub-groups either within their villages, from neighboring villages or from formal information sources. Though not mapped in this socio-grams; but analyzed statistically there exist weak ties (as measured by frequency of interaction) with formal sources of information that the farmers in Sakai sub-location have access to with 44.8% and 23.6% of the respondents saying they only communicated once and twice respectively with formal sources in a whole crop season and 10% of the respondents saying they never interacted with the formal sources of information on climate change adaptation. Frequency of interaction is a key feature of social networks (Wasserman and Faust 1984) and is a component of the betweenness centrality measure.

According to the average in-degree and out-degree values which is 1.15 (Table 12) the Sakai sub-location has a structure that supports the flow of information since at least every farmer acts as a source of information to one famer and receives information from one other farmer on average. However this is on average; at individual level variations were recorded with the highest out-degree being 11 in Nthongoni village (Table 11).

There are many central and peripheral actors clustered in several groups in Sakai sub-location social networks. Most peripheral actors are connected to the central actors with a few isolated sub-groups (networks). Bridges are a common feature in the socio-grams of the Sakai sub-locations and are a pointer to influence that heterophilic actors have over their followers (Figures 20, 39, 41, 42 and 44). Strong intra-group bonds apart from facilitating exchange of information can also limit adoption of innovation by actors due to group norms (Lin, 2000), as actors tend to go to the same source for information or are constrained by group norms that may restrict information sharing. Bonding ties create dense network structures with strong but localized trust (Newman & Dale, 2004) which though advantageous in enhancing effective intra-group communication may reduce resilience. Weak ties on the other hand were characterized by infrequent encounters with heterophilic groups and mostly occur between actors who weren't similar hence offer opportunities for access to new information and supports the initial stages of diffusion of innovations.

The bonding ties in Sakai-sub-location are relational ties between family members, friends and relatives and group memberships (Figures 34 and 49). These relations explain the existence of strong bonding ties and weak bridging ties in Sakai sub-location. This ties act as pathways for information that exist in one network to a member of another network; (Granovetter 1973) termed this phenomenon as the "strength of weak ties".

4.12.2 Relational and Structural Factors that Affect Information Flow

Strong intra-group bonding ties in the Sakai sub-location indicate high frequency of interactions, feeling of closeness and existence of multiple types of relationships that potentiate each other result in strong bonds that facilitate sharing of information. Strong intra-group bonds in Sakai sub-location exist between neighbours, friends, relatives and people within the same social groups showing a trust build over time.

In Sakai sub-location homophily based on same socioeconomic characteristics creates strong bonding ties based on relational trust while heterophily creates the bridging ties between the groups. The bonding ties resulted in dense network structures with strong and localized trust which can lead to imposition of social norms which have the effect of reducing the diversity and hence resilience of groups (Newman and Dale 2005). The extension agents are heterophilic actors who spread the information vertically through weak bridging ties as shown by their less frequent encounters with farmers. This weak links play a key bridging role as they serve as conduits for novel information, resources or opportunities that exist in one network to a member of another network Granovetter (1973) and Borgatti (2002).

In summary Sakai sub-location social networks have nodes linked with strong bonding ties that result in cohesive groups that share information. Both bonding (strong) and bridging (weak) ties are structural traits that support the diffusion of information on climate change adaptation; this is in agreement with Granovetter (1973), Putnam (2000) and Woolcock (2001).

The findings of the correlation analysis corroborates the social network analysis data by showing the individual demographic traits like age, level of education and land size affect access to information on climate change adaptation. The strong positive correlation observe between people with a higher level of education and large farm size and access to climate change adaptation may based on the knowledge of negative impacts of climate change and thus high risk perception which is also higher with more investment on larger farms. Such farmers will be more interested and will seek information that will enable them avoid risks due to climate change. This positive information seeking behavior can yield many linkages with other farmers with larger farmers once again creating the homophily in such groups.

4.12.3 The Patterns of Information Flow in Social Networks

Information in Sakai sub-location flows both horizontally among farmer groups with similar demographic traits and vertically with heterophilic groups. Information is shared between farmers in hemophilic groups and is internalized through the adoption of climate change adaption technologies; through strong ties build on relational trust among group members. Communication patterns among homophilic groups in this study were characterized by horizontal diffusion of adaptation techniques among farmers based on relational ties build upon similarities. According to Granovetter (1973), Conley & Udry (2010) farmers confirm their expectations of a technology or innovation’s utility using the experience of their fellow farmers under similar conditions.

Vertically information flows from formal sources that include agro-chemical extension agents from both the government and the private sector, faith based organizations and agricultural para-professionals. These sources offer vital information on climate change adaptation measures through field trainings or farm demonstrations.

Heterophilous communication between dissimilar individuals may cause cognitive dissonance because an individual is exposed to messages that are inconsistent with existing beliefs; hence result in an uncomfortable psychological state Rogers (1973). This explains the high education levels and cosmopolitan nature of bridging links.

4.12.4 Homophily, Heterophily and Source Characteristics in Communication

Homophily, heterophily in social network analysis can be compared and contrasted with source characteristics in communication theory. Source attractiveness in communication are composed of similarity, familiarity and liking; this compares with homophily in social network analysis. They both enhance effectiveness of communication.

While heterophily enhances communication in social network analysis to the contrary communication theory sees a heterophilic source as dissimilar to the audience and hence doesn't support communication.

4.12.5 Effective Pathways of Disseminating Climate Change Adaptation Information

According to this research, (see Figure 51) are characteristics of an effective pathway through which information on climate change can be disseminated to farmers. The pathways must have both horizontal and vertical actors; the vertical actors need to be expertise in a given field and weakly linked to the target audience. At the horizontal level kinship ties offers an effective information exchange pathways.

Below (Figure51) is a diagrammatic representation of factors that facilitate the flow of information in Sakai sub-location. The structure is based on Borgatti (2013) diagram on types of relational data in an informational social network.

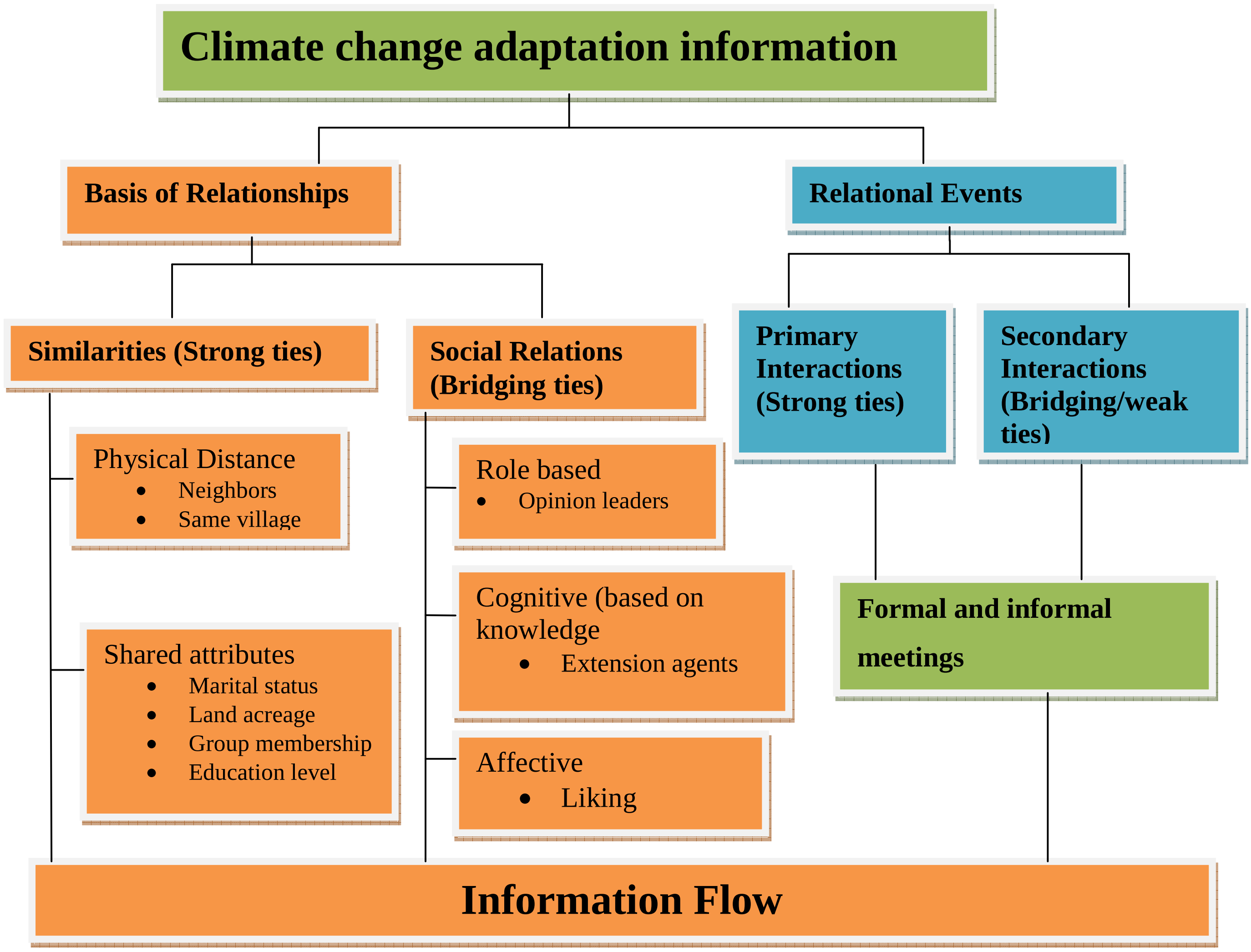


Figure. 51. Diagrammatic representation of information flow through the social network

CHAPTER FIVE

5.1 Conclusion

Climate change adaptation is context specific with socioeconomic characteristics, social networks and local knowledge playing critical roles in shaping the adaptation measures adopted by the communities. The research findings show that communication groups are formed by a combination of similarities in socio-demographic traits (homophily) and differences (heterophily) in social systems, homophilic ties among groups are sustained by relational ties built over time while heterophilic ties are relatively weak and based on limited frequency of communication encounters with formal information sources. The sum total of these relations affects the network structure which subsequently affects the flow of information on adaptation to climate change.

The study also shows the social capital embedded in social networks can be harnessed to facilitate the diffusion of climate change adaptation information and subsequent attitude and behavior change. Sakai sub-location social network have both a mix of farmers who are different in terms of age, education and marital status which yield homogenous sub-groups largely influenced by heterogenous actors. These affect the flow of information through social networks, as they determine the position an actor occupies and relative power of an actor and these structural characteristics can be harnessed to enhance diffusion of information and adaptation to climate change.

The study illustrates the importance of informal social networks in the diffusion of information on climate change adaptation and their utilization in climate change adaptation communication.

5.20 Study Recommendations

5.21 Academic and Field Application of SNA in Agricultural Extension

Social network analysis is a relatively new important multi-disciplinary methodology that can be applied in the study of farmers' social systems in relation to diffusion of information and innovations. Climate change is already affecting agricultural production thus adaptation is inevitable.

This calls for a multi-disciplinary approach in understanding how farmers are adapting by studying how information flows through social networks. Social network analysis needs to be studied as a research methodology and be applied in agricultural extension. Its ability to combine graph theory, statistics and computer science to produce visual maps and statistical indices can enrich the field of agricultural extension. This methodology can be used to further explore the effect of shared interests, relational trusts and bonds and the underlying processes of group formation in relation to adoption and application of agricultural technologies.

Although criticized by Durland *et al*. (2005) as being academic and lacking in practical applicability and limited references documenting its participatory applications in the field. Social Network Analysis can be applied in agricultural extension as shown by this study.

5.22 SNA as a Communication Survey Tool

Social network analysis can also be used a feasibility study tool before implementation of communication action plans by mapping effective channels of communication in a given social system. The methodology can identify important players in the dissemination of information and also classify audiences according to their informational needs and access to such information. SNA when appropriately used cuts the cost of rolling out a communication plan by making it focused on the relevant actors and effective pathways.

The methodology can also be applied in the objective identification of opinion leaders using the individual centrality measures.

5.23 Policy Implication

The knowledge of climate change adaptation communication among farmers is an important resource for the policy makers. Climate change is already a policy issues and the policy makers can utilize SNA when doing awareness creation and assisting the public to adapt to climate change. The study also shows that social climate change adaptation through local social networks is an effective strategy that can be adopted by the policy makers as it is not under the constraint of conventional framework and is relatively cheap considering the fact that these social networks already exist in every community. The social capital embedded in the social network can be employed in effective communication by mapping out the prominent actors in a network and empowering them with necessary skills. The findings show that you don't need an agricultural extension officer talking to every farmer but to a few opinion leaders who will strategically disseminate information to their group members.

5.30 Future Study Recommendations

As an area of further research this study recommends for more studies to be done on:--

- Integration of SNA and other statistical research methods

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Appendix A : Questionnaire

Questionnaire no. ....

This questionnaire is part of a research which aims at understanding how social networks affect the communication patterns among farmers adapting to climate change. Any assistance accorded is highly appreciated.

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 bracket of the household head?

a) 18-35 { }

b) 36-50 { }

c) 51-60 { }

d) 61-100 { }

Q. 3 What is the education level of the farmer?

a) Primary { }

b) Secondary { }

c) Tertiary { }

d) None...... { }

Q. 4 What is the religious denomination of the household head?

a) Catholic { }
b) Protestant { }
c) Muslim { }
d) Non believer { }
e) Others ....

Q.6 What is the marital status of the respondent?

a) Married { }
b) Divorced { }
c) Widowed { }
d) Single { }

Q.7 What is the approximate size of your farm in acres?

a) < 3 { }
b) 3-6 acre { }
c) > 6 acres { }

Q.8 Do you belong to any local membership group?

a) Yes { } go to Q.9
b) No { } go to Q. 10

Q. 9 On what basis are these groups formed?

a) Religious
b) Family
c) Friendship
d) Others ....

Section B) Farming and Social Network Data

Q 10. A Do you know anyone from whom you can learn about new crops and farming techniques? List at most four of them. (Write at least 2 names - family & other)	**Q.10. B** Where does this person**(Q9.A)** live/reside? 1.Neighbor 2. In my village 3. Outside my village (name the village)	**10. 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 group	**Q.11.A** After getting this information **(from Q.9A)**whom do you share it with? List at most four of them. (Write at least 2 names - family & other)	**Q.11.B** Where does this person**(Q.10A)** live? 1. Neighbour 2. Within the village 3. Outside the village name the village	**11.C** How are you related/relate to this person? 1.Neighbour 2.Relative 3.Friend 4.Worship together 5.Same social group 6.In the same age group	**12.** Which are these new crops and techniques have you learned from these friends? (list the crops and techniques) and have you adopted the technique or started growing the crop(s) if yes mark (√) or (x) if not grown or adopted	**13.** Why did you adopt this technique/crops you have mentioned? 1.To increase production 2.Because my friend did 3.To cope with prolonged sunny seasons 4.Others(specify) ....
1.			**1.**			Crops Technique	
2.			**2.**			Irrigation	
3.			**3.**			Hybrid seeds	
4.			**4.**			Mulching	
						Others............	....

Formal Networks

Q. 14 Name the formal sources of information on these new crops 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.15** 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 16** Which of these source(s) of information do you prefer	**Q.17** Do you believe that temperature patterns over the past five years are different from patterns that were typical ten or more years ago in this village?	**Q. 18** If your answer in Q16 is 1or 2 how is this phenomenon called? (either in vernacular, Kiswahili or English)
1.			1.Strongly agree	
2.			2.Agree	
3.			3.Strongly disagree	
4.			4.Neutral (no opinion)	
5.			5.I don't know	

Thank you for the information and the time

Appendix B **Map of Sakai Sub-location**

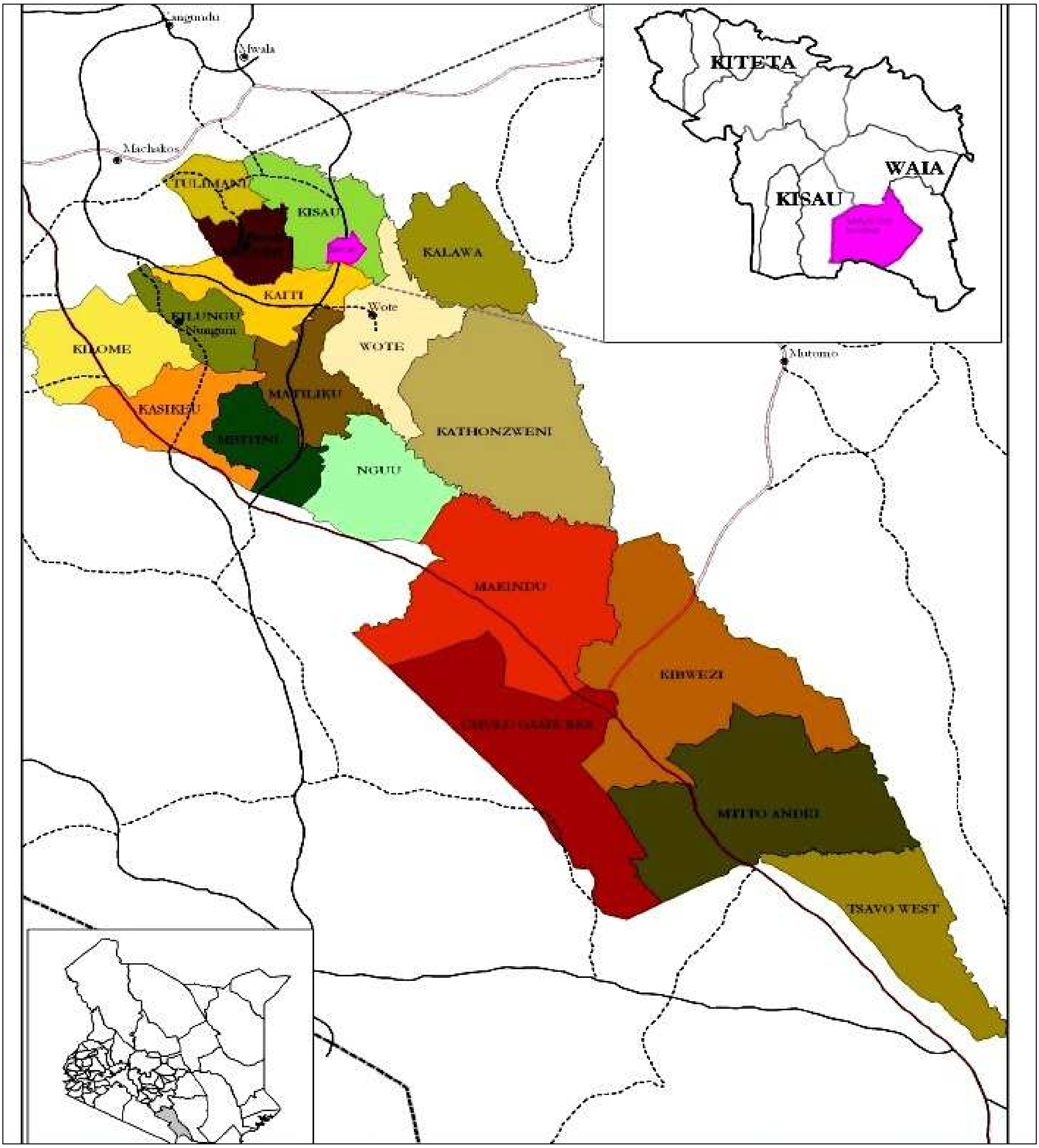

Figure 52. Sakai sub-location map (source CSTI)

Appendix C **Protocol for Questionnaire Administration**

Protocol for the SNA Questionnaire Administration

It is important that the statement below is read to the respondent before you administer the questionnaire.

Dear Respondent

This questionnaire is part of a research which aims at understanding how social networks affect the communication patterns among farmers adapting to climate change. Any assistance accorded is highly appreciated.

Your answers are going to be used for research purposes only and will be accorded the confidentiality they deserve.

We are asking everyone for their (two) names in order to see to map out how farmers exchange information on climate change adaptation in Sakai sub-location.

The questionnaire will take you about 10 to 30 minutes to complete.

Thank you very much for taking part in this important research whose findings will assist in understanding climate change adaptation communication.

Appendix D **Observation Guidelines**

As a research assistant you will be required to make some observation in the identification of suitable respondents for the interview:-

Carefully follow the guidelines below:-

1) To identify a respondent who has adapted to climate change
    - Check his farm for the following attributes
    - If growing drought resistant crops like millet, sorghum, soya beans,
    - If water conservation agriculture for example practicing mulching, drip irrigationetc
    - Ask whether he/she has a farm elsewhere and what kind of farming he/s is practicing

    If they fulfill any of this criterion interview them; this applies to all the respondents that you will be referred to.