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Towards sustainable rural livelihoods: Participatory social network analysis of food securing upgrading strategies in Tanzania

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Abstract

The challenges of the current food systems in Tanzania are given mainly by the increasing food demand, unpredictable climate and rural poverty. Therefore, improving the current smallholder agricultural production systems is vital for increasing the system´s resilience against future hazards that results into enhanced rural livelihoods. In this line, the Trans-SEC project (Graef et al., 2014) aims to improve the food situation of the rural poor population by implementing food securing site-specific upgrading strategies (UPS) along local and regional food value chains through a participatory platform. The UPS are presently being tested and adjusted to site-specific settings in four villages of two districts, which are located in two different regions in Tanzania. The objective of this study was to define the role of the key actors and their interlinkages inside and in between the different UPS groups from a farmers' perspective in relation to knowledge, money and materials, as well as determining the factors and activities that enhance the proper functioning of the UPS. The participatory research methods included in-depth interviews, interview based mapping tool Net-Map for social network analysis and Focus Group Discussions (FDG). Social Network Analysis (SNA) was used to analyze the interactions between the actors influencing the implementation of the UPS, while understanding the integration of the UPS in the current coping strategies of the smallholder farmers' livelihoods.

The results reveal that there are different factors affecting the development of the UPS groups social networks, such as the implementation stage and type of knowledge and materials required for the innovations. These factors have an impact in the diversity of the actors and the strength of its relations. In addition, high levels of knowledge density and reciprocity were observed in almost all UPS groups, while considerably lower values were observed in the materials and money networks. Furthermore, the results for the knowledge networks revealed that knowledge is linked to the availability of natural resources. The high centrality levels for the group leaders, secretaries and researchers reflect them as influential actors in the UPS implementation. The motivations for participating in a UPS group differ to some extent between all UPS groups and all types of actors, whereby enhancing food availability, more joy, more income, more knowledge, better reputation and social relations were most frequently mentioned. In addition, knowledge and income increases the human and financial capital, and it is important for participants as it allows the diversification of their current livelihood strategies. In conclusion, this study was important for understanding the relationships built in the UPS groups, which allow us to evaluate the long-term sustainable performance of the UPS as well as the impacts on the participant's livelihoods.

Factors positively affecting the development and sustainability of the UPS groups are: the enhancement of the social and human capital (such as knowledge and education) of the

participants, more time for their families and personal business, better working conditions, better health and access to financial assets among others.
In addition, strengthening the leadership capacities (groups organizational skills), improving links to material and service suppliers, technical knowledge and better marketing skills are required for the proper functioning of the groups. The thesis serves as a landmark for understanding stakeholders' roles and their influence in implementing upgrading strategies and their impacts on their livelihoods.

Key words: Social network analysis, sustainable livelihoods, upgrading strategies, food security, Tanzania, stakeholders, Net-Map, food value chain

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Abbreviations and Acronyms

CSS	Case Study Site
DFID	UK Department for International Development
FAO	Food and Agricultural Organization
FAOStat	Food and Agricultural Organization
FGDs	Focus Group Discussion
FVC	Food Value Chain
GDP	Gross Domestic Product
GlobeE	Research for the Global Food Supply
GVC	Global Value Chain
ICS	Improved cooking stoves
IDS	Institute of Development Studies
MVIWATA	Mtandao wa Vikundi vya Wakulima Tanzania
MS	Maize sheller
MT	Millet tresher
NBS	National Survey
PLT	Poultry-crop integration
PYR	By products for bioenergy
SLA	Sustainable Livelihoods Approach
SN	Social Network
SNA	Socila Network Analysis
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
SUN	Sunflower oil processing
Trans-SEC	Innovating Strategies to safeguard Food Security using Technology and Knowledge Transfer: A people-centred Approach
UN	United Nations
UPS	Upgrading Strategy
USAID	United States Agency for International Development
VC	Value Chain
WFP	World Food Programme
WFS	World Food Summit
ZALF	Leibniz Centre for Agricultural Landscape Research

1. Introduction

1.1 Background information and problem statement

Food security is a function of food availability, food accessibility, food stability and food utilization (FAO, 2009). Food insecurity still is a predominant challenge in many developing countries around the world. Sub-Saharan African (SSA) countries are particularly undergoing the fastest global population growth rates (The World Bank, 2015) and are currently facing the challenges of food accessibility and production (FAO et al., 2015). The region has been identified as one of the most vulnerable regions in the world facing the consequences of climate change. Improvements on the food production systems that are resilient to the forecasted climatic changes are vital in order to reach food security in the region.

Agriculture is very important in the economy of Tanzania and accounts for half of the national Gross Domestic Product (GDP) (URT, 2005). Over the last decade Tanzania had an annual GDP growth of 2.3% (MOFEA, 2008). Even though Tanzania has experienced an economic growth, it has not improved living conditions of the country´s poor population (Pauw & Thurlow, 2011). An 87% of the poor population of Tanzania lives in rural areas with most dependent on agriculture (URT, 2005) with about 9.3 million women and 7.7 million men active in agriculture (FAOStat, 2014). Smallholder farmers are the most food insecure in the country, as they tend to be more and more threatened with environmental volatilities that increase the insecurity of regional food supply (Foley et al., 2011). Given the challenges of increasing food demand, unpredictable climate, and rural poverty, there is a strong need to improve current smallholder agricultural production systems for enhancing food security.

In order to ensure the food and livelihood security it is necessary to develop and maintain highly productive and ecologically stable agricultural systems (Mutabazi et al., 2015). In addition, the adaptation efforts in agricultural development, should involve effective governance of natural resources since they function as safety nets to vulnerable groups such as smallholder famers (Paavola, 2008). Social networks are essential for successful management and are increasingly analysed to understand why management works in some cases and not in others (Schiffer & Hauck, 2010).

Enhancing food systems requires site-specific upgrading strategies (Graef et al., 2015), which consider the local traditions and knowledge in order to ensure better adoption rate and local ownership (Hernandez, 2016). Understanding the structure of the social networks that sustain the livelihoods of the famers implementing the innovations is essential to adapt effectively the strategies to the local context. The success of the innovations often relies on

the interactions among the key actors. The misunderstanding and lack of management of these processes can lead to poor performance or failure of it (Adekunle & Fatunbi, 2012). The improvement of the performance and efficiency of the site-specific upgrading strategies (UPS) needs to be based on the integral understanding of the relations among the different actors.

This research is part of the Trans-SEC project which aims to improve the food situation for the most-vulnerable rural poor population in Tanzania by identifying successful food securing upgrading strategies (UPS) along local and regional food value chains. The UPS are being tested and adjusted together with the local stakeholders to site-specific, sustainable settings and tailored for regional and national outreach (Graef et al., 2014) . The activities are carried out applying an action research approach. The analysis of the complex relationships of the actors across the UPS aims at enhancing the implementation and development of long-lasting sustainable solutions.

Several development strategies have attempted to enhance food security by improving the agricultural production of the smallholder farmers (Schindler et al., 2015). However, a lot of these management attempts tend to fail, as they do not capture the social realities in which they are implemented (Schiffer & Hauck, 2010). In this line, Social Network Analysis (SNA) is an increasingly used tool to understand the complex patterns of formal and informal interactions between different actors within a social network. In this study SNA is used to analyse the interactions between actors influencing the implementation of the UPS. In SNA, the analytical unit is neither the whole actor system or the parts but rather the relation between the actors (Stein et al., 2011). Furthermore, SNA is a great tool for understanding the integration of the UPS in the current coping strategies of smallholder farmer's livelihoods. However, despite the recognized importance of social networks in supporting rural livelihoods, social network analysis has gained little attention in livelihoods research (Misra et al., 2014).

1.2 Aim of study and research questions

The overall aim of the study is to determine and understand the role of actors and the interlinkages among the UPS groups. It is important to deeply understand the relationships in order to evaluate the long-term sustainable performance of the UPS that are currently being implemented.

1.2.1 Specific objectives

The three defined objectives in this thesis are:

- To define the key actors and factors (motivations and social values) that determines the performance of an UPS group.
- To determine the relationship (linkage) among the participants, between the different UPS groups and other actors.
- To determine the activities (joint and individual activities) that enhances the proper functioning of the UPS groups and the implementation of the UPS.

1.2.2 Research questions

The formulated research questions in this thesis are:

- Who are the key actors in the different UPS groups?
- What are the motivations of the different actors within a UPS group to participate in the implementation?
- What is the linkage between the different members and beyond?
- How do the UPS members manage and facilitate themselves in order to reach their goals?
- What are the activities that enhance the proper functioning of and engagement in the UPS groups and the UPS?

1.4 Outline of the study

The thesis is divided in eight main chapters. In this first chapter the background, problem statement and objectives of the study were presented. Following in chapter two is a literature review on food security in Tanzania, upgrading strategies for smallholder farmers, social networks and social network analysis and natural resource management and some examples of the implementation of the Net-Map tool. In chapter three the framework for this study is drawn in social network analysis scenario. The Trans-SEC project is presented with a description of upgrading strategies (UPS) implemented and the case study sites in chapter four. The fifth chapter explains the methodology with a description of the methods employed for data collection and analysis. The results from the SNA of the different UPS groups are presented in chapter six, followed by the discussion of the results in chapter seven. This study finalizes with the conclusions and recommendations in chapter eight.

2. Literature review

In the following section the literature review is presented. Firstly, the food security concept is discussed followed by a description of the scenarios in Sub-Saharan Africa and Tanzania. The second section approaches the concept of upgrading strategies for small farmers' agriculture. The final section presents a review of the role of social networks for small farmers, and the role of participatory social network analysis is discussed in the field of resource management in order to understand the limitations and the opportunities through this approach.

2.1 Food security

2.1.1 Definition of food security

The way food security is theorized, measured and analyzed affects the policies that will be adopted in order to approach it (Burchi & De Muro, 2016). Therefore, it is important to understand the development and different approaches of its definition. The concerns of food security as a concept can be traced back to the Universal declaration of Human rights in 1948, which recognized the right of food as a core element of an adequate living standard (Maxwell & Smith, 1992). Historically after the world food crisis of 1972-1974, the concept became more important to the development principles. Food security as a concept has been defined in more than 200 approaches (Smith et al., 1993). The complexity of the concept is related to the analysis levels ranging from international and national to household and individual levels. Nevertheless, current definitions for food security start with an individual approach recognizing the complex interlinkages between the individual, the household, the community, the nation and the international economy (Maxwell, 1996). In the time lapse from the decade of the 80´s to the 90´s three main shifts on the concept of food security were identified by Maxwell (1996): (a) from a global scale and the national household and the individual; (b) from a food first perspective to a livelihood perspective; (3) from objective indicators to subjective indicators. More recently Burchi and De Muro (2016), discussed the different main approaches in the analysis of food security in the academic world along with the ones proposed by international organizations. They distinguished five main approaches which are: (a) Food availability; (b) income-based; (c) basic needs; (d) entitlement and capabilities, and (e) sustainable livelihoods.

These approaches have influenced the final definition of food security. The entitlement and capabilities approaches are the ones having a major influence in currently used definitions (Conceição et al., 2016). The most commonly used concept was presented for the first time in 1996 at the World Food Summit, and later in 2009 was improved. Food security is defined

as the condition that is reached *"when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life"* (FAO, 2009). Within this concept four dimensions can be identified: availability, access, utilization and stability (Ziervogel & Ericksen, 2010). Therefore, there is not a single way to measure food security (Kassie et al., 2014). The physical *availability* of food focusses on the supply of food that is determined by food production, stock levels and net trade. Increased food supplies do not automatically enhance the *access* to food by the poorer groups of the society (Iram & Butt, 2004). The concerns about insufficient food *access* have led to the development of policies' focus on income, expenditure, markets and prices in achieving food security objectives (FAO et al., 2015). The *utilization* of food refers to the act of processing the nutrients of food. The nutrient and energy intake also depends on the feeding practices, food preparation, diversity of the diet and intra-household distribution of food. There are different conditions that influence the *stability* of the food secure status such as weather conditions, political instability, or economic factors i.e. unemployment and rising food prices. In order to reach food security, all four dimensions must be fulfilled simultaneously (FAO, 2008).

Food insecurity has a temporal dimension. It is defined as transitory when a person suffers from a short-term temporary decline on food consumption and as chronic when a person is persistently unable to acquire sufficient food (Kassie et al., 2014; Chung et al., 1997). When a household is in a transitory food insecure situation, it can potentially adopt different strategies to overcome this stage. However, poor households often deplete their productive assets leading them to chronic food insecurity in the longer term (Kassie et al., 2014). Cyclical food insecurity is often referred to as seasonal and associated with the seasonal fluctuations in climate, cropping patterns, work opportunities and disease (Devereux, 2006).

Food access remains one of the biggest challenges of food security, especially in the poorest regions of the world such as sub-Saharan Africa and some parts of South-east Asia (FAO & IFAD, 2014). Even though the availability of food is growing globally and the Millennium Development Goal to halve the number of malnourish people by 2015 has progressed, the threats to food security are still persistent (Poulsen et al., 2015). Some of the processes that impact food security at different and multiple levels (local, regional and national) include the loss of soil fertility and soil degradation (AbdulRahim et al., 2008; Thornton et al., 2007) urbanization, land use changes such as replacement of food crop areas with biofuels (Mnenwa & Maliti, 2010), industrialization, population growth, droughts, domestic and foreign government policies, fluctuating market situations and climate change (Lotze-Campen et al., 2010; Riisgaard et al., 2010; Von Braun, 2007).

To understand and measure food insecurity it is necessary to identify what are the common determinants on a global and a local scale. Recent studies by Smith et al., (2017) draw a conclusion of this determinants across countries by pinpointing the five characteristics that are most strongly associated with the likelihood of experiencing food insecurity: having low levels of education, little social capital, weak social networks, low household income, and being unemployed. Other studies have also recognized the relation between food insecurity and poverty and vulnerability, especially amongst farming households in rural areas where the income and crop production (especially food crops) overlap strongly (Devereux, 2016). In this scenario, social protection programs have emerged in order to promote the enhancement of food security by: stabilizing incomes, raising income and enhancing social justice (ibid). The enhancement of food availability and entitlement is critical for reinforcing essential human capabilities and, therefore, constitutes a precondition for sustainable human development (Conceição et al., 2016).

2.1.2 Food security in Sub-Saharan Africa

Sub-Saharan countries account for a large amount of the world´s poorest and vulnerable population (UN, 2014). In the countries of this region nearly 218 million people (ration of one in four) are undernourished (UNPD, 2012). There are several factors threatening food security in the area such as population growth, climate change, biofuels, poverty and ecosystem degradation to mention some. The population in the region has increased from 507 million in 1990 to 936 million in 2013 according to the reports of FAO et al., 2015. This rapid population growth in SSA countries directly affects their abilities to assure supplying and accessing food (ibid).

The role of agriculture is central for improving food security and reducing poverty in Africa (Conceição et al., 2016). In most parts of SSA agriculture has a direct impact on the availability of food, as food needs cannot be easily reached through trade and imports (ibid). Agriculture in the region is assumed to determine the food availability and access for the 70 to 80 percent of the poor population as people relay on it for its own production, income and work (UNPD, 2012). At the same time, it determines how sustainable they use their resources in regards of amount of land and water use (ibid).

Smallholder farmers practice the majority of the agriculture in the SSA region. The UNDP (2012) reported that smallholder-focus agricultural growth is the most effective path for reducing poverty, enhancing food availability and accelerating human development. Enhancing smallholder agriculture would increase in overall agricultural productivity, which when carefully managed can even sustain the environment (Conway, 1998 ; Pretty et al.,

2011). On the other hand, Collier and Dercon (2014) argued that while agriculture plays a key role in the life of many people in SSA, there might be better ways for enhancing food security and development in the region than those that focus mainly in agricultural development i.e. in economies that are resource-rich or with good locations for engagement into manufacturing exports.

Several governments have supported biofuels initiatives in SSA in their efforts for boosting the economic growth rural development and energy security (Mitchell, 2010). The impacts of biofuels on food security are part of the food-versus-fuel debate (Rosillo-Calle & Johnson, 2010) and there is no doubt that biofuel production in SSA can compete directly or indirectly with food production in SSA. However, the involvement in fuel production activities can have beneficial outcomes in specific scenarios at the household level, by providing income from employment in plantations (Gasparatos et al., 2015).

Climate change is projected to have several negative impacts in agriculture in SSA, especially on smallholder livestock production systems, which play an important role in the livelihoods of the rural communities (Battisti & Naylor, 2009). The temperature rise will potentiate food insecurity in the region while at the same time there will be an increase in the occurrence of agricultural droughts with cause in elevated evapotranspiration, lower soil moisture, and higher rates of water runoff from hard pan soils when it rains (Wheeler & von Braun, 2013). Moreover, climate change has direct repercussions in food production in terms of stability, storage, food access and utilization. It is estimated that 90 percent of the population depends on rain-fed crop production and pastoralism to meet their basic needs (Barrios et al., 2008). The current predictions for the SSA show that the rice, wheat and maize yields are likely to drop in the next thirty years by 15 percent, 34 percent and 10 percent respectively (Nelson et al., 2009). These potential negative impacts are less distinct at regional or local scales. Wheeler and von Braun (2013) have predicted that the climate change variability will aggravate food insecurity in areas currently vulnerable to hunger and undernutrition. All this raises an urgent and continuous need for better-integrated food systems.

2.1.3 Food security in Tanzania

In the particular case of Tanzania, agriculture is very important in the economy and accounts for half of the national Gross Domestic Product (URT, 2005). Moreover, 87 percent of the poor population of Tanzania lives in rural areas and are highly dependent on agriculture (URT, 2005) with about 9.3 million women and 7.7 million men active in agriculture (FAOStat, 2014). Food insecurity is closely linked to poverty in the country and households below the

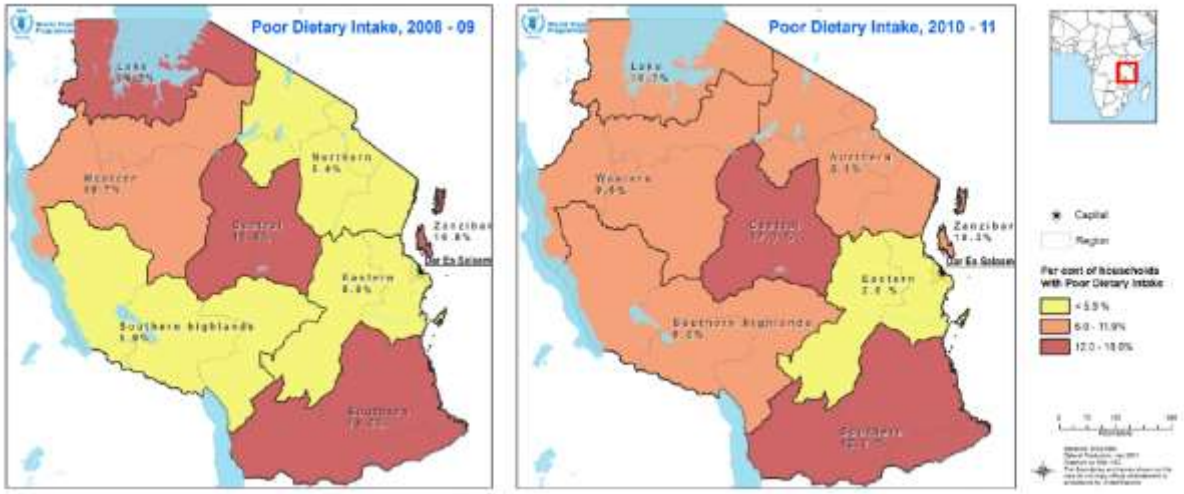
poverty line are more likely to be food insecure than other households (WFP, 2013). Even though Tanzania has experienced an economic growth in the last decade (MOFEA, 2008), it has not matched the improvements and living conditions of the country´s poor population (WFP, 2013). This weak relation between growth and poverty has been explained as the result of the structure of the agricultural growth, which favored larger-scale production (large-scale farmers are less likely to be poor) and has been concentrated among crops grown in specific regions (Pauw & Thurlow, 2011).

Projections from the General Circulation Models show that food security in Tanzania is likely to decline in the next 30 years as a result of climate change (Arndt et al., 2012). Therefore, improving farmer's adaptive capacities to climate change is essential. In Tanzania, smallholder farmers account for about 84 percent of cultivated land, of which 45 percent is devoted to maize supporting the livelihoods of 82 percent of smallholders, i.e. 4.5 million households (USAID, 2010). Rainwater harvesting has been pointed out as having the highest potential to improve Tanzania's agricultural productivity (Arslan et al., 2017) among other technics like the introduction of intercropping (maize-legume), soil and water conservation measures, the use of organic fertilizers, inorganic fertilizers and high yielding varieties.

The analysis of the food security situation in Tanzania from the 2012 WFP's Comprehensive Food Security and Vulnerability Analysis (CFSVA) show that the rural poor population is the most vulnerable. The main food security indicator used in the CFSVA is the poor dietary intake, but also other indicators are concerned with the diversity of food consumed, calorie intake, economic vulnerability and nutrition (see more WFP, 2013). In 2010, around 730,000 households (or 8.3% of all households) in Tanzania were classified as having poor dietary intake. This represents a slight drop from 9.8% in 2008. Figure 1 shows the prevalence of households with poor dietary intake between the two years.

The improvement on the production of staple crops like maize, which is already grown extensively by subsistence smallholders, is identified as a key factor for reducing both poverty and undernourishment in Tanzania (Pauw & Thurlow, 2011).

Fig. 1. *Map Poor Dietary Intake (2008-2009 and 2010-11). Source: WFP, 2013.*



2.2 Upgrading strategies in smallholder agriculture

Upgrading agriculture is making products better and processes more efficient. In a daily base, corporations want to be more competitive while adapting to the demands of the market. The upgrading concept has often been used in industrial scenarios, defining it as the capacity of innovation of a corporation for increasing the value of its products and processes (Kaplinsky & Readman, 2001). When talking about improvements, value chains (VC) is a key concept for understanding the ways on which upgrading can emerge. VC were defined by Kaplinsky and Morris (2001), as *"the full range of activities which are required to bring a product or service from conception through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use".* In the case of Global Value Chains (GVC), the activities are international and not only reserved to a country.

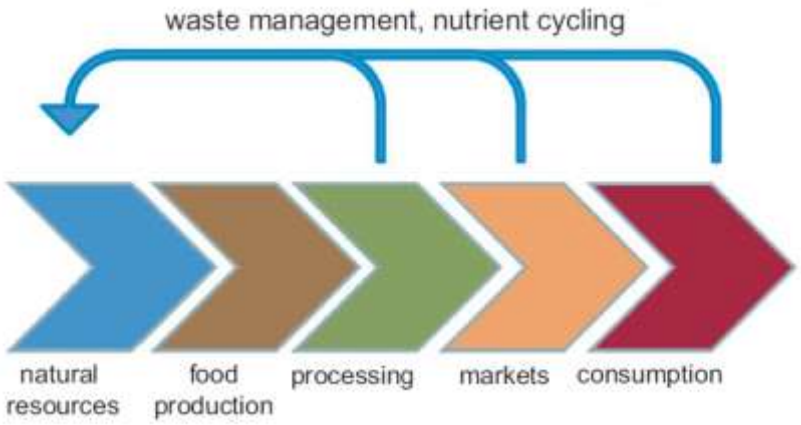
The challenges and opportunities that small farmers face on the current transformation of the agricultural production systems is increasingly researched. There is a tendency to believe that they may be marginalized from higher value supply chains as they are unable to meet buyer specification of the current markets without donor support (Ellis & Keane, 2008), limiting their possibilities of upgrading. In addition, there is an open debate regarding the role of smallholder farmers in the future, some authors like Collier and Dercon (2014) proclaim there is no future for them, while others underpin the importance of small farmers for economic growth and poverty reduction (Barrett, 2008). Nowadays smallholder farmers are the base of the agricultural production in SSA countries (ibid), and closing the gap between them and the needs of a fast-moving market is essential for their subsistence.

The analysis of the involvement of smallholder farmers in the agri-food value chains need to be strategically used for enhancing their participation in the upgrading process. Upgrading on these chains has been often linked to the identification of the leverage points for innovation change. Some of these leverage points are beyond the reachability of producers as they require political, financial and human resources (Riisgaard et al., 2010). These barriers limit the integration and development of poor producers in the agri-food systems (Kilelu et al., 2017). The interventions therefore often involve the strengthening of the relations with stronger chain actors or linking the small producers with external actors (Riisgaard et al., 2010). Hence, it is of great importance to understand the interaction and social networks of the actors involved in the different stages of the FVC. Enhancing and promoting relations among key actors can bring benefits to the social networks in the upgrading process, especially to small producers.

The development of site-specific strategies that enhance the food systems needs a focus on different scales (Graef et al., 2015). Three different categories for upgrading strategies (UPS) have been identified specifically for small producers by Riisgaard (2010): (i) *improved process, product or volume* staying in the same node or component in the value chain (Figure 2) through improvements in technology and management; (Riisgaard et al., 2010) *Change and/or add functions* refers to a situation when producers take a new function in the value chain by performing downstream activities such as transporting, advertising, processing, etc. or by engaging in upstream functions such as the provision of service, inputs or finance; and (iii) *Improve value-chain co-ordination* which can happen in two dimensions: it is vertical when producers get better deals through closer and better ties with buyers, and horizontal where agreements among producers to cooperate over input provision, marketing and certification among others. In addition, an essential element in the design and implementation of UPS is the participatory involvement of key stakeholders and institutions with knowledge about UPS (König et al., 2012; Riisgaard et al., 2010). Furthermore, the UPS implemented need to fit into the local and regional value chains that are composed of natural resources, crop production, processing, markets, consumption and waste management (Graef et al., 2014)

UPS within the interdisciplinary participatory Trans-Sec project are defined "*as a food-securing success story, good practice and/or technological innovation that is likely to improve productivity, efficiency or economic return of a food system and reduce related risks to the livelihoods of its stakeholders. One UPS can represent a set of practices and/or behaviors*" (Graef et al., 2015). Moreover, these UPS can impact one or more food value chain (FVC) component (Fig 2). Some of the UPS implemented by Trans-SEC project include improved processing, poultry-crop integration, improved cooking stoves and sunflower oil pressing among others. These UPS are further explained in the chapter 4.

***Fig. 2**. Food value chain components. Source: Graef et al., 2014.*



2.3 Social network analysis and natural resource management

2.3.1 Social networks (SN) and Social Network Analysis (SNA)

There is not a clear trace of the beginning of social network analysis. As a discipline, it can be traced back to the anthropologist Radcliffe-Brown (1952) who developed the concept of "social structure" along with the studies of Jacobs Moreno about sociometry in the 1930s. Building on this concepts and studies other sociologist and anthropologist started to use terms such as the fabric and web of social life. Through these metaphors the studies aimed to understand the "interweaving" on how social relations are organized. It was until the 1950s, when scientists focused on developing formal translations to these metaphors, and in the 1970s key concepts used in modern social analysis emerged (Scott, 2012). Social Network (SN) is defined as the *"finite set of actors and their relation or their relations defined on them"* (Wasserman & Faust, 1994). SNs are composed by actors who are linked to each other by meaningful relations (Prell et al., 2009). An actor can be defined as an individual, an organization or even a nation. SNs are an important component of social capital as it inheres in the structure of the relations between and among people (Coleman, 1990). The structure of these networks influences in the levels of trust, norms and reciprocity that are an important component of the social capital and allows people to act collectively in order to achieve common goals (Putnam, 1995). In addition, it is important to consider that not all networks are created equal regarding to their structures, thus different outcomes are expected from networks of different structure as the structural patterns can potentially impact the actors' behavior (Bodin & Crona, 2009).

Social Network Analysis (SNA) has emerged as a tool for identifying important actors in a SN describing their relations. The purpose of SNA is to develop and apply effective approaches

to measure and analyze patterns of social relations (Borgatti & Foster, 2003) while evaluating the types, numbers, and length of the ties-links among actors (Stein et al., 2011). SNA utilizes matrices to organize data to represent the links between actors using numbers that can represent the presence or absence of a link and the strength of it. The matrices are used to represent a particular relation, for example trust or flow of resources such as money and information. The importance of network analysis relies on its strength to examine individual actors as well as the behavior of the whole network (Emirbayer & Goodwin, 1994). As a tool, it has been applied in different fields such as health, environment and development & management among others, providing the analytical tools and concepts to understand the structures of social networks (Prell et al., 2008). Its implementation has enabled researchers to identify detailed influential individuals and marginalized groups (Reed et al., 2009; Crona et al., 2011) that otherwise would be omitted. Hence, this information is vital in natural resource management initiatives that seek to influence the behaviors of different actors through key influential actors (Rogers, 1995; Prell et al., 2008; Reed et al., 2009).

2.3.2 Social Networks and Rural Livelihoods

Social networks play a central role in the survival strategies for the rural poor. Even though these networks might not be visible or clear on first instance, community members rely on them when meeting various critical requirements of their daily life, when they are not able to meet these requirements by themselves. These survival strategies are often related to food nutrition security (Martin et al., 2004), co-management of scare resources (Pretty, 2003), climatic variations (Adger, 2003) access to credit in distress (Servon & Bates, 1998) and managing job in hard times. Understanding how networks operate is of big importance for pro-poor research and development (Misra et al., 2014). The livelihoods of the rural poor are complex systems and there is big flow of materials, services and information which are transmitted and exchanged in the form of complex networks, which help them to manage various uncertainties (ibid). Improving the network capacities is highly important for the rural poor, for them visualizing their Networks enables creating new capacities (Douthwaite et al., 2006).

Furthermore, recent studies show that the complexities of the rural livelihoods increase as a result of the increased human pressure on natural resources, economic liberation, structural adjustments and climate change (Ellis, 2000). In this line, their livelihoods depend on the environmental resources since the income and food from agriculture might not be sufficient to enhance their livelihoods. All this together justifies the need of understanding the social networks of these communities in order to improve the livelihoods systems. Understanding interactions is expected to also enable a better implementation of the UPS.

2.3.3 Social Network Analysis in Natural Resource Management

The implementation of the long lasting sustainable UPS is directly linked to effective management of resources that enhances the livelihoods of the rural poor. Therefore, it is important to understand the role of social network analysis in improving and understanding natural resource management.

The Natural resource management is often challenging, and failure is very common. Management approaches have often failed, as they do not develop an understanding of the complex social realities in which they are implemented (Schiffer & Hauck, 2010). Diverse studies have concluded that the governance of natural resources highly depends on the collaborative relations and interactions between the actors involved or affected by the use and management of them (Mills et al., 2014; Bodin and Crona, 2009; Bodin et al., 2006; Ostrom, 1990). Thus, understanding how social structures enhance or hinder the governance processes of natural resources is crucial in natural resource management (Pretty & Ward, 2001).

Until recently the approaches to understand the behaviors of networks were limited to individual actor perspective instead of group or community overview and the amount of studies that describe these relations are still limited (Bodin & Crona, 2009). According to Bodin and Crona (2009), the structures of the SNs have an influence in the (i) the generation, acquisition and diffusion of different types of knowledge within the network; (Riisgaard et al., 2010) mobilization and allocation of key resources for effective governance; (iii) commitment to common rules among actors; and (iv) conflict resolution mechanisms. Some of the structural characteristics that have been pointed out as relevant for resource governance are cohesion, the number of ties, the actor's position with the network and the influence (ibid). Moreover, the analysis of the interactions among a network holds great potential and can be used in large scale (global networks of trade) and small scale (local social networks) (ibid). Together with the analysis of the networks' structures, researchers have also studied the differences between strong and weak ties related to different outcomes (Prell et al., 2009). The strength of a tie is the combination of different factors such as the amount of time, emotional intensity, mutual confiding and reciprocal services which characterize the tie (Granovetter, 1973). The relation of the strength of the ties is relevant in resource management as actors sharing strong ties are more likely to influence one another (Coleman, 1990); share similar views (Bodin and Crona, 2006), offer one another emotional support and help in times of emergency (Cross & Parker, 2004); and communicate effectively regarding complex information and tasks (Friedkin, 1998). Therefore, strengthening ties is important for enhancing mutual learning and sharing resources and advice among actors in the network (Crona & Bodin, 2006).

The recognition and comprehension of the relations among networks actors can enhance collective action and lead to successful natural resource management (Bodin et al., 2006; Newman & Dale, 2005). Furthermore, it has been recognized that key players have an important role as change agents in natural resource management on shifting to more sustainable practices (Olsson et al., 2006). In addition, Burt (2004) widely studied the positions of actors linking isolated components on the network and its value to affect change. SN in social science is often considered as an instrument for identifying the best option for influencing an actors' behavior (Frija et al., 2017). In this context, scholars argue that SN could be more important than formal institutions for effective implementation and compliance with environmental regulations (Bodin & Crona, 2009; Scholz & Wang, 2006).

Other studies have focused on the relation of the SN and resilience to environmental impacts such as ecosystem degradation (Orchard et al., 2015). SN are assumed as fundamental as they enhance the resilience to change as communities are able to self-organize and generate the necessary social capital to support their livelihoods (Djalante et al., 2013). However, despite the importance of social networks in fostering resilience through supporting rural livelihoods and self-organization, social network analysis has gained little attention in livelihood research (Misra et al., 2014).

2.3.4 Important characteristics of Social Networks

Social networks literature has proved that the process of work and ideas do not necessarily flow through organizational hierarchy, but rather through informal networks (Chung & Crawford, 2016). Through social ties individual actors learn about innovations, opinions and perspectives, learning about new tasks or reinforcing their belief in previously held ideas (Prell et al., 2008). Actors having stronger ties in a network are usually assumed to have more influence than the actors sharing weak ties. Strong SN are assumed to have high levels of trust and reciprocity within a community (McOmber et al., 2013). On the other hand, weak ties allow the flow of more diverse information between actors enhancing the generation of new ideas (Prell et al., 2008). Weak ties are characterized by less frequent communication. As actors having stronger ties for a long period of time tend to have the same knowledge for example regarding resource management. Research has proved that having weak ties between dissimilar others may offer the individual actors and the whole network to a more diverse pool of information and resource (Prell et al., 2008). However, these ties might be easier to break. Therefore, it can be assumed that having diverse external ties can make networks more resilient and adaptive to change but these also then to be more fragile (Bodin & Crona, 2009; Prell et al., 2009). SNA provides a framework to

organize and assess knowledge of social situations and vulnerabilities (McOmber et al., 2013).

Another concept discussed in the in the literature related to resource management and innovation is centralization. A centralized network is the one which one or a few actors share the majority of ties with other actors within a network. Centralization on an early stage of a group implementation might be beneficial for building support and collective action (Crona & Bodin, 2006; Olsson et al., 2004). However, researchers have recognized the importance of decentralize networks for the implementation of longer term goals (Crona & Bodin, 2006).

The concept of density is also relevant in this framework; it was defined by Wasserman and Faust (1994) as *"the ratio of the existing ties to the theoretical maximum",* the number of ties that exist. The higher the level of density the more there is potential for collective action (Bodin & Crona, 2009). Recent studies have observed the benefits of joint action as result of increased tie density, and the importance of many ties from different type of actors i.e. between the community and governmental officials (Sandström & Carlsson, 2008). Moreover, high density in a network can enhance the creation of trust and promotion of norms that are adequate for resource use (Pretty & Ward, 2001). The development of knowledge and understanding are also benefited from having many social relations, through the exposure to new ideas and increased amount of information (Bodin & Crona, 2009). In the field of agricultural development, it has been shown that important information on new technologies and sustainable practices tend to flow in informal social ties (Isaac et al., 2007).

In addition, highly dense networks are related to homophily, a situation where similar actors are attracted to each other (Friedkin, 1998; McPherson et al., 2001). When actors are in this situation the information flow is better as they are able to communicate in a tacit way also exchanging complex information as there is a better level of understanding among them (Prell et al., 2008). Nevertheless for successful natural resource management organization within a project require new views from different perspectives and opinions (Bodin et al., 2006), therefore the project may be beneficiated when increasing the diversity of the stakeholders involved.

Reciprocity along with density and strong ties are often assumed as supporting the development of trust inside the networks (Schiffer & Hauck, 2010). It is possible to study the networks relations observing the actual number of the reciprocal ties between two nodes in relation to the possible reciprocal ties within a network (Jansen, 2006). High levels of reciprocity and density are indicators for trust (Coleman, 1990; Pretty & Ward, 2001).

Other important characteristic of SN is the level of cohesion, how close together is the group instead of being divided into sub-groups (Wasserman & Faust, 1994). High cohesion in a network lacks clearly divided sub-groups, which could be a challenge for collective action (Bodin & Crona, 2009). Many factors can promote the formation of the subgroups such as

geographical borders specialization or division of labor (ibid). In less cohesive groups the density of the relational ties can be low therefore having negatives effects on the collaboration (Granovetter, 1973). However, if actors connecting the subgroups have the ability and motivation to coordinate the group's activities towards the common goal, this limitation could be overcome (Bodin & Crona, 2009).

From an actor perspective measuring the position of the actor is relevant. The centralization levels can influence the resource flow within a network as actors affect how information and resources are exchanged. The concept of centrality has been recently approached in the resource management literature (Bodin et al., 2006; Crona & Bodin, 2006; Crona et al., 2011). However, the distinction between the different types of centralities and their impacts in resource management are still scarce (Prell et al., 2008). Degree centrality and betweenness are the most frequent centralities that have been used in SN for resource management projects. Degree centrality represents the number of actors that an actor is connected to, Freeman (1978) is often credited with the development on the centrality concept. Actors having a high centrality degree are often perceived as important players for mobilizing the network and bringing actors together (Prell et al., 2008). The betweenness centrality indicates how many times an actor lies between other two actors who are themselves disconnected (Freeman, 1978; Wasserman & Faust, 1994). High betweenness centrality enhances the potential of an actor to control the flow of diverse resources to the network. Actors holding high betweenness centrality are important for long term resource management planning, as they bridge new ideas and resources that could be important for the networks sustainability (Bodin et al., 2006; Prell, 2003; Prell et al., 2009).

In this study covering the networks social relations is therefore fundamental for understanding the development of the groups implementing the different upgrading strategies. In this thesis, the approach of the SNA will be on the local scale within a participatory approach, with the small farmers implementing the innovations being in the center and main source for the analysis. The SNA of the UPS is expected to reflect the levels of the actor's involvement and cooperation. Through this approach we also try to understand through the farmers' perspective who are the important stakeholder or actors for the implementation providing a description of the current ties of the networks in the upgrading process.

2.2.5 The Net-Map tool in Social Network Analysis

The traditional approaches of social network analysis present a variety of problems when doing research on the field (Schiffer and Hauck, 2010). The collection of data for SNA usually follow the next steps: (i) identify actors name using a name generator (ii) followed by a set of

questions for tracing the possible relation between two actors, for each possible pair of actors. One of the main challenges in this framework is the time constraint as the number of questions tends to be very high. In consequence, the number of participants learning in the process is minor (Schiffer & Hauck, 2010). Moreover, in a research held in Kenia by Ayuku et al. (2003) with scavenging street children other challenges were detected in the field work such as low level of trust, short attention span and low level of reasoning. The adaptation of research towards a participatory approach to overcome and discuss possible intercultural differences is therefore important (Schiffer & Hauck, 2010). In order to overcome these challenges, the Net-Map tool was developed in a combination of the pen-and-paper network approach, while integrating goals of the actors (see more Schiffer, 2007).

The Net-Map tool has been applied to different scenarios, and it is proposed to be used as research tool as well as instrument for organizational development and strategic network planning (Schiffer, 2007). In Ghana, the method was successfully applied in a study on the development of multi-stakeholder water governance (Hauck & Schiffer, 2012). The results indicated that the Net-Map is a strong tool for gathering data which could be used to support organizational development. Moreover, actors increased their understanding of the environment where they are working (Schiffer & Hauck, 2010). Other studies in Tanzania used Net-Map for analyzing the political economy of charcoal sector. Providing valuable information about whom and who are needed to engage in the sector in order to promote and support the design of viable policy reforms to make the sector more environmentally and economically sustainable (Sander et al., 2013). In the field of agricultural biodiversity governance, Hauck et al. (2016) carried out research at a local and regional level, which revealed the importance of information flows and regulations as well as social pressure possibly influencing biodiversity governance.

In this study Net-Map is a tool that will enable to capture the current state of interaction among the groups implementing the different UPS. The tool could be used as a monitoring system of the development of the group relations over time. We expect that apart from helping in the identification of influential actors in the development of the strategies we will be able to see how these relations are connected to their specific goals and their livelihoods coping strategies. The participatory approach is expected to create a platform where the different actors can understand their roles and learn more about their communities.

3. Sustainable Livelihoods Framework

In the following section the framework for this thesis is explained in relation to Social Network Analysis. The primary aim here is justifying the use of the framework, followed by the definition of the sustainable livelihoods concept and the main components of the framework.

3.1 Social Network Analysis and Sustainable Livelihoods

Applying a Social Network Analysis (SNA) in order to explore the complex interactions in a livelihood system needs a conceptual framework. In this thesis, the Sustainable Livelihoods Approach (SLA) will be used in order to understand how the different UPS impact the livelihoods of the small farmers implementing them in a food deficit context. Through this analysis we will be able to understand the individual as well as group networks that sustain the rural livelihoods. In addition, the analysis can potentially reveal strategic improvements of the UPS implementation. SNA is a great tool for understanding the coping strategies, in this special case the UPS implementation, of poor people in order to combat vulnerability and other challenges among peoples' social networks. Moreover, from a farmer based approach we will get some insights on their motivation for getting involved in the UPS implementation. Also, it provides information regarding measurable impacts on the farmers' capital assets (explained below) and the integration of the UPS within their Livelihood strategies that are likely to impact their food security situation.

3.2 Sustainable Livelihoods Approach

The concept of Sustainable livelihood (SL) goes beyond the conventional definition of poverty and its eradication. The Sustainable Livelihoods Approach (SLA) is a framework often used by development agencies for planning and addressing development interventions. There is a variety of Sustainable Livelihoods (SL) frameworks that have been developed and adapted by donor agencies, NGOs, and research organizations (Arun et al., 2004). Chambers and Conway (1992) firstly introduced the SL framework, applying it to a household level:

"*A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contribute net benefits to other livelihoods at the local and global levels and in the short and long term "*

In recent times, the Institute for Development Studies (IDS) and the British Department for International Development (DFID) have been working on the concept and putting into practice. This lead to a modified definition proposed by Scoones (1998):

"*A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base"*

The framework developed by the DFID is one of the most widely used nowadays, and it is also the one used in this thesis. The main principles within the DFID´s framework are: (i) *people centred*: putting people´s social and at the centre of development; (ii) *sustainability-focused*: the four pillars of sustainability are equally important – economic, institutional, social and environmental; (iii) *holistic*: holistic view is aspired in understanding the stakeholders' livelihoods as a whole, with all its facets, by a manageable model that helps to identify the most pressing constraints people have to face; (iv) *implemented in partnership:* with the public and private sector; (v) *linking the micro with the macro scale*: poverty alleviation will only be achieved by working at multiple levels, ensuring that micro le-level activity informs the development of effective policies, and macro-level structures and processes support people to build upon their own strengths; (vi) *dynamic*: external support requires to understand the dynamic nature of livelihoods; and (vii) *building on the strengths of the poor:* a central issue of the approach is the recognition its ow potentials instead of focusing on its constrains.

(Kollmair & Juli, 2002)

3.3 Elements of Sustainable Livelihoods Approach (SLA)

The Sustainable Livelihoods framework is composed of four main components (Figure 3):

1. People are conceived living in vulnerability context in which they are exposed to risk, sudden shocks, trends over time, and seasonal change. Vulnerability emerges when people face shocks and don't have the capability to respond efficiently.

2. People have a number for capital assets, which they rely on to make their living, these include Social capital (social networks), Natural capital (natural resource stocks), Financial capital (savings, income, credit), Physical capital (transport, shelter, water, energy, communications), and Human capital (skills, knowledge, labour). The mentioned capitals are represented in an "assets pentagon", which is used to assess people's overall asset base.

3. The assets are drawn on with the people's livelihood strategies, which are the choices and activities of the peoples in order to pursue a positive livelihood outcome. The livelihood strategies in this context are influenced by the UPS as they are supposed to enhance the current strategies adopted by the farmers for enhancing directly or indirectly their food security situation.

4. Policies, institutions and processes shape peoples access to assets and livelihood activities. In addition, they have a direct impact on weather people are able to achieve a feeling of inclusion and wellbeing.

Fig. 3. *Sustainable Livelihood Framework. Source: DFID, 2001*

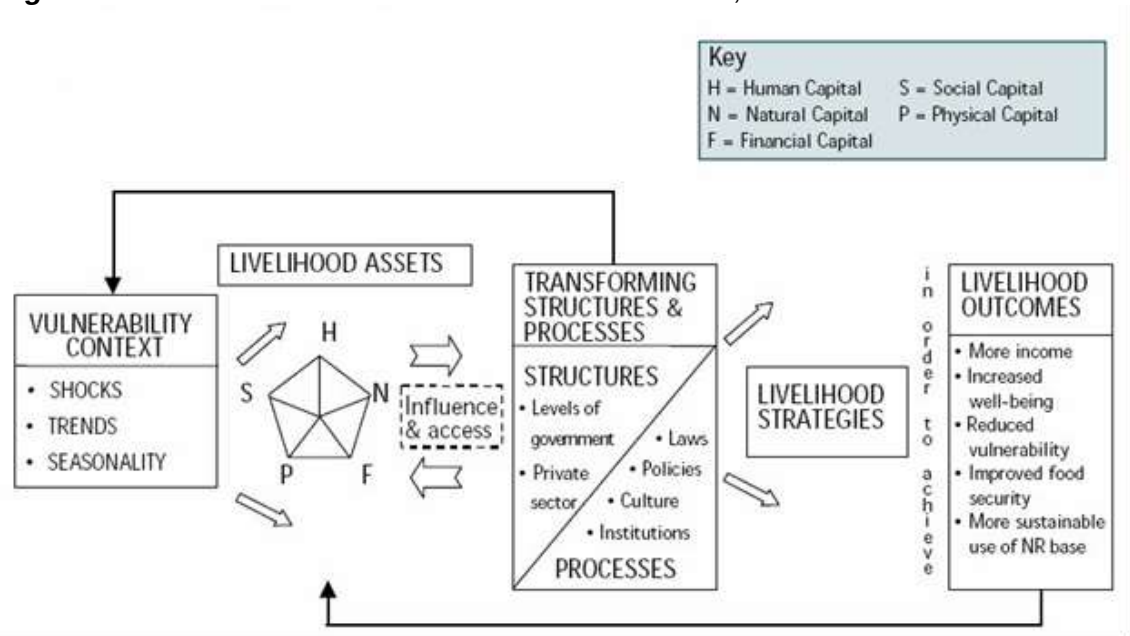
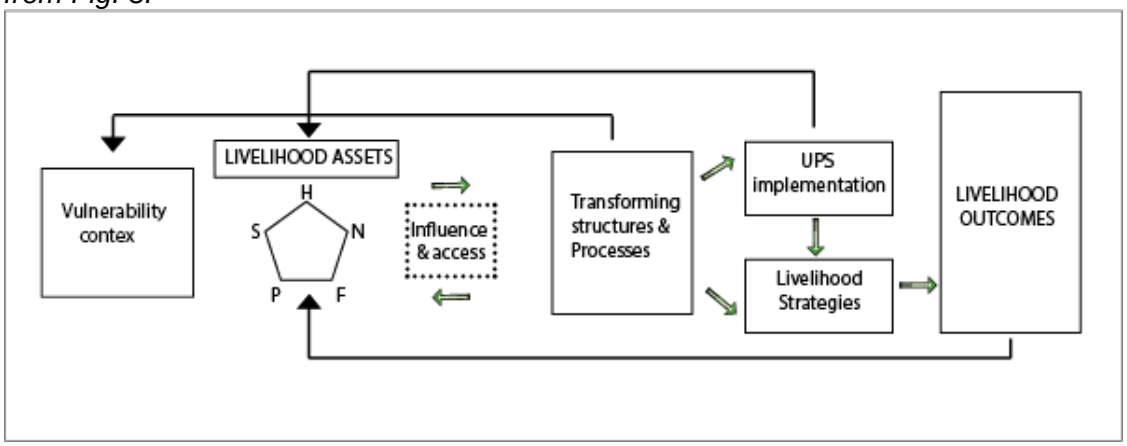


Figure 3 presents the sustainability livelihood framework. The pentagon of the livelihoods assets is influenced by structures and processes form one side and from the vulnerability context form the other. Structures and processes operate in all levels from household to international levels, as they determine the access to the various types of capital assets and the livelihood strategies. However, the availability of the livelihood assets also influences the structures and processes. These livelihood strategies influence the livelihood outcomes such as increased income and enhanced food security, which impact the availability of the livelihood assets.

Furthermore, when we locate the UPS into this framework we could say that Livelihood strategies and UPS are at the same level. The UPS implementation enhances the current existing livelihood strategies, which are expected to result in improved livelihood outcomes.

Moreover, the UPS implementation enhances directly the household's livelihood assets, as the participants gain access to different types of assets i.e. knowledge, tools, machinery, loans, etc. (Fig. 4). For instance, participants from the UPS improved cooking stoves gain access to construction skills, knowledge about the environmental and health benefits of the stoves and construction tools, among others.

***Fig. 4**. Integration of the UPS into the Sustainable Livelihoods Framework. Source: adapted from Fig. 3.*

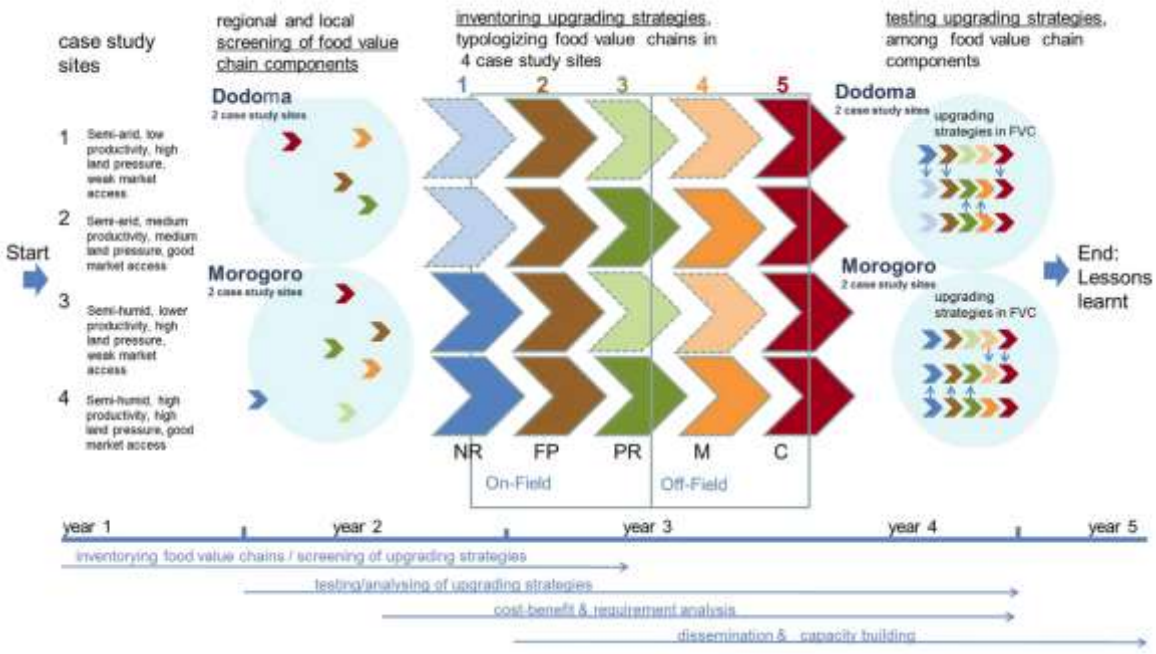


4. Case Study

4.1 Trans-SEC project

This thesis is part of the collaborative Trans-SEC project whose main objective is to improve the food situation for the most-vulnerable rural poor population in Tanzania. The project is designed to identify successful food securing upgrading strategies (UPS) along local and regional food value chains, test and adjust them to site-specific, sustainable settings and tailor these concepts to be disseminated for national outreach (Graef et al., 2014). Different approaches in FVC analysis usually only focuses on one part of the chain, while in the Trans-SEC project the entire FVC is considered. The project involves research centers, universities, government bodies, private sector, and local actors. Trans-SEC framework focuses on rural FVC and considers both subsistence and surplus farming for local and regional markets (ibid). The project is currently on the 4th year out of 5 (Fig. 5), however the data collected for this study was held during the 3rd year. During and after the project lifetime, the results are expected to be implemented at different levels of policy, extension and research.

Fig. 5. *Food value chain and temporal succession of research tasks (NR – natural resources, FP – food production, P – processing, M – markets and institutions, C – consumption; more description given in text). Source: Graef et al., 2014*



4.1.1 Upgrading Strategies

The process of selection of UPS for each village can be divided into two main steps, UPS prioritization (pre-selection) and the UPS final selection for implementation. The selection of the UPS for each village was highly participative including the small farmers and the key stakeholders. The steps for the pre-selection were: (i) Stakeholder mapping across the food value chain, (ii) Inventorying FVCs constraints and strategies, (iii) Identification of the food security criteria through existing literature, focused groups and panel discussions (iv) Identification of 3-5 Groups per FVC component (Graef et al., 2015). The final selection and prioritization of the UPS was held through a participative method, in groups of 9-13 stakeholders with different backgrounds and knowledge. The selected UPS by stakeholders in Ilakala, Changarawe, Ilolo and Idifu are shown in Table 1.

Table 1. *Upgrading strategies choices in the 4 case study sites. Source: Author's data.*

UPS	Ilakala	Changarawe	Ilolo	Idifu
1. Rainwater harvesting, fertilizer micro-dosing	✓ (tide ridges)	✓(tide ridges)	✓(tide ridges)	✓(tide ridges)
2. Byproducts for bioenergy	✓			
3. Improved processing	✓(maize sheller)	✓(maize sheller)	✓(millet thresher)	✓(millet thresher)
4. Improved wood supply			✓	
5. Improved stoves	✓(training)	✓	✓	✓
6. Sunflower oil processing				✓
7. Optimized market-oriented storage	✓	✓		
8. Poultry-crop integration		✓		
9. Market access system (m-IMAS)	✓	✓		
10. HH nutrition education & kitchen garden training	✓	✓	✓	✓
UPS groups (total)	7	7	5	5

✓ = main UPS selected; add-on in parenthesis, due to existing demand of other stake holders and agreement of implementing partners; Trainings are limited in time and other outputs such as farmer field school training and others. (Suggested UPS "Biogas", "Improved wood supply", "Manure collection", "New product development", "Technologies for processing, preservation and storage" where not selected).

This study will only focus on the following UPS: (i) Byproducts for bioenergy; (Riisgaard et al.) Improved processing (maize sheller and millet thresher); (iii) Improved cooking stoves;

(iv) Sunflower oil processing and (v) Poultry-crop integration. These UPS are found in 2 stages of the value chain: Post-harvest processing and biomass/ energy supply and markets and income generation. The description of these UPS is found in Table 2 and the pictures of the UPS are found in Figure 5.

Table 2. *Upgrading strategies across agri-food value chain components and description. Source: modified from Graef et al., 2015*

FVC component and upgrading strategies	Description of upgrading strategy
Post-harvest processing & biomass/energy supply	
Byproducts for bioenergy (pyrolisor)	low-cost (US$ 300) pyroliser (manufactured from 100-200 l oil barrel) producing charcoal from maize cobs and simultaneously used for cooking (Ikelle & Ivoms, 2014).
Improved processing: maize shelling; millet threshing	mobile maize shelling machines in sub-humid region and millet shelling machines in the semi-arid region, including participatory business plans for investment and pay-offs (Mejía, 2003).
Improved stoves	small scale stoves reducing energy consumption from loam for household use with one or two holes at US$ 3-5/stove, locally constructed by trainers training other stakeholders (Kshirsagar & Kalamkar, 2014).
Markets and income generation	
Sunflower oil production	enhanced horizontal and vertical coordination of sunflower oil production, including investment in sunflower oil press (RLDC, 2008).
Poultry-crop integration and marketing	poultry keeping, disease management, utilization of crop by-products in raising poultry, utilization of poultry manure (Mlozi et al., 2003) and selling on local or regional markets.

Fig. 6. *UPS images. Author's source.*

4.2 Study Site

The research is undertaken in four villages of two districts, which are located in two climatically different regions in Tanzania, sub-humid Kilosa district that is within Morogoro region, and semi-arid Chamwino district in Dodoma region.

4.2.1 Sub-humid Morogoro

Food systems in the region are primarily based on maize, sorghum, legumes, rice and horticulture, partly with livestock; the annual precipitation of the region is 600-800 mm (Graef et al., 2014). Highlands, flat plains and alluvial valleys dominate the geography of the region (Mnenwa & Maliti, 2010). Areas with different levels of food insecurity characterize Morogoro Region (Graef et. al., 2014). Kilosa is located to the west of Morogoro town in east central

Tanzania. The crops grown in the district include maize, sesame, rice, sorghum, banana, cotton and vegetables. The selected Case Study Sites (CSS) in Kilosa are Ilakala and Changarawe. Ilakala has 6 sub villages, and Changarawe 5.

4.2.2 Semi-arid Dodoma

The region is primarily semi-arid and covers an area of 41,311 square kilometers with altitudes between 830 and 2000 meters above sea level (URT, 2012). Flat plains and small hills predominantly characterize Dodoma. Furthermore, it is one of three regions ranked top in the list of drought stricken areas of Tanzania. Dodoma comprises three livelihood zones namely; (i) the “Bulrush millet, Sunflower, and Livestock Livelihood Zone”; (ii) the “Singida-Dodoma Sorghum Livelihood Zone”; (iii) and the “Dodoma Lowland Sunflower, Grape, and Sorghum Livelihood Zone”. In the “Dodoma Lowland Sunflower, Grape, and Sorghum Livelihood Zone” grapes are produced and sold for wine making and fruits. The major sources of income are through livestock sales, cash crop, hired labor and seasonal casual labor. The food system is primarily based on sorghum and millet, with a strong integration of the livestock component (Mnenwa & Maliti, 2010). Pest, unreliable rainfall and diseases affecting plants and animals often pose threats to livelihoods (USAID, 2008).

4.3 Case Study Sites

Trans-SEC has four case study sites (CSS) in two contrasting regions (semi-arid, sub-humid). The focal crops are maize in the sub-humid region (Fig. 7), and millet and sunflower in the semi-arid region (Fig. 8), also including intercropped commodities such as pigeon pea and groundnuts or other crops if adding high value to the food system (Graef et al., 2015). The target regions are selected to represent the large variability of farming systems in the region. The criteria for selection of the case study sites are; (a) village sizes with 800–1500 households; (b) similar climates (c) differing rain fed cropping systems, possibly integrating livestock; and (d) differing market access.

The Tanzanian smallholder farmer association MVIWATA is an active organization in these regions. Another aspect for selection of the villages is to select where there is an active participation of the Tanzanian smallholder farmer association MVIWATA and also where there is no intervention of large research and development (R&D) projects. Other selection criteria include; available logistics, the number of stunted children below 5 years as an indicator for food insecurity, soil types, infrastructure and facilities, differing wards, and population density.

Each CSS consists of at least one local market place and the surrounding 2–3 sub- villages and has at least partial access to markets for cash crops to create a design with comparable and diverse environmental and socio-economic conditions (Graef et al., 2015). This goes a long way to enable proper investigation of food security upgrading strategies along the different components of the Food Value Chain (FVC). The features of the villages are further described in tables 3 and 4.

Fig. 7. *Case Study Sites (in gray color) in Morogoro Region. Source: (Sieber & Graef, 2013)*

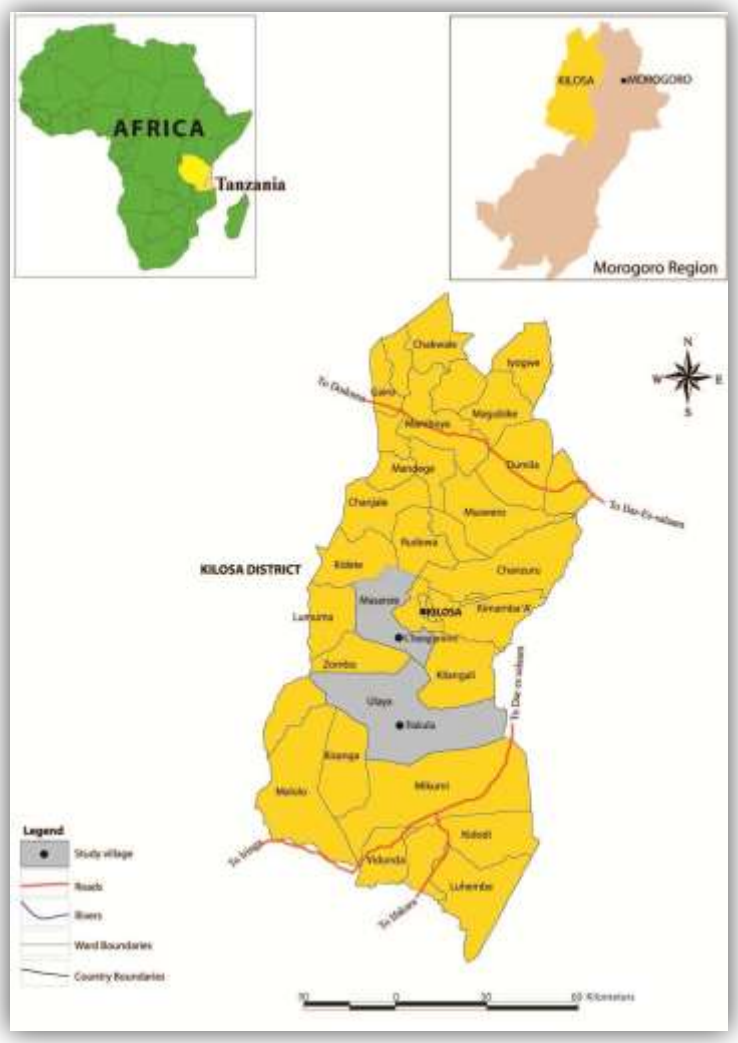


Fig. 8. *Case Study Sites (in yellow color) in Dodoma Region Source: (Sieber & Graef, 2013)*

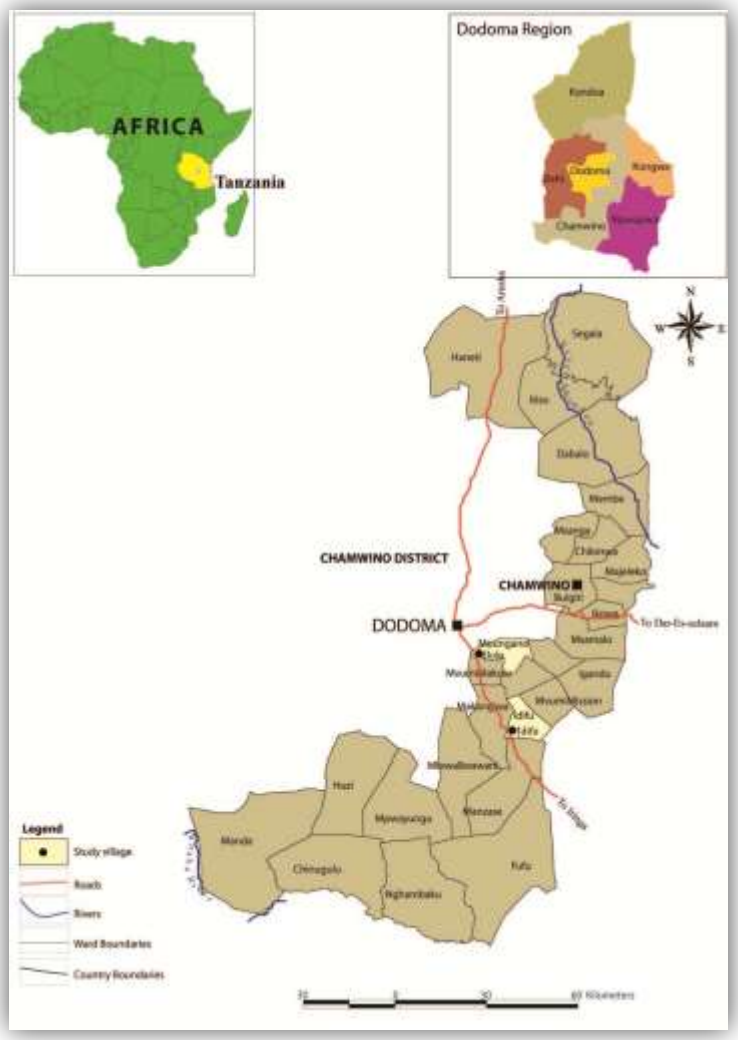


Table 3. *Village Features Morogoro. Source: Höhne, 2015.*

Category	Features Ilakala	Features Changarawe
Natural	• Semi-humid climate • Proximity to Mikumi National Park • Village forest reserve	• Semi-humid climate • Annual river
Physical	• Main road connecting Kilosa & Mikumi • 7 milling machines • Partial mobile phone network • 6 solar panels	• Electricity in village center • 5 milling machines • 6 machines for processing timber • Main road to Kilosa • Proximity to Kilosa • High mobile network

		coverage
Economic financial	• Sunday market for vegetable and other products • CARE community bank	• 2 acres of state land • Village community bank
Social	• 36 Tribes • Christians and Muslims • Conflict between pastoralists and farmers	• Many tribes • Christians and Muslims • Conflict between pastoralists and farmers

Table 4*. Village Features Dodoma. Source: Höhne, 2015*

Category	**Features Idifu**	**Features Ilolo**
Natural	• Semi-arid climate • Lowland	• Semi-arid climate • Lowland
Physical	• 4 milling machines • Oxen and Oxen carts for rent • Distance to Mvumi • Mobile phone network • Medical station	• 15 solar panels • 4 milling machines • Groundnut processing • Oxen and oxen carts for rent • Proximity to Mvumi • High mobile network coverage • Main road connecting Dodoma & Mvumi
Economic financial	• TASAF aid	• Village community bank
Social	• Gogo People • Christians	• Gogo people • Christians

5. Methods

Studying the UPS from a SN perspective started by listing the potential important actors involved, defining the relations (ties) to be analyzed, and finally generating the data for mapping the relations in order to be analyzed.

5.1 In-depth interviews

The carried-out interviews were composed of two main parts, the in-depth interviews and the Net-Map. A total number of 88 interviews were conducted. The research was carried out in 10 UPS groups implementing the five UPS described before. Eight to ten actors on each group were chosen based on generic selection criteria. These criteria were: (a) actors needed to have taken part in the household (HH) baseline survey; (b) gender balance (at least 1/3 women or men; optimum 50:50); (c) actors mental capability for a two-hour interview (ability to sit for 2 h); (d) economic status (poor and better off); and (e) integration of people from sub-villages (2-3). Individual interviews were carried out for each interviewee followed by social mapping using the Net-Map tool.

The individual semi-structured interviews were held from the period of April-July 2016. Participants were asked to describe their role in the group, their impressions and ideas for improving the implementation of the UPS, their impacts perceived in their food security situation, changes in their lives through the UPS implementation, group conflicts, and their group vision for the future (see Annex A). Furthermore, the group leaders and secretary were asked to provide more details about the group management and current tasks in order to get insights of the groups´ modus operandi. The interviews were held in Swahili with the participation of an English translator through the whole session. The in-depth interview was the first part of the sessions, which had duration from around 15 to 20 minutes. Firstly, the participants were asked for their consent to record the audio, and it was proceeded with the confidentiality statement, where the researcher stated that the data from the interview was only be used for research purposes and not for its own benefit. Followed to this a series of questions were asked, in order to have better insights on the UPS implementation and the impacts perceived on their food security. These questions are presented in Annex A. The interviews were held in both outdoor and indoor places. Each of the sessions was audio recorded and an average of 3 interviews were translated and transcribed for each UPS group. Notes were also taken on each session for the purpose of evaluation.

5.2 Social Network Analysis using the Net-Map tool

The Net-Maps tool was the selected method to implement the SNA, which is an innovative empirical research tool that combines social network analysis and power mapping tools as described above (Schiffer, 2008). The Net-Map tool has the advantage that implicit relational concepts can be visualized and thus made explicit; actors' characteristics and how they are linked to one another can be made obvious. It enables participants to learn about their own position in the community and discuss their views with others (Schiffer, 2008). After the in-depth interviews the researchers and participants started with the mapping process, which comprises the following steps (see Annex A for more details):

1. *Introduction of the method.* The participants were introduced to the mapping session, mentioning the different steps. Letting them know that there is no evaluation of their answers, as we just wanted to know their opinions about the groups' functioning.
2. *Identifying who are the important actors for the implementation of the UPS*. Respondents were asked to think who are the influential actors in the implementation of the UPS. In order to familiarize the participants with the process, a list of possible influential actors at a village level was generated previously. Respondents were presented with the provisional fixed list of names of the actors written in small colored paper. In addition, the names of the actors were complemented with icons representing each actor, for those who could not read. Respondents were also allowed to add actors they think they are influential. The final selected actor name cards were fixed in a large sheet of paper.
3. *Ties/Links between actors.* In this step, the ties regarding (a) Knowledge, (b) materials and (c) money relations between actors were drawn. Each type of relation was drawn with an arrow which indicated a flow from one actor to another. In case there was a mutual exchange the arrows indicated it. The knowledge flow was the first to be drawn and all the possible ties between actors where asked. For reason of not extending the session for too long the materials and money relations were asked together.
4. *Motivations for participation in the UPS.* The perceived motivations for each actor were asked. In this step, a list of 8 possible motivations was presented to the participants, each motivation was represented by an icon. The motivations presented were: more income, enhancing food availability, more time, more joy, better recognition, preventing shocks, better social relations and more knowledge. In addition, the actors were asked to include any motivation that was considered as important that was missing on the list. Following to this the respondents selected 3

motivations for each actor and the icons representing the motivations were drawn next to the actor name.

5. *Influence towers.* Influence towers were set up for each actor. These towers measured the influence in the implementation of the UPS in regards of: (a) importance, (b) trust, (c) food, (d) income and (e) knowledge. Wood pieces were stacked forming a tower measuring each influence category for each actor. The rating of the influence was from 0 to 5. The higher the tower the more influential the actor. Additionally, the actors were asked to give reasons for the levels attributed to the different actors to add qualitative attributes to the data or to have a better description.
6. *Summing up.* To close the session, the interviewee was given the opportunity to ask any questions of his interest, regarding the session or the project (Trans-SEC). The participant was invited for a Focus Group Discussion (FDG) in order to discuss the findings of the mapping session within the same UPS group

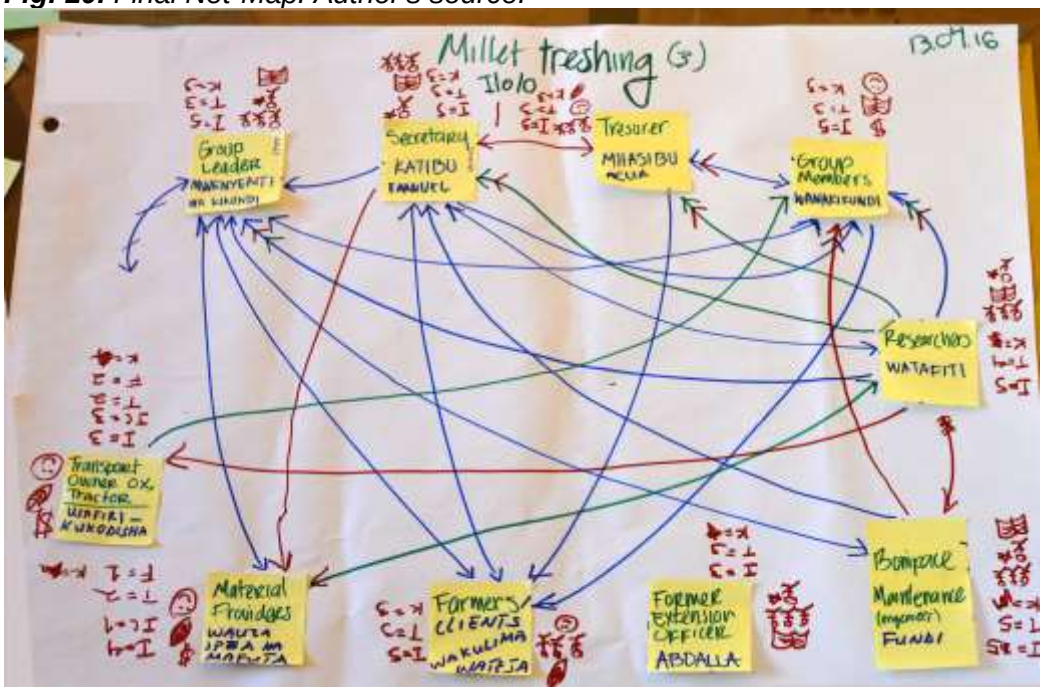
Fig. 9. *Net-Map session. Author's source.*

Table 5. *Total number of Net-Maps administered by village for each UPS. Source: Author's data.*

Village	Sample size (n)	Males	Females
Improved cooking stoves			
Ilolo	8	5	3
Idifu	8	5	3
Ilakala	8	3	5
Changarawe	8	4	4

Improved processing			
Ilolo	9	8	1
Idifu	8	4	4
Ilakala	8	5	3
Changarawe	8	6	2
Byproducts for bioenergy (pyrolisor)			
Ilakala	8	5	3
Sunflower oil press			
Idifu	7	4	3
Poultry-crop integration			
Changarawe	8	4	4

Fig. 10. *Final Net-Map. Author's source.*



5.3 Focus Group Discussion

All participants from the individual interviews were called to participate upon a Focus Group Discussion (FGD). FGDs are discussions among five to ten people on a given topic. A moderator kept the discussion focused with a minimal self-involvement (Jakobsen, 2012). A total of 11 FDG´s were conducted. This session took place in both open and closed spaces. An average of 8 to 10 participants took part on each session which had a duration of one and a half hours to two hours. The main goal of the FDGs was to get deeper insights about the groups social network. A representative Net-map of the group was selected for being used in

the session, and all together discussed about the important actors and their relations, motivations and influence, in regards of the UPS implementation. The Net-Map was placed in a wall and all were seated in a semicircle to be able to start the discussions. In addition to the Net-Map review, a couple of questions were discussed for detecting the major opportunities and constraints the stakeholders face in their collaboration and implementation of the different UPS (Annex A). Through their participation on the sessions respondents were able to dialog about their perception on the groups functioning. Moreover, at the end of the sessions we held brainstorming looking for potential actors that on their perception could be important to integrate them into their social network, which could benefit the UPS implementation.

In most of the groups the participation of the group leaders was very dominant, and most of the time the leaders were men. Woman had to be encouraged to participate in the discussions.

Table 6. *Total number of Net-Maps administered by village for each UPS. Source: Author's data.*

Village	Number of FGDs	Sample size (n)	Presence of women during FGDs	Presence of men during FGDs
Improved cooking stoves				
Ilolo	1	7	4	3
Idifu	1	9	5	4
Ilakala	1	10	7	3
Changarawe	1	11	6	5
Improved processing				
Ilolo	1	7	1	6
Idifu	1	8	4	4
Ilakala	1	5	1	4
Changarawe	1	8	2	8
Byproducts for bioenergy (pyrolisor)				
Ilakala	1	8	3	5
Sunflower oil press				
Idifu	1	6	3	3
Poultry-crop integration				
Ilakala	1	6	2	4

Fig. 11. *Focus Group Discussion. Author's source.*

5.4 Net-Map data collection and analysis

This research investigates the characteristics of the UPS groups implemented in the 4 different CSS. The analysis of these characteristics is based on the SN cohesiveness attributes (density, average distance, size, reciprocity) and actors' embeddedness (indegree centrality, outdegree centrality and betweenness) indicators. The aforementioned indicators reflect the level of collaboration between actors and their levels of influence in the network. Table 7 shows the definition of each indicator.

Different software can display SNs and calculations related to the network analysis. In this research, the software UCINET 6.514 was used. The calculation for the cohesiveness was done for all groups, and the embeddedness measurement were applied for the knowledge, materials and money relations. Moreover, in order to consider an actor as part of the Network he had to be mentioned by at least 3 respondents on each group, otherwise he was removed from the analysis. The average for the influence categories and motivations for each actor was done by calculating the average scores on each UPS group. Correlating the influence categories with the embeddedness is essential for identifying the influence of each actor. Graphical network mapping was done with Gephi software using the Fruchterman Reingold configuration. The non-parametric Mann-Whitney U test and Chi-Square tests were utilized

with IIBM SPSS Statistics 23 to obtain additional indications for characteristic differences between the actors, the UPS, the CSS and the regions.

Table 7. *Networks measures. Source: Wasserman et. al, 1994; Wasserman & Faust 1994; Hanneman & Riddle 2005; Degenne & Forsé 2004; Bodin et al., 2006; Freeman, 1979.*

Level of analysis	**Network measure**	**Definition**
Network or subgroup	*Density*	Is defined as the ratio of the existing ties to the theoretical maximum (Wasserman et. al, 1994).
	Size	It takes into account the number of actors present in a network (Wasserman and Faust 1994).
	Reciprocity	It estimates the percentage form all possible ties that are part of reciprocated structures (Hanneman and Riddle 2005).
	Distance	The shortest path between two actors in a network (Wasserman et. al, 1994).
Actor or individual	*Degree centrality*	It is measured according to the number of direct links an actor is connected to other actors (Degenne and Forsé 2004).
	Betweeness centrality	Is defined as the number of times a given actor is on the shortest path that connects two actors in a network (Bodin et al., 2006). It measures the influence that an actor has over a certain relation for example spread of knowledge and therefore it identifies the brokers that are able to control the flows in the networks.
	Outdegree centrality	It measures the number of ties directed from an actor (Freeman, 1979). It captures the ability of an actor to influence other actors by providing, i.e. money, information or advices.
	Indegree centrality	It measures the number of ties directed to an actor (Freeman, 1979), capturing the access that an individual actor has to i.e. knowledge, money and resources.

5.5 Data comparison

Due to the big amount of data processed, a combination of two different design approaches was followed for the results analysis. After having all the statistical calculations done the cohesiveness attributes were compared between all groups. The design approaches were as follows:

a. Most similar cases design: comparing very similar cases. In this case the four groups of the Improved cooking stoves UPS were compared in-depth (first part of the results), while the four groups from the Improved processing UPS were also compared using less indicators.

b. Most different cases design: comparing very different cases. In this case the By-products for bioenergy, Sunflower oil press and Poultry-crop integration UPS were compared.

A detailed description of the indicators used for the analysis is found in Annex B.

6. Results

This section presents the results of the network analysis of ICS, MT, MS, SUN, PLT and PYR groups. It begins with an overview analysis of the networks cohesion attributes (density, reciprocity and average distance) and size at group level as well as centrality measures (indegree, outdegree and betweenness) for the actors across the groups. Then motivations for participating in the implementation of the UPS are approached at a group and actor level along with the influence towers (importance, income, food, trust and knowledge).

6.1 Actor roles

We find a broad number of actors across the different UPS. In order to understand their roles and diversity of the groups the table below presents the name and roles of all actors.

Table 8. *Description of actors´ roles. Source: Author's data.*

Actors	Role	UPS group
Councilor	Is an elected leader as well representing 4 to 5 villages, with responsibility to tender the village's problems to the District Councilor and render solutions.	ICS, MT, SUN
Customers	They pay for the services of the group's activities. For instance, they pay to have their maize shelled.	ICS, MT, MS, PLT, PYR, SUN
Feed providers	Business selling chicken fodder.	PLT
Field assistant	In charge of supporting the groups and linking them with the researchers and trainers. They are also the farmers' extension officers from the village.	ICS, MT, MS, PLT, PYR, SUN
Group leader	Each UPS group has elected an internal group leader.	ICS, MT, MS, PLT, PYR, SUN
Group members	The group members are the individuals participating in the different UPS. In the OMOS they are the bag users. In the TR they are the small farmers. In MT and MS they are the machine owners.	ICS, MT, MS, PLT, PYR, SUN
Group technician	This is a group member with the best knowledge on the machine's operation.	MS

Laborers	These are the persons hired to carry out different tasks. They can be hired directly by the group members or the customers.	MS, SUN
Machine operator	The person in charge of operating the machine.	MS
Machine providers	The company that sold the machine.	MS, MT
Material providers	They are the ones selling the fuel, oil, spare parts, etc.	ICS, MT, MS, PLT, PYR, SUN
Medicine providers	Business selling medicament for the chickens to the members.	PLT
Monitoring group	Group members selected to make frequent revisions to the households owning an improved cooking stove in order to verify if there are any construction issues and to make sure it´s been used.	ICS
MVIWATA	A national farmer's organization which aims to unite small-scale farmers in order to defend their interest and address their challenges. In some groups, they consider it as being a different actor than the Trans-SEC researchers.	MT, MS, SUN
Researchers	Sometimes the researchers are the trainers in certain training sessions.	ICS, MT, MS, PLT, PYR, SUN
Secretary	Every group has selected their own secretary. This is the person in charge of keeping the records of the contributions and the minutes of the group meetings.	ICS, MT, MS, PLT, PYR, SUN
Small chick providers	Chicken breeders contacted by researchers, group members do not have direct contact with them.	PLT
Stove constructors	Group members that have mastered the technic of constructing stoves, they are the most active and they support other members teaching them the right technics.	ICS
Sub-group leader	Groups have been divided in sub-groups in order to have a better performance; they have elected an	ICS

	internal leader.	
Sub-group secretary	Sub-groups have elected an internal secretary. That is in charge of keeping the records of the meetings.	ICS
Subgroup treasurer	Sub-groups have also elected an internal treasurer.	ICS
Supervisor	The person organizing the activities during the maize shelling. He/she assigns the roles to the people participating on the activity.	MS
Technician	This is an external person from the group who is in charge of machine maintenance and repairs and is usually someone from a bigger nearby village.	MS
Trainers	Persons that are not researchers in charge to provide skills to the group members.	ICS
Transport owners	In the case of MT, it is possible to transport the machine with cows. For the MS, a tractor, power tiller or car is needed for this transport.	MT, MS
Treasurer	In charge of keeping the contributions and profits of the group's activities.	ICS, MT, MS, PLT, PYR, SUN
Village chief	His role is to govern and make decisions about the village because he has that authority since he was elected. Elections take place every five years.	ICS, MT, MS, PLT, PYR, SUN
Village executive officer	Employed by the local government, i.e. by the district director. He is in charge of representing the district director in the village and has a major role in supervising all the projects sponsored by the government. He is also the village treasurer and secretary and must thus give and read the financial report in every annual village meeting. Finally, he plays the role of a police station, receiving all the conflicts and claims and attempting to resolve them along with the village chairman.	ICS, MT, MS, PLT, PYR, SUN
Piki piki (bike riders)	Individuals owning a motorbike who provide transportation to the group members, i.e. bringing them to the customer’s field and bringing oil for the	MS

machine.

ICS = Improved cooking stoves; MT= Millet thresher; MS= Maize sheller; PLT =Poultry-crop integration and marketing; PYR = By-products of bioenergy; SUN= Sunflower oil product.

6.2 Networks cohesion attributes

6.2.1 Knowledge network cohesion attributes

For the Net-Map interview sessions knowledge was translated as *"the exchange of ideas or advises between the actors that are important for the implementation of the UPS".* Ideas and advice represented a good alternative for overcoming the language barriers, as the literal translation of knowledge in Tanzania is usually linked to learning at school. Sharing ideas and advice most of the time promote constructive communication enabling the creation and spread of knowledge.

Cohesiveness indicators in Table 9 provide insights about all UPS groups knowledge ties. A first remark is that the network density of the PYR form Ilakala village is the highest among all groups, being 2 times bigger than the group with the lowest density. In addition, is at the same time the group has the smallest size. This suggests that the network size (NS) has an influence in the development of the knowledge density. Some examples of knowledge flowing in the network are the use of the pyroliser itself, the incorporation in the soil and properties of the charcoal, and the information regarding group management. Furthermore, similar results can be observed when comparing the ICS groups' density values between villages as they vary according to the network size i.e. Idifu and Changarawe are denser when compared to Ilakala. Contrasting to this assumption, Ilolo has the second smallest size from all UPS groups and lowest density from all.

Within the *semi-arid region* contrasting density values are observed. In Ilolo, we find the lowest density degrees in the ICS and the MT with 27%, while in Idifu we find the second and third most highly dense groups SUN (55%) and ICS (54%) respectively. These low values indicate a lower knowledge sharing levels among the actors concerning the implementation of the UPS. ICS Idifu was one of the first groups that started to implement the UPS; this could be an explanation for the high knowledge density. As group members mastered the knowledge, they became more comfortable with sharing new ideas among themselves, the community and researchers, in particular improvements of the stove adaptations for enhancing fire efficiency. *"Other advice was on the height of the stove we advised them (the researchers) that the stove needs to be reduced in its length so that clients can cook*

comfortably. But they didn't respond to it and I decided to think deeply and come with the solution" (F2 ICS ILO). For the SUN group, the high-density can be linked to their low group size, 6 group members in total, and their overly high participation and commitment. All members considered this to be crucial for their success. Some examples of the knowledge flow on the network are the operation of the machinery, the technical information on how to build the barn, knowledge received for storing and processing seeds and advertisement of the UPS among the villagers.

Having a closer look at the data, it can be noticed that high density values are associated with low distance values i.e. the groups of PYR in Ilakala and SUN Idifu. These results provide confirmatory evidence of a negative correlation between density and distance. This indicates that short distances in the knowledge flow are associated with high-density values.

High reciprocity values can be observed in both villages of the sub-humid region, while in the semi-arid high density values are found in Idifu and the lowest reciprocity among all groups is found in Ilolo. This may be due to differences in internal management of the UPS. SUN from Idifu and PLT from Changarawe have the highest reciprocity with 75% each followed by PYR from Ilakala with 64%. A possible explanation for this result might be that the level of trust between the actors has enhanced the knowledge exchange. Additionally, when comparing distances and reciprocity it can be observed that short distances are usually associated with higher reciprocity, for instance the SUN and the PYR groups have the shortest distance and high reciprocity levels.

Table 9. *Cohesiveness attributes for the knowledge network Improved cooking stoves (ICS), Maize sheller (MS), Millet thresher (MT), Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author´s data.*

	Morogoro (sub-humid)								**Dodoma (semi-arid)**							
	Ilakala				Changarawe				Ilolo				Idifu			
UPS	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance
ICS	16	0.39	0.56	1.6	11	0.41	0.65	1.5	10	0.27	0.26	1.4	11	0.54	0.52	1.7
MS	14	0.32	0.55	1.6	11	0.28	0.53	1.7								
MT									11	0.27	0.45	1.6	11	0.35	0.59	1.6
SUN													11	0.55	0.75	1.4
PLT					11	0.34	0.75	1.6								
PYR	7	0.62	0.64	1.4												

Size: indicates the average number of actors in a network; Density: is the number of ties that exist within a network out of all possible ties, the more ties in a network the denser it will be; Reciprocity: the percentage of all possible ties that are reciprocated structures; Distance: average shortest path length between two actors.

6.2.2 Material network cohesion attributes

Examples of materials that respondents considered important for the implementation were the machines and tools such as stove construction tools, the maize sheller, millet thresher, pyrolysis machine, small chicks for growing and the sunflower oil press. Other materials mentioned as important by the group members were the notebooks and pens provided on the trainings by the researchers. The cohesion attributes for the materials network are presented in Table 10.

When comparing the density, reciprocity and distances between the material and knowledge networks, it can be observed that values are much lower when it comes to materials. The results indicate that there is a lower amount of materials exchanged in the networks as the exchange process often deals with other means like money or labor, while in the knowledge flow it is often reciprocated with other knowledge. It can also be observed that distances are shorter overall as the number of actors involved in the materials exchange is lower than in the knowledge network.

The highest density and reciprocity values were found in the PYR group, as a result of the small size of the network. The materials flowing on the network are: maize cobs, pyrolysis machine, charcoal and ashes as the result of the cobs pyrolysis. In addition, some of the highest density values were found across the ICS groups, where some of the materials in the UPS are the construction tools i.e. shovel, buckets and pipes; bricks for stove structure; rice husk and the soil mixture. The groups with the lowest densities are MT and SUN both from Idifu village in the semi-arid region. These groups have not yet started to work, hence the values. High distance values are often associated with low reciprocity, as it can be seen across all UPS except for the SUN group which has the shortest distance and a reciprocity value of zero. At a regional level, higher values can be noticed in the sub-humid region when compared to the semi-arid. This could be explained with the fact that the all groups have started to work except for the PYR.

The shortest distances are found in the SUN, PYR, and MT Ilolo groups. While the longest distances are found in MS Ilakala and PLT Changarawe, as there is a higher number of material providers in the networks.

Table 10. *Cohesion attributes for the materials network Improved cooking stoves (ICS), Maize sheller (MS), Millet thresher (MT), Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author´s data.*

	Morogoro (sub-humid)								**Dodoma (semi-arid)**							
	Ilakala				Changarawe				Ilolo				Idifu			
UPS	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance
ICS	16	0.11	0.07	1.5	11	0.12	0.11	1.4	10	0.09	0.05	1.4	11	0.12	0.1	1.4
MS	14	0.09	0.09	1.7	11	0.11	0.16	1.5								
MT									11	0.09	0.00	1.2	11	0.08	0.05	1.4
SUN													11	0.08	0.0	1.1
PLT					11	0.11	0.02	1.6								
PYR	7	0.16	0.15	1.3												

Size: indicates the average number of actors in a network; Density: is the number of ties that exist within a network out of all possible ties, the more ties in a network the denser it will be; Reciprocity: the percentage of all possible ties that are reciprocated structures; Distance: average shortest path length between two actors.

6.2.3 Money network cohesion attributes

All of the UPS are providing services to their communities. Some of them are already generating an income to the group members i.e. ICS, MS and PLT. There are some constant money flows in all groups such as payments for loans on the post processing groups (MT & MS), fees for constitution and group registration, group cooperation fees and the small allowances provided by the researchers for interviews and trainings. Cohesiveness indicators provide better insight of the UPS group's overall money ties.

In Table 11, we can observe there is a higher flow of money in UPS from the sub-humid region when compared to the semi-arid. The highest density values in the money network are for the PLT with 17% followed by the MS in Ilakala with 16%. As the activities from these groups generate larger money flows in their communities. In the case of the PLT group, we found that there are a lot of materials that need to be bought by each group member such as medicine, feed, small chicks and the material for building the chicken coops. MS Ilakala group pays for materials and services like: machine transport (tractor, power tiller or cow), fuel, spare parts, oil is needed for the implementation. In the same group, we also find the highest reciprocity with 16%. The lowest densities are observed in the SUN in Idifu and the ICS in Ilolo.

Reciprocity values are very low as it is to be expected in the money flow where usually money is exchanged for materials or services. Nevertheless, the reciprocity values for the MS group in Ilakala show a relevant difference when compared to the other villages. This can be explained with a couple of examples, (1) group members are paid for the days they work but at the same time, they pay their contributions for the registration and group fees; (2) group members receive small allowances from the researchers when they participate in the interviews and trainings but they also have to pay the researchers for the machine loan. The lowest values of reciprocity for the PYR and ICS groups. PYR group has no activity at the moment and the only activities held were part of the trial sessions.

Regarding the distances, there is no clear relation among the variables, suggesting that distance is not relevant for the groups´ money ties.

Table 11. *Cohesion attributes for the money network for the Improved cooking stoves (ICS), Maize sheller (MS), Millet thresher (MT), Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author´s data.*

	Morogoro (sub-humid)								**Dodoma (semi-arid)**							
	Ilakala				Changarawe				Ilolo				Idifu			
UPS	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance	Size	Density	Reciprocity	Distance
ICS	16	0.14	0.05	1.6	11	0.12	0.03	1.5	10	0.09	0.00	1.2	11	0.15	0.04	1.3
MS	14	0.16	0.16	1.9	11	0.14	0.14	1.9								
MT									11	0.13	0.01	1.3	11	0.12	0.12	1.5
SUN													11	0.09	0.05	1.1
PLT					11	0.17	0.08	1.8								
PYR	7	0.12	0.00	1.0												

Size: indicates the average number of actors in a network; Density: is the number of ties that exist within a network out of all possible ties, the more ties in a network the denser it will be; Reciprocity: the percentage of all possible ties that are reciprocated structures; Distance: average shortest path length between two actors.

6.3 Networks oversight centrality measures

6.3.1 Knowledge network centrality measures

Indegree centrality knowledge network

The highest assumed indegree centrality scores correspond in all UPS groups mainly to the *group members* followed by the *group leaders and secretaries*. In the case of the ICS groups, stove constructors have high indegree values as they are the group members that have mastered the technic of building stoves. Apart from receiving the knowledge from trainers they have direct contact with the customers. Hence they receive feedback regarding improvements for the stoves construction.

Table 12. *Centrality measures of the knowledge networks Improved cooking stoves (ICS), Maize sheller (MS), Millet thresher (MT), Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author´s data.*

	Morogoro (sub-humid)						Dodoma (semi-arid)					
	Ilakala			Changarawe			Ilolo			Idifu		
Actors representing the 3 highest degrees for each centrality	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**
	Improved cooking stoves (ICS)											
Group Leader	37	**47**	**38**	30	23	0.5	**23**	24	13.1	45	**57**	**5**
Secretary	**40**	**47**	0.8	**40**	**47**	1.3	**23**	**29**	11.1	**47**	**54**	**4.4**
Treasurer	27	21	0.7	33	24	0	17	9	0.9	34	37	**3.1**
Group Members	**44**	36	1.5	**53**	**54**	**8.8**	**33**	23	**17.5**	**51**	**44**	2.4
Stove constructors	37	36	0.5	-	-	-	**27**	**33**	**33.7**	**50**	40	3.1
Researchers	30	**52**	**15.1**	37	**54**	**3.3**	7	**35**	**16.1**	22	41	3
Customers	**55**	27	**76**	**56**	**56**	**21.8**	8	2	0	44	23	2.6
	Maize Sheller & Millet thresher (MS & MT)											
Group Leader	**43**	**57**	**16.6**	**37**	44	**23.2**	**38**	**34**	**26.4**	**48**	**40**	**10.6**
Secretary	42	37	5.5	26	28	6.1	**31**	23	**5.6**	35	37	**6.6**
Treasurer	41	**44**	**15.9**	31	28	4	16	16	0.7	33	33	4.9

Group Members	**44**	**43**	6	**42**	**55**	**15**	**49**	**32**	**7.9**	**51**	**39**	3.6
Machine operators	36	40	**18.7**	-	-	-	-	-	-	-	-	-
Researchers	28	**44**	4.2	27	**29**	**24.6**	15	25	4.3	25	**39**	**7.1**
MVIWATA	-	-	-	-	-	-	14	**26**	2.2	-	-	-
Customers	**46**	37	2.1	**32**	14	3.4	**31**	17	2	**44**	28	0.1
	Sunflower oil production (SUN)											
Group Leader										**63**	**63**	**20**
Secretary										**52**	**53**	**7.7**
Treasurer										41	39	**11.7**
Group Members										**57**	**53**	5.3
	Poultry-crop integration and marketing (PLT)											
Group Leader				**35**	**37**	5						
Group Members				**59**	**56**	**25**						
Researchers				**46**	**55**	**18.7**						
Research field assistant				29	**37**	**7.6**						
	By products for bioenergy (PYR)											
Group Leader	**28**	25	**0.5**									
Group Members	**32**	**27**	**2.5**									
Researchers	16	**28**	**0.5**									
Customers	**32**	**27**	**2**									

Indegree centrality measures the knowledge ties to an actor, the outdegree measures the knowledge ties from an actor and the betweenness indicates the actor's potential to control the communication.

Customers are assumed to have a high indegree in all groups except for the SUN, PLT and ICS Ilolo groups. The SUN group has not yet started to operate, therefore the indegree for customers is perceived as low. While in the MT group, which has also not yet started to operate, customers are assumed to have a high indegree centrality as members are constantly promoting the UPS among the community. In the case of PLT group there is not a

direct interaction with the customers as they tend to be restaurants or hotels in the nearby cities, hence the low indegree centrality for the customers.

Furthermore, interesting results are also found for the group of PLT in the sub-humid region, where *researchers* are assumed to have a high indegree and betweenness levels. It can therefore be assumed that there is a significant amount of knowledgeable feedback they are receiving regarding the innovation.

Outdegree centrality knowledge network

Knowledge is dynamic inside these UPS groups. This is reflected on the high outdegree and indegree centrality of the *group members, leaders* and *secretaries* in all UPS groups. These findings suggest that UPS groups are constantly exchanging advices and ideas among themselves and their communities.

From the results, it can be noticed that the *researchers* are perceived to have a high outdegree centrality since they provide knowledge to a broad number of actors in the networks. However, in the SUN group *researchers* are not consider as high knowledge providers in the implementation. There is a possibility that the result is due to a lack of communication between the group members and researchers.

Differences between same UPS groups of different villages are found for instance ICS *costumers* in Changarawe are assumed to be highly influential for the knowledge network as they provide feedback regarding the cost of the construction and the benefits of the stoves are not clear for them. *"The clients fail to understand the innovation and they don´t want to gather the materials needed (like the soil, bricks and rice husk) they don´t like to do their part"* (F3 ICS CHA).

Overall, we can observe that the SUN group has the highest outdegree values while PYR group has the lowest outdegree values. These results can be explained with the fact that PYR group is considerably less active, hence the low outdegree values. It is worth to be mentioned that both groups have not yet started to operate, but the understanding of the innovation and commitment of both groups is reflected by the results.

Betweenness centrality knowledge network

Regardless of the agro-climatic region the highest betweenness degree is frequently held by the group leaders. Suggesting they are key actors for spreading the knowledge in the networks.

Regional differences are found for the researchers, as they are assumed to have a higher betweenness in the sub-humid region compared to the semi-arid. These results suggest that for the UPS groups in the sub-humid region researchers are more strongly perceived as key actors for the knowledge flow as they link the UPS groups to actors that are important for the implementation i.e. customers, material providers and governmental authorities. This can, however, be also interpreted as a disadvantage as knowledge flow could also be controlled by themselves.

Interesting results are found in the sub-humid region where *customers* are perceived to have the highest betweenness centrality, a possible explanation to this result is the fact that in these villages customers receive information directly from researchers regarding the UPS groups, group members and also from governmental authorities such as the Village chiefs, locating them in an advantaged position for connecting actors for the spread of knowledge. Similar results are found in the PYR group.

For the Ilakala MS group the *machine operators* are perceived to have a high betweenness degree because they are the ones that know how to operate the machine. At the same time they are in charge of organizing the tasks between the clients, members and labourers on the working days. Machine operators are only present in Ilakala as the group has developed different roles in order to be more efficient when operating the machine.

The field assistant in the PLT group is considered a broker in the knowledge network, as he was mentioned to provide the group members with veterinarian advices and connecting the members with the researchers and providers.

6.3.2 Material network centrality measures

Table 13. *Centrality measures of the materials networks Improved cooking stoves (ICS), Maize sheller (MS), Millet thresher (MT), Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author´s data.*

	Morogoro (sub-humid)						Dodoma (semi-arid)					
	Ilakala			Changarawe			Ilolo			Idifu		
Actors representing the 3 highest degrees for each centrality	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**
	Improved cooking stoves (ICS)											
Group Leader	11	**9**	**25**	6	**1**	**6.5**	6	4	0.5	8	**9**	0.3
Secretary	9	0	0	**13**	2	1.3	6	5	3.5	10	7	**0.8**
Treasurer	**13**	2	0	11	4	**1.8**	3	0	0	**13**	6	**0.8**
Group Members – Stove constructors	**14**	**10**	**21.5**	**35**	**13**	**26.8**	**15**	**5**	**11**	**13**	3	**7.5**
Stove constructors	**22**	8	**23**	-	-	-	**15**	4	**16.5**	**26**	**9**	**15.3**
Researchers	3	**47**	5	1	**44**	**1.8**	3	**20**	**11.5**	0	**44**	0
Customers	12	8	**21.5**	**21**	8	0	**7**	4	3	**16**	6	0.5
Wood suppliers	0	5	0	0	**10**	0	0	**16**	0	0	8	0
	Maize Sheller & Millet thresher (MS & MT)											
Group Leader	7	0	0	**16**	7	**2**	**10**	0	0	**15**	3	0
Secretary	8	2	0	**9**	1	0	7	**1**	0	**8**	0	0
Treasurer	**15**	3	**10**	**9**	0	0	**9**	0	0	7	0	0
Group Members	**36**	**13**	**18.3**	**47**	**16**	**15.5**	**35**	0	0	**28**	**11**	**14**
Researchers	7	**30**	**8**	7	**32**	**2.5**	4	**32**	**4**	**8**	**28**	**10**
Customers	**15**	10	4	8	8	0	1	0	0	0	0	0
Machine providers	0	7	0	0	**12**	0	0	0	0	1	**8**	0
Transport owners	0	**11**	0	2	7	0	0	**8**	0	0	0	0

	Sunflower oil production (SUN)											
Group Leader										**8**	3	**3**
Treasurer										**8**	3	1
Group Members										**24**	1	**5**
Researchers										2	**10**	**3**
Filed assistant										1	**8**	2
MVIWATA										1	**14**	1
	Poultry-crop integration and marketing (PLT)											
Secretary				**16**	2.0	1.5						
Treasurer				**12**	1.0	1						
Group Members				**33**	8.0	**26**						
Researchers				7	**27**	**7**						
Feed providers				1	**15**	**12.5**						
Material providers				0	**14**	0						
	By-products for bioenergy (PYR)											
Group Leader	**8**	3	**15**									
Secretary	**7**	1	**5**									
Group Members	**19**	**9**	**1**									
Researchers	1	**21**	0									
Customers	6	**5**	0									

Indegree centrality measures the material ties to an actor, the outdegree measures the ties from an actor and the betweenness indicates the actors' potential to control the materials flow.

Indegree centrality materials network

The results from Table 13 reveals that *group members* in all groups are perceived to be receiving high amounts of materials for the UPS implementation, as they have the highest indegree centrality values. In the special case of ICS Idifu and Ilakala *stove constructors* are important for the materials flow as they are provided with the tools and materials for constructions. *Group leaders* are influential in the materials flow as they were elected by the group members to keep the tools and machinery needed for the UPS implementation.

Interesting results are also found for the *customers* as they are assumed to receive a relevant amount of materials in the network in all ICS groups except for Ilakala and MS Ilakala. In ICS members provide customers with the molds to make bricks (as they are not provided by the group) and the pipes and different tools for the construction. In the case of the MS Ilakala, the members bring the machine to the customers' fields for shelling the maize.

Outdegree centrality materials network

Researchers are assumed to be highly influential in the material flow in all groups as they provide the primary tools and machinery necessary for the implementations to all UPS groups. Similarly, group leaders are considered important in the distribution of materials as they distribute the tools among the members.

Important material inputs in the ICS network in Ilolo are assumed to come from *wood providers*. In the case of the improved post processing groups (MT & MS) *transport owners* and *machine providers* are perceived as influential in the material flow. Machine providers apart from selling the machines they provide spare parts for the repair and for the transport of the machines tractors, power tillers, cows and cars were mentioned to be hired. For the PLT group *feed providers* and *material providers* are assumed as influential in the UPS implementation as the provide fodder and materials needed for building the coops.

The *research field assistant* in the SUN group is the direct link between members and researchers from Tran-SEC and Mviwata, they provide materials through him.

Betweenness centrality materials network

Observing the table of results, it can be noticed that in all groups *group members* are assumed to have a high betweenness centrality, as they are the ones receiving and providing the tools to their customers. Furthermore, researchers are also perceived to have a high betweenness centrality in almost all groups, as they are the link for the groups to important material providers. For the improved processing groups (MT & MS) and SUN group *researchers* are important for getting spare parts need for the machines. Researchers in PLT provide the small chicks to the members that they get from a special breeder.

Differences across ICS groups were found. In Changarawe the groups are fully dependent on the *researchers* to get tools for construction while in the other villages the *group members* have started to use construction tools found in their environment such as wood logs for measuring and banana stems for constructing the pipes.

Evaluating the findings, it can be understood that both group members and researchers have an influential position in the materials network as they can potentially hinder the materials flow. The high influence that the researchers currently have on the network could be restricting for the development and sustainability of the UPS groups, as they are dependent on them for getting the materials.

In ICS we find stove constructors and the leaders (including secretaries and treasurers) having a high betweenness degree as they control the materials in the network. In the case of ICS Ilakala customers have a high betweenness as they were getting the rice husk (needed for the soil mixture) from a material provider as it is hard to find in the village.

6.3.3 Money network centrality measures

Table 14. *Centrality measures of the materials networks Improved cooking stoves (ICS), Maize sheller (MS), Millet thresher (MT), Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author´s data.*

	Morogoro (sub-humid)						Dodoma (semi-arid)					
	Ilakala			Changarawe			Ilolo			Idifu		
Actors representing the 3 highest degrees for each centrality	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**	**Indegree**	**Outdegree**	**Betweenness**
	Improved cooking stoves (ICS)											
Group Leader	16	10	1	6	3	0	5	3	0.3	10	7	0
Secretary	**38**	12	**11.3**	10	8	3.3	7	4	0	**12**	8	4
Treasurer	**21**	11	**10**	**33**	4	**24.8**	**16**	2	**7.5**	**41**	4	**27**
Group Members – Stove constructors	10	**15**	1.3	**13**	**14**	**9.8**	**10**	**11**	**3.5**	**12**	**14**	**21.5**
Stove constructors	**13**	9	**9.3**	-	-	-	1	0	**2.3**	**13**	9	**6.5**
Researchers	0	**58**	0	2	**47**	**33**	0	**25**	0	0	**46**	0
Customers	2	**13**	0	3	**19**	2	0	**7**	0	0	**13**	0
Wood	7	0	0	**11**	0	0	**12**	1	0.3	8	0	0

suppliers												
	Maize sheller & Millet thresher (MS & MT)											
Group Leader	17	15	6.5	8	7	0	17	9	5.7	8	9	0
Secretary	**21**	12	**8**	9	10	0.5	15	7	4.7	18	13	2
Treasurer	**39**	**32**	**30**	**35**	**33**	**24.3**	**19**	5	**10.7**	**28**	10	0
Group Members	**20**	19	5.5	**20**	**23**	**5.1**	**17**	7	**6**	16	**21**	**10**
Machine operators	13	**40**	3.7	-	-	-	-	-	-	-	-	-
Researchers	9	**49**	**25.3**	7	**43**	**12.3**	0	**45**	0	1	**47**	**7**
MVIWATA	-	-	-	-	-	-	3	**29**	0	-	-	-
Clients	0	25	0	1	9	0	1	0	0	0	0	0
Transport owners	0	23	0	11	1	0.6	9	1	0	13	3	1
Material providers	1	17	0	**13**	0	0	**20**	0	0	**17**	0	0
	Sunflower oil production (SUN)											
Group Leader										**10**	8	**1**
Secretary										**11**	**9**	**6**
Treasurer										**21**	**9**	**13.5**
Researchers										0	**21**	0
Material providers										**10**	0	0
MVIWATA										0	**17**	0
	Poultry-crop integration and marketing (PLT)											
Secretary				**13**	**13**	3.1						
Treasurer				**17**	7	**5.6**						
Group Members				12	**36**	**15**						
Researchers				9	**28**	**19**						
Medicine providers				**15**	0	0						
Material providers				**13**	0	0						
	By products for bioenergy (PYR)											
Group Leader	**7**	**1**	0									

Secretary	**9**	0	0									
Group Members	**7**	**1**	0									
Researchers	0	**21**	0									

Indegree centrality measures the material ties to an actor, the outdegree measures the ties from an actor and the betweenness indicates the actors' potential to control the money flow.

Indegree centrality money network

Taking a close look to the results we can see that the highest indegree in all groups is for the *treasurer*. They receive the money from the implementation of the UPS, they also keep the personal contributions from the group members for reasons such as group registration and saving accounts. This all suggests they are acting accordingly to their role. In some groups, we also find the *secretary* and *group leader* having a high indegree as they are given money group to buy materials when needed.

Likewise, *group members* are also perceived to have a high indegree in all UPS groups with an exception in the SUN, as they receive money for their group's activities, and they also get a small allowance every time they meet with the researchers for interviews or trainings. In the SUN UPS group *leaders* are assumed to receive high money flow as they receive money from the researchers to pay for some of the materials to construct the barn for the machine.

Other important actors in the money flow are the *material providers*, as it can be observed in the improved processing groups (MS and MT) SUN and PLT. The innovations depend on a big extend to the availability of this inputs having a relation with the suppliers will bring benefits for the community. Comparing the results to the materials network we can observe that they also have a high outdegree centrality of materials meaning that they are getting paid for providing the supplies.

Outdegree centrality money network

The results in Table 14 shows that *researchers* are assumed to have high outdegree across all UPS groups, suggesting they are having a high input in the money flow. Researchers provide small allowances to the group members for the trainings, meetings and interviews. *MVIWATA* researchers in MT groups are also considered to have a high outdegree as they together with the Trans-SEC researchers give allowances to the group members on meetings. Similar results are found in SUN group as MVIWATA researchers are paying for the materials needed for the barn construction.

Furthermore, in all ICS groups, *group members* are perceived to have a high outdegree as they meet very often and pay group fees to the treasurer, for the savings account, the group's constitution and registration. Similarly, *customers* are assumed to have a high outdegree as they buy bricks for the strove construction and wood for the daily use.

Machine operators in Ilakala MS group are assumed to be highly influential in the money flow. They are considered to have a high outdegree as they, pay the group members for the working day as well as paying for transport, the materials such as fuel and oil needed for the machine operation.

PLT Groups members have big expenses for building the coops and providing feed and medicines to the chickens, hence their high outdegree.

Betweenness centrality money network

Treasurers are assumed to be highly influential in the money flow as they are assumed to have a high betweenness centrality in all groups except for the MT Idifu. They receive the money from the group members and provide money to the groups in case any material is needed on the implementation. *Group members* in the ICS, MS and MT UPS groups are assumed to have a high betweenness degree as they are constantly receiving money directly from customers and researchers as well as they provide money to the groups registration and savings.

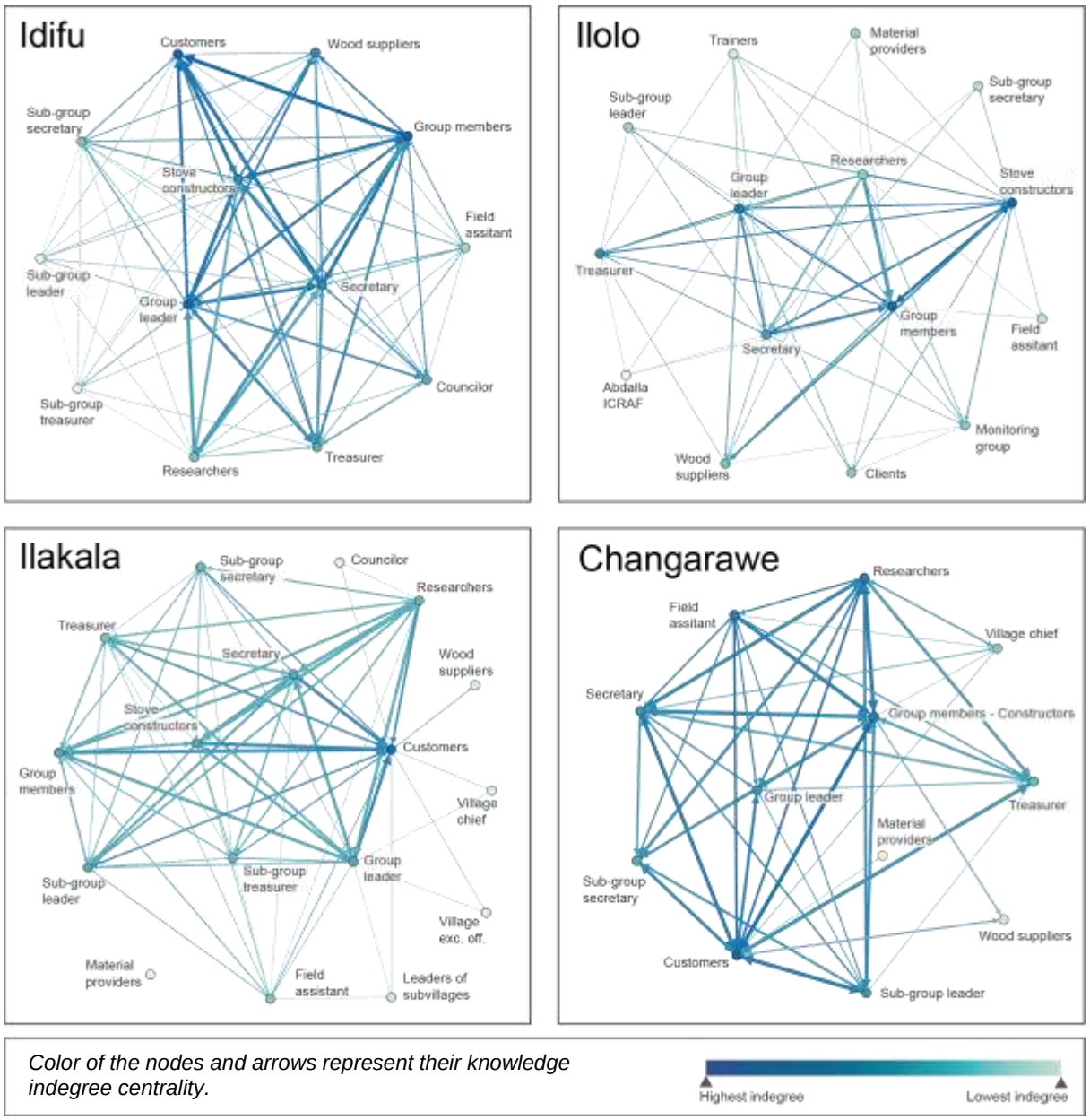
Researchers have important intermediary role in the money flow in PLT and all improved processing groups except for MT Ilolo, as they receive money from the group members to pay the loan of the machines and the have also paid for some repairs and in the case of the PLT group the researchers provide the chicks as a loan.

There is no betweenness centrality in the PYR group as there is not a big money flow on the group.

6.4 In-depth comparison Improved cooking stoves: Differences at regional and village levels

6.4.1 Knowledge network for the Improved cooking stoves UPS groups

Fig. 12. *Knowledge network maps in the Improved cooking stoves (ICS) UPS group. Source: Author's data.*

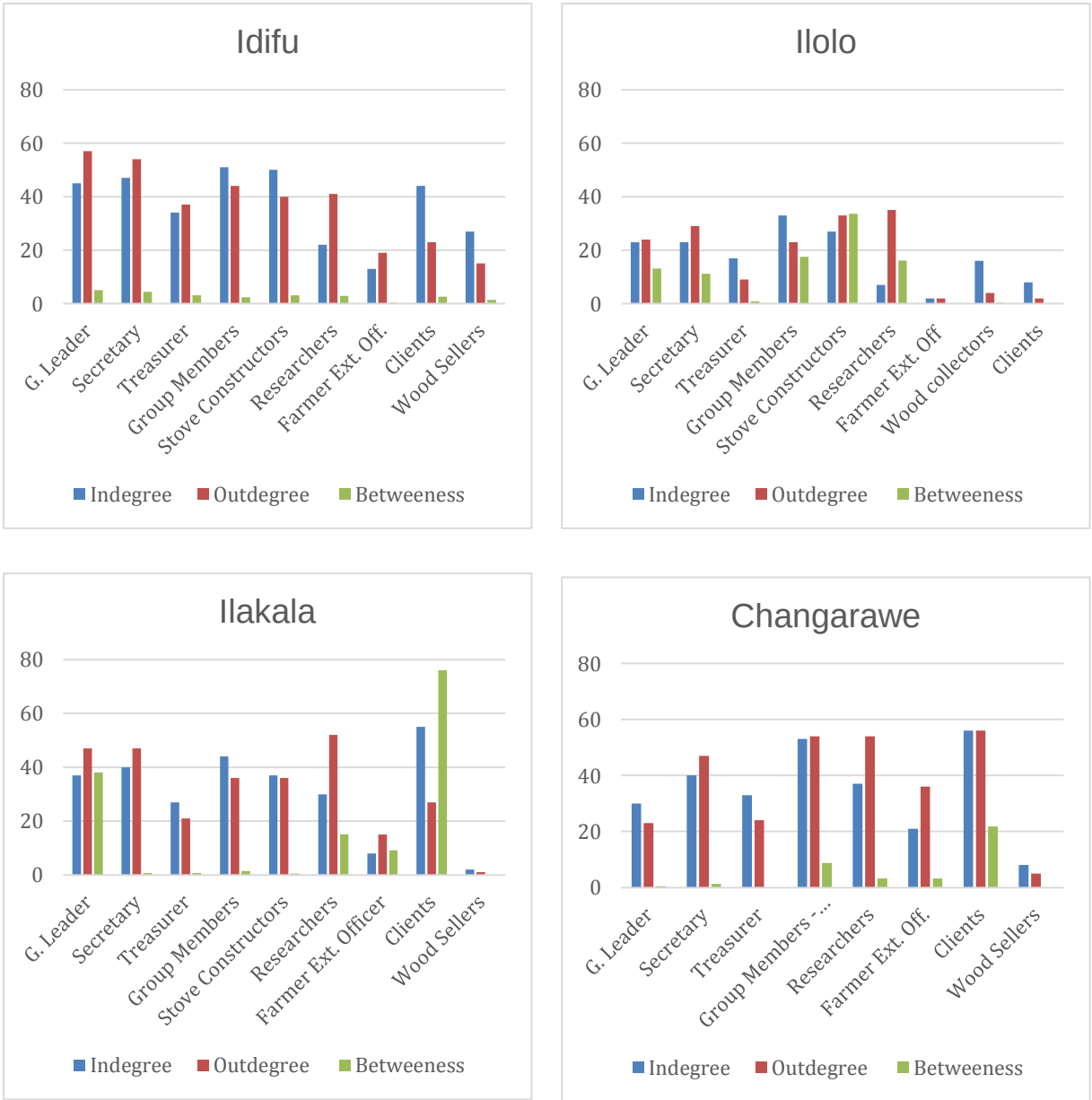


Note: *The indegree can be visualized in the network with the arrows coming in the actor's nodes, while the arrows coming out form the nodes represent the outdegree. The amount of times this link was repeatedly mentioned on the interviews can be visualized with the thickness of the arrow, the bigger the arrow the higher the value.*

Figure 12 provides the maps of knowledge networks of all ICS groups. These maps include all of the actors mentioned as participants in the knowledge flow across all ICS groups.

Some similarities between maps are depicted while other differences across villages are also remarkable. For instance, the network in Ilolo is assumed to have the lowest knowledge flow, while Idifu and Changarawe are assumed to have the highest, as more actors were frequently mentioned to be active in the knowledge exchange. It can also be observed that governmental authorities from the local level are present in all maps. However, they are not

***Fig. 13**. Centralities knowledge networks Improved cooking stoves (ICS) UPS group. Source: Author's data.*



assumed to be very active in the knowledge exchange except for the councilor in Idifu. It was reported that the wife of the councilor is member of the group; therefore, the councilor is more involved with the group activities.

In difference to Table 5 (where only the 3 highest scores for each centrality were displayed) Figure 13 on top represents the results for the centralities of the knowledge for the 10 most important (measured by the highest importance towers) actors in the knowledge network in order to have a better comparison of the actors' roles across villages within the same UPS. Furthermore, only the actors present in across the four groups were included in the analysis.

The results show that all values in Ilolo village are overall lower when compared to the other villages. A possible explanation for this result might be related to the fact that this group was the first to be interviewed and adjustments were made to the methodology for the other groups in order to improve the sessions.

Indegree centrality knowledge network for the Improved Cooking Stoves UPS groups

From the Figure 2 it can be noticed that the actors assumed to be receiving the highest knowledge in the network are the *group members*, *customers*, *stove constructors*, *secretary* and *group leader*. Regional similarities are also visible in the results. In the semi-arid region *group members* are assumed to have the highest indegree centrality while in the sub-humid region *customers* have the highest indegree centrality. The result may be explained by the fact that in the sub-humid region *customers* are more frequently receiving information about the benefits of the innovation, as the impacts in the households are not so well understood or important as in the semi-arid region*. Stove constructors* have a high indegree in all villages except for Changarawe where there are no differences between stove constructors and group members as all members construct the stoves together.

In Changarawe and Ilakala villages *researchers* are considered to have a relatively high indegree centrality. The result may be explained by the constant feedback they receive form the group members regarding construction techniques and the difficulties they face for getting customers. Contrasting to these results *researchers* have a lower indegree centrality in the semi-arid region as groups have already mastered the knowledge of building stoves and few feedback is provided to the researchers.

For the groups of Changarawe and Idifu it can be observed that group members are considered to have the highest indegree and outdegree values. This finding shows that that as they receive the knowledge they equally spread it to the other group members and clients.

Outdegree centrality knowledge network for the Improved Cooking Stoves UPS groups

Researchers are assumed to have a high outdegree in all groups as they provide the groups with knowledge regarding stoves constructions, group management and promotion. This knowledge also reaches other actors such as the *village officers* and *customers* in the village farmer field days where they promote the UPS among the community.

In Changarawe *customers* are consider having a high outdegree. They provide feedback to the group members regarding the pricing and construction of the stoves.

The *stove constructors* in the semi-arid region are important providers of knowledge as they support their peers on the mastering of the stoves' construction. Likewise, they promote the innovation among the villagers and teach their customers to build the stoves so that they can also become constructors. In Ilakala we can also observe a high degree for the stove constructors. *"We not only build we also provide the education (about building stoves), everything we do together (with the customers)" (FDG ILA).*

In Ilakala the *group leader* and *secretary* are having high outdegree levels. A possible explanation for this result might be because of the large number of sub-villages that are far apart within the same village and the leaders are key actors in charge to promote the innovations among them. Similar results are found in Idifu as the group *leader* and the *secretary* are very active constructors promoting the stoves in different villages.

Betweenness centrality knowledge network for the Improved Cooking Stoves UPS groups

Idifu village is assumed to have the lowest betweenness values among the four villages. It can therefore be assumed that the knowledge flow is not perceived to be controlled or hindered by any actors and it is possible that every actor can spread it through the network at the same level. While in the same region in Ilolo, *stove constructors* followed by the *group members* and *researchers* are considered to be highly influential in the control of the knowledge flow.

Researchers are assumed to have high betweenness levels in the knowledge network of Ilolo, Ilakala and Changarawe, as they can potentially connect actors for transferring knowledge and information through them. These results suggest that they have a high potential to control the flow of knowledge in the groups, which could have negative impacts in the future development of the networks.

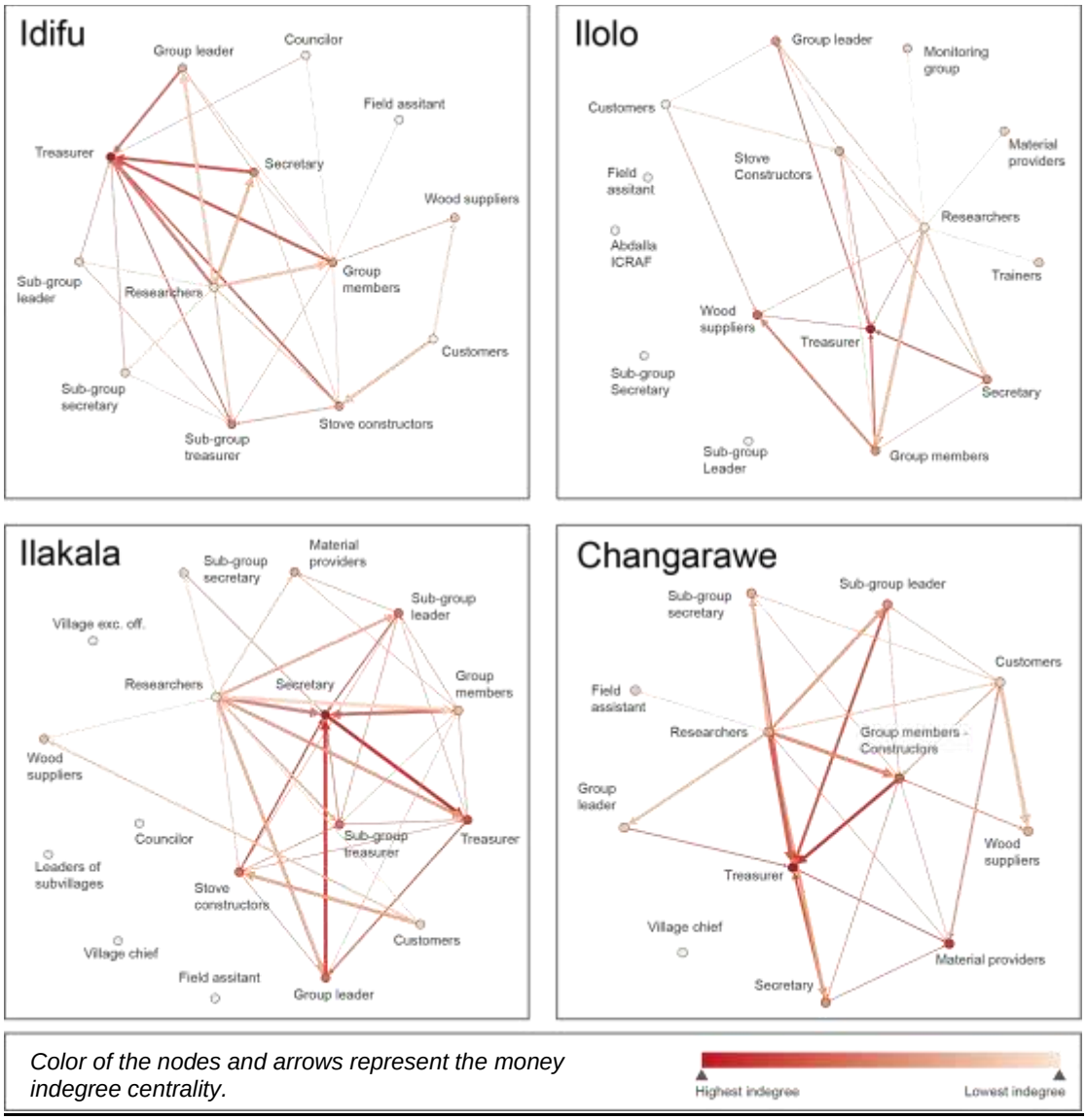
Similarly, in the sub-humid region *customers* are considered to have the highest betweenness centralities. These results are directly related to their high indegree and outdegree as they can transfer knowledge and information between actors within the network that other ways could not be linked. In the case of Ilakala is to remark this is the highest betweenness value in all of the knowledge networks. There is a possibility that the result is due to the geographic characteristics of the village as the sub-villages are far apart from each other and contact between actors is more limited than in the semiarid region. The findings suggest that customers are important actors for the spread the ICS knowledge in their communities.

6.4.2 Money network for the Improved Cooking Stoves UPS groups

In the ICS groups after a stove is built the customers give the money directly to the constructors, they keep a share for them (the share varies on each village) and the other share is handed to the sub-group treasurer, which at the same time gives it to the group treasurer. From an overall overview, it can be noticed that the group with the lowest density in the money networks is the group from Ilakala as sub-group leader and sub-group treasurer are more actively involved in the money network when compared to other groups (Fig. 14). In addition, the maps revealed that treasurers are assumed to have a high indegree in all groups. They receive from the group members the share of the money from the stoves construction and group fees i.e. group meetings cooperation, constitution and group registration. In the special case of Ilakala the secretary and group leader are also assumed to have high indegree since they act as treasures because the current one is not very active in the group.

Other important money flows can be observed from group member and customers to wood sellers in the villages of Changarawe and Ilolo. Likewise, in the village of Changarawe material providers receive money from group members and clients as they buy bricks for the stoves construction. However, in the villages of the semiarid region there are not big flows of money to the material providers since group members and clients make their own bricks.

Fig. 14 *Money network maps Improved Cooking Stoves (ICS) UPS group. Source: Author's data.*



Note: *The indegree can be visualized in the network with the arrows coming in the actor's nodes, while the arrows coming out form the nodes represent the outdegree. The amount of times this link was repeatedly mentioned on the interviews can be visualized with the thickness of the arrow, the bigger the arrow the higher the value.*

6.4.3 Materials network for the Improved Cooking Stoves UPS groups

The important materials for the implementations of the ICS UPS are the tools for constructing the stoves, such as pipes (to build the smoke channels), buckets and shovels (to prepare the soil mixture), the mold to make bricks, rice husk or dry grass for the mixture, soil, water and the wood (for using the stoves).

Figure 15 shows that the group of Ilakala has a broader number of actors perceived to have high betweenness levels when compared to the other groups. These results suggest that the group is more susceptible to the control of materials need for the implementation, which

could risk the efficiency of the group. Idifu group is assumed to have the lowest betweenness values across all groups, the highest levels in the group are assumed for the stove constructors and group members. It can therefore be assumed that materials can be directly accessed by them, placing them in an advantageous position within the network.

The *group leader* and *clients* in Ilakala are assumed to have a high betweenness degree as they are key actors for getting the rice husk needed for the soil mixture in the stoves construction as it is scarce in the region.

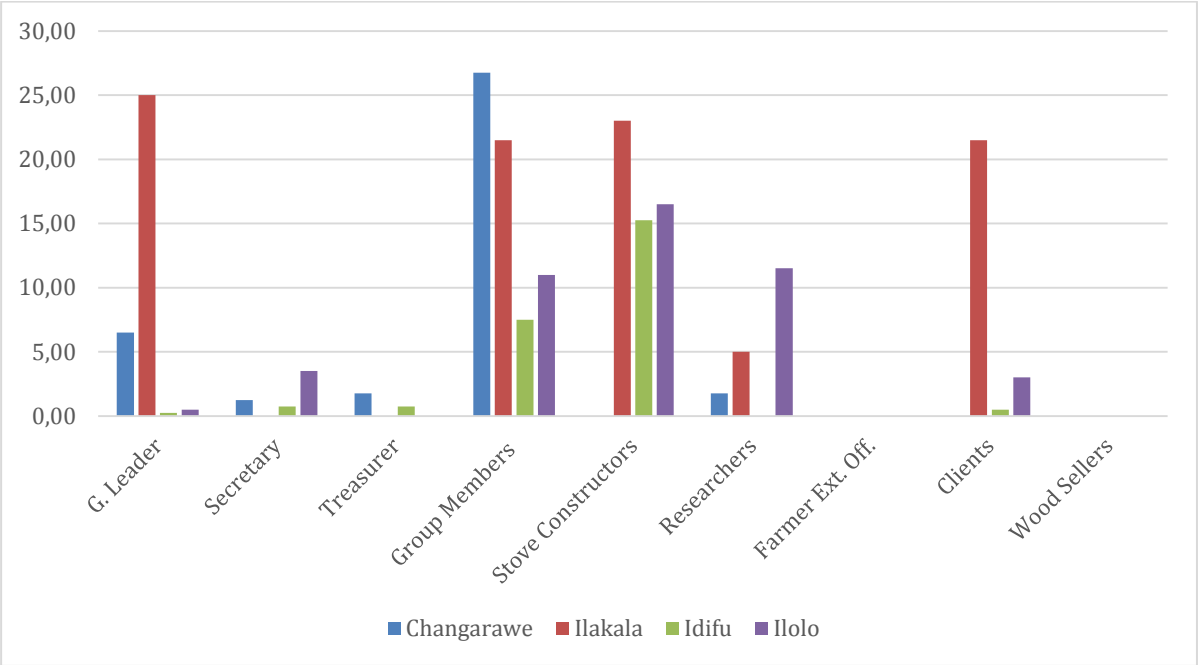


Fig. 15. *Betweenness centralities material networks Improved Cooking Stoves (ICS) UPS group. Source: Author's data.*

Group members and *stove constructors* are considered to have high betweenness degree for material in all villages. It can therefore be assumed that they have potentially a big outreach for getting the materials needed for the construction of stoves. They provide the tools to the members and customers.

In the village of Ilolo it can be observed that *researchers* have a high betweenness degree as they are still depending on them to get tools. This results contrast in the same region, in Idifu the researchers have no betweenness degree as they are the group that has been implementing the UPS for longer, they have developed different technics in order to supply some of the tools needed for the construction, "*We have reduced the height of the stoves as*

the first model was not heating properly, we have discovered we can use a wood log to make the right measures" (F1 ICS IDI).

6.4.4 Influence towers for the Improved Cooking Stoves UPS group

Importance tower for all actors

Table 9 below shows the results for the importance influence tower of all actors mentioned as important for the implementation during the Net-Map sessions. Five is the maximum rank for an actor meaning that is very important and 0 is the lowest meaning the actor is not important at all.

Summarizing we find that the actors assumed to be the most important in all villages are the researchers, followed by the stove constructors and the secretary. The perceived importance of the group members vary according to their commitment, i.e. group members of Idifu are the most committed among all groups in contrast to Changarawe (which has a lower score) where not all of the members are perceived to be committed to the group success.

The group leaders´ assumed importance is significantly lower for Changarawe compared to Ilakala ($p < 0.01$) and Idifu ($p < 0.001$). Assessment comparisons for the treasurers´ assumed importance exhibited overall high ($p<0.5$) to highly ($p<0.001$) significant differences across all UPS and the semi-arid region accordingly. Furthermore, the importance assumed for the group leaders and treasurers vary across all groups, suggesting that their commitment is not the same in all ICS groups and sometimes their role may not be clear for them.

Leaders of the sub-groups are assumed to be less important than the main group leaders. Nevertheless, they are considered important for the implementation even though their roles are not very clear for some members.

Contrasting results are found for the customers where in Ilolo and Ilakala they are considered fairly important, in Idifu they are important and in Changarawe only slightly important. The low importance of the customer in Changarawe was linked to the fact that costumers are hard to find in the village.

Governmental authorities were pointed out as important most frequently in Ilakala as they help to promote the innovation across the village. In the special case of Idifu the councilor is

important as he has demonstrated support to the group members during farmer field days and also had a stove built in his house.

***Table 15**. Importance influence tower for all actors in the Improved Cooking Stoves (ICS) UPS group. Source: Author's data.*

Actors	Idifu			Ilolo			Ilakala			Changarawe		
	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.
G. Leader	8	4.8**	0.7	8	3.8	1.8	8	4.5*	0.8	6	2.83*/**	1.5
Secretary	8	4.9	0.4	8	4.1	0.8	8	4.9	0.4	8	4.38	0.9
Treasurer	8	4.9*/***	0.4	6	2.8*/***	1.5	8	4.5*	0.8	8	3.6*	1.5
Group members	8	4.8	0.5	8	3.8	1.6	8	4.1	0.8	8	3.5	1.2
Stove constructors	8	5.0	0.0	8	4.6	1.1	8	4.5	0.8	-	-	-
Sub-group leader	3	3.0	1.7	5	2.4	1.5	7	2.7	1.8	8	3.5	1.7
Sub-group secretary	4	3.5	1.9	5	2.8	1.9	5	3.4	1.9	7	3.57	1.3
Sub-group treasurer	4	2.0	2.2	-	-	-	5	3.8	2.2	-	-	-
Researchers	8	5.0	0.0	8	5.0	0.0	8	5.0	0.0	8	5	0.0
Research field assistant	4	4.3	1.0	1	3.0		6	3.7	2.0	8	4.63	0.5
Customers	8	3.1	2.0	5	4.4	1.3	8	4.1	1.0	8	2.5	1.3
Material providers	-	-	-	5	4.0	1.2	4	4.0	1.4	7	3	1.5
Wood suppliers	6	2.7	2.1	8	3.9	1.8	5	3.0	1.2	8	2.75	1.5
Village chief	-	-	-	-	-	-	2	3.5	0.7	4	3.5	1.9
Councilor	6	4.7	0.8	-	-	-	2	3.5	2.1	-	-	-
Leaders of sub-villages	-	-	-	-	-	-	3	4.3	1.2	-	-	-
Village ext. Off.	-	-	-	-	-	-	2	3.5	0.7	-	-	-

Assessment comparison between same actor role across different UPS groups: *p < 0.05; **p < 0.01; ***p < 0.001

Influence towers for the most relevant actors

This chapter presents the results of different influential categories for the most relevant actors in the Improved Cooking Stoves networks. For the sake of simplicity only the five most relevant actors are presented in Table 10. The three most important actors (measured by the average value of the importance tower in the four villages) from all groups were selected: researchers, stove constructors and secretary. Additionally, group members and customers were added to the table as they are the ones adopting and implementing the innovations. It is important to recall that group members and stove constructors are the same actors in Changarawe as all members go build the stoves together.

Five different influence categories were measured during the Net-Map sessions, importance, income, trust, food and knowledge. For measuring the towers, the interviewees answered the questions: *Who is the most important actor in the implementation of the ICS? (importance); Who gets the most income out of the implementation of the ICS? (income); Who is the most trustworthy actor in the network? (trust); Who gets the highest amount of food out of the implementation of the ICS? (food); Who learns the most in the network? (knowledge).*

Importance: The results are presented in the previous chapter. no significant differences were found between the actors.

Income: The actors rated at the top of the income distribution are the *stove constructors* and the *group members*. The assumed income levels for the group members in Changarawe are significantly lower ($p < 0.01$) when compared to Idifu and Ilolo.. Changarawe is the village with less adopters (people having an improved cooking stove) while the groups from the semi-arid region have the highest amount of adopters, which is translated into higher income for the stove constructors and group members. Regional differences are observed for the researchers. In the semi-arid region researchers are assumed to receive indirectly some income from the implementation as they are employed by Tran-SEC project they get a salary. While in the sub-humid region researchers are not assumed to receive money from the implementation. However, researchers do not get a direct income or salary for working in the project.

Trust: There is a high level of trust in the network since all of the actors except for the customers in all villages were ranked with high levels of trust. Group members expressed that customers are not always trustworthy as it has happened many times they wanted a stove and by the date for construction they couldn´t find them in their houses.

Food: Stove constructors were ranked getting the highest amounts of food in the network. Interviewees mentioned that with money received from the construction of the stoves they have been able to afford more food. Researchers are assumed to receive significant lower ($p<0.05$) amounts of food in Idifu when compared to Ilolo. Across regions the difference is very significant ($p<0.001$) when comparing Ilolo to Changarawe and Ilakala as in the semi-arid region researchers are assumed to not receive any food at all. A possible explanation for this results is that in Ilolo village researchers were perceived to receive food from the project as they are getting paid to do their job and with this money they are getting food. Which is not correct at all.

Knowledge: Actors assumed to learn the most out of the UPS implementation are the *secretary*, *stove constructors* and *group members*. The majority of the group members in all groups indicated that apart from learning how to build the stoves they also learn about the health benefits it brings to their families. In the semi-arid region, the positive environmental impacts of the use of the improved stoves in their communities was additionally mentioned. We find differences for the distribution of knowledge for customers across villages. Interesting results are found for the researchers as they are assumed to also learn from the groups. Some examples of knowledge are the improvements on the stoves construction and the life in the communities.

Moreover, the assessment comparison did not exhibit significant differences for the assumed motivations across different actors in the same UPS group.

Table 16. *Importance, income, trust, food and knowledge towers from most relevant actors in the Improved cooking stoves (ICS) UPS group. Source: Author´s data.*

Village	Importance			Income			Trust			Food			Knowledge		
	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.
Secretary															
Idifu	8	4.9	0.4	8	0.0	0.0	8	4.5	1.1	8	0.0	0.0	8	4.9	0.4
Ilolo	8	4.1	0.8	8	0.4	1.1	8	3.9	1.4	8	1.1	2.1	8	3.9	1.1
Ilakala	8	4.9	0.4	8	0.0	0.0	8	4.6	0.7	8	0.5	1.4	8	4.9	0.4
Changarawe	8	4.4	0.9	8	0.0	0.0	8	4.6	0.5	8	0.5	0.9	8	4.3	1.0
Stove Constructors															
Idifu	8	5.0	0.0	8	3.5	1.7	8	5.0	0	8	3.6	1.8	8	5.0	0.0
Ilolo	8	4.6	1.1	8	3.3	2.1	8	4.8	0.7	8	3.5	1.9	8	4.8	0.7
Ilakala	8	4.5	0.8	8	2.9	1.2	8	4.6	0.7	8	3.1	0.8	8	4.9	0.4
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Researchers															
Idifu	8	5.0	0.0	8	0.6	1.8	8	5	0	8	1.1*	2.1	8	2.5	2.7
Ilolo	8	5.0	0.0	8	2.6	2.6	8	5	0	8	3.3*/ ***	1.9	8	3.9	1.9
Ilakala	8	5.0	0.0	8	0.0	0.0	8	5	0	8	0.00***	0.0	8	1.9	1.9
Changarawe	8	5.0	0.0	8	0.0	0.0	8	5	0	8	0.00***	0.0	8	2.0	2.3

Group members															
Idifu	8	4.8	0.5	8	3.6**	0.9	8	4.6	0.7	8	0.4	1.1	8	4.1	1.4
Ilolo	8	3.8	1.6	8	3.8**	1.7	8	3.5	1.3	8	1.9	2.2	8	4.3	1.4
Ilakala	8	4.1	0.8	8	2.5	1.6	8	4.4	0.7	8	0.9	1.6	8	4.6	0.7
Changarawe	8	3.5	1.2	8	1.6**	1.1	8	4.4	0.9	8	1.3	1.9	8	3.9	1.0
Customers															
Idifu	8	3.1	2.0	8	0.0	0.0	8	3.0	2.0	8	0.0	0.0	8	2.6	2.3
Ilolo	5	4.4	1.3	5	1.0	2.2	5	2.8	2.3	5	1.0	2.2	5	2.8	1.9
Ilakala	8	4.1	1.0	8	0.0	0.0	8	4.6	0.7	8	0.5	1.4	8	3.6	1.3
Changarawe	8	2.5	1.3	8	0.3	0.7	8	2.9	1.6	8	0.4	0.7	8	2.4	1.3

*Assessment comparison between same actor role across different UPS groups: *p < 0.05; **p < 0.01; ***p < 0.001*

6.4.5 Motivations of actors in the Improved cooking stoves implementation

Table 11 presents the five most frequent motivations found for the five most relevant actors (presented in the previous chapter) across all villages. From the results it can be observed that the motivations for participating in ICS differ to some extent between all groups. *More knowledge* and *better social relations* are the most frequent among all actors, followed by *more joy*, *enhancing food availability* and *better reputation.*

Group members across villages were assumed to have knowledge and social relations as frequent motivation for their participation in the UPS. Respondents reported these motivations to be important for their personal and community development.

Assessment comparison for the stove constructors exhibited high ($p<0.5$) to highly ($p<0.01$) significant differences across the semi-arid region for more joy, more knowledge and enhanced food availability. The motivation of *enhancing food availability* is assumed to be significantly higher in Idifu village when compared to Ilolo, as respondents in Idifu reported that stove constructors bring more food to their households with the money they receive from the construction of the stoves. *More joy* has a significant higher assumed rank in Idifu village when compared to Ilolo, as constructors are assumed to feel happy about participating in the UPS. In addition, *more knowledge* was assumed to have a significant higher rank in Ilolo when compared to Idifu. Knowledge is assumed to be already mastered by more constructors in Idifu, therefore it was rated lower. Some of these differences in the semi-arid region can be related to the fact that Idifu village was the first to start implementing the UPS.

Better reputation is a highly rated motivation for the *secretaries* in all villages. Their leadership position puts them in an advantageous position with regard to find opportunities for succeeding in their communities since they are better known. Group members in Ilolo and Ilakala also have *better reputation* as a high motivation for participating in the groups. They feel proud about their groups and they would like to share it with to other community members i.e. with caps and T-shirts with their group´s name printed.

Customers in all villages are using their stoves as they are able to get *more food* as they save time on cooking. This allows them to do other activities such as farming or taking care of their personal business. Additionally, *more joy* is brought by the stoves to the customers of all villages as they feel happier about creating better environments to their families with tastier and healthier food. In the case of the stove constructors *more joy* comes as a

consequence of the time they save on cooking and collecting wood, now that they have the stoves at home the can spend more quality time with their families and this makes them feel more joy. Researchers in Idifu and Changarawe are perceived to feel happy about doing their job and bringing the innovation to the villages.

Moreover, the assessment comparison did not exhibit significant differences for the assumed motivations across different actors in the same UPS group.

Table 17. *Motivations for participating in the Improved cooking stoves (ICS) UPS group for the five most relevant actors. Source: Author's data.*

	Enhancing food availability			**More Joy**			**Better Social Relations**			**More Knowledge**			**Better Reputation**		
	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.
	Secretary														
Idifu	8	0.0	0.0	8	0.4	0.5	8	0.8	0.5	8	0.5	0.5	8	0.6	0.5
Ilolo	8	0.0	0.0	8	0.1	0.4	8	0.8	0.5	8	0.6	0.5	8	0.8	0.5
Ilakala	8	0.3	0.5	8	0.3	0.5	8	0.5	0.5	8	0.9	0.4	8	0.6	0.5
Changarawe	8	0.3	0.5	8	0.3	0.5	8	0.4	0.5	8	0.8	0.5	8	0.5	0.5
	Stove Constructors														
Idifu	8	0.8***	0.5	8	0.8*	0.5	8	0.3	0.5	8	0.3*	0.5	8	0	0
Ilolo	8	0.0***	0.0	8	0.1*	0.4	8	0.6	0.5	8	0.9*	0.4	8	0.3	0.5
Ilakala	8	0.4	0.5	8	0.4	0.5	8	0.5	0.5	8	0.6	0.5	8	0.3	0.5
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Researchers														
Idifu	8	0.6	1.1	8	0.8	0.5	8	0.6	0.5	8	0.5	0.5	8	0.3	0.5
Ilolo	8	0.3	0.5	8	0.3	0.5	8	0.4	0.5	8	0.9	0.4	8	0	0
Ilakala	8	0.4	0.5	8	0.1	0.4	8	0.4	0.5	8	1	0	8	0.4	0.5
Changarawe	8	0.1	0.4	8	0.4	0.5	8	0.6	0.5	8	0.9	0.4	8	0.3	0.5

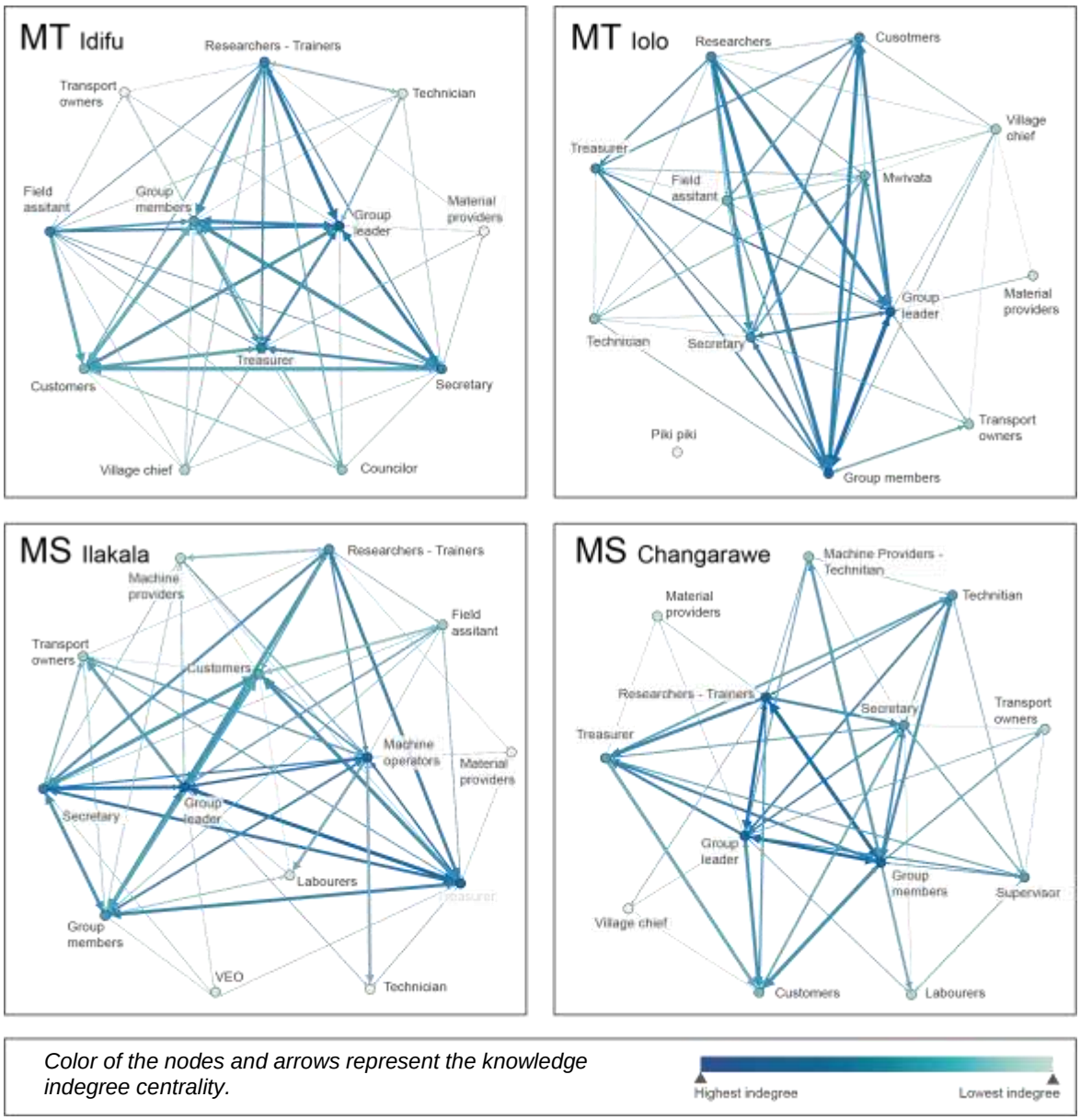
	Costumers														
Idifu	8	0.5	0.5	8	0.8	0.7	8	0.3	0.5	8	0.5	0.5	8	0	0
Ilolo	5	0.4	0.5	5	0.4	0.5	5	0.2	0.4	5	0.4	0.5	5	0.2	0.4
Ilakala	8	0.6	0.5	8	0.4	0.5	8	0.6	0.5	8	0.5	0.5	8	0.3	0.5
Changarawe	8	0.4	0.5	8	0.4	0.5	8	0.3	0.5	8	0.8	0.5	8	0	0
	Group Members														
Idifu	8	0.6	1.1	8	0.5	0.5	8	0.5	0.5	8	0.6	0.5	8	0.3	0.5
Ilolo	8	0.0	0.0	8	0.1	0.4	8	0.4	0.5	8	1	0	8	0.6	0.5
Ilakala	8	0.4	0.5	8	0.1	0.4	8	0.6	0.5	8	0.5	0.5	8	0.6	0.5
Changarawe	8	0.3	0.5	8	0.1	0.4	8	0.6	0.5	8	0.6	0.5	8	0.1	0.4

*Assessment comparison between same actor role across different UPS groups: *p < 0.05; **p < 0.01; ***p < 0.001*

6.5 Comparison between the Maize sheller and Millet thresher UPS groups: Differences at regional and village levels

6.5.1 Knowledge network for the Maize sheller & Millet thresher UPS groups

Fig. 16. *Knowledge Network Maps Millet thresher (MT) & Maize sheller (MS) UPS groups. Source: Author's data.*



Note: *The indegree can be visualized in the network with the arrows coming in the actor's nodes, while the arrows coming out form the nodes represent the outdegree. The amount of times this link was repeatedly mentioned on the interviews can be visualized with the thickness of the arrow, the bigger the arrow the higher the value.*

Figure 16 illustrates the findings for the knowledge flow in all the villages. It can be observed that *group members*, *customers*, *group leaders, secretaries, treasurers and researchers* are the actors most actively involved in the knowledge flow across all villages. Regional differences can be appreciated since the groups in semi-arid region have a relatively lower

flow of knowledge when compared to those in the sub-humid region. Furthermore, it can be observed that most frequently mentioned ties or links in the groups are mainly reciprocated structures, meaning that knowledge is dynamic inside the groups. The presence of laborers, machine operators and supervisors suggests the groups have developed different roles and integrated different actors that are important for the groups´ functioning. A possible explanation for these results might be the implementation stage of the groups since groups in sub-humid region has started the operation of the machines while in the semi-arid region the operation has not yet started.

Figure 17 presents the indegree centrality measures for the actors found in all groups. Overall it can be noticed that *group members* are located on top of the indegree centralities followed by the *group leaders* and *customers*. Moreover, *transport owners* and *technician* have a significantly higher position in the distribution of knowledge in the sub-humid region. The constant communication with the transport owners in Ilakala has been key for their operations´ success.

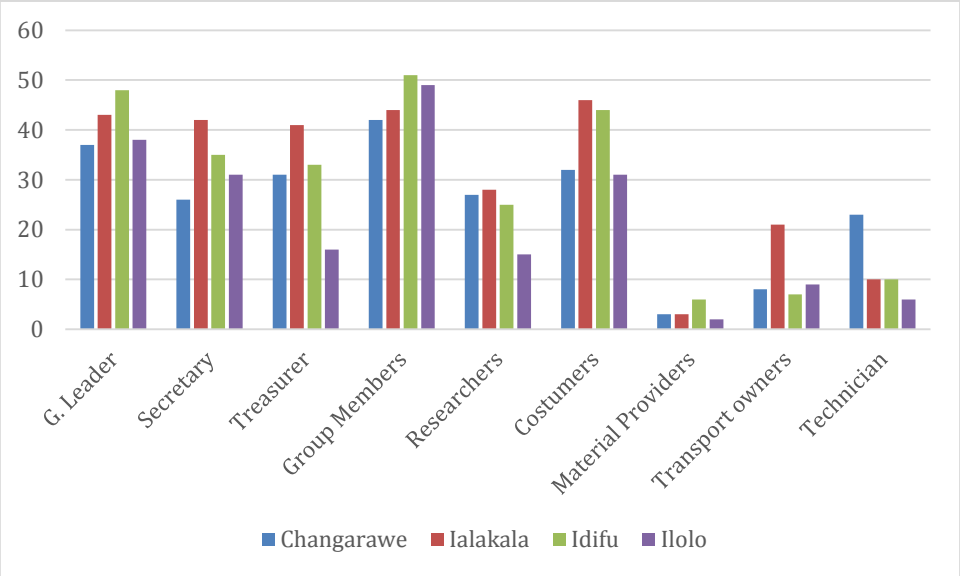


Fig. 17. *Indegree centrality knowledge networks Millet thresher (MT) & Maize sheller (MS) UPS groups. Source: Author's data.*

Group members learn constantly from the researchers in terms of machine operation and group management. They get feedback from the customers regarding prices and they also get advices regarding operation processes and strategies from the groups´ leadership.

In all villages customers have a high indegree centrality, especially in Ilakala and Idifu where they have the highest indegree centrality among all actors. Group members are constantly promoting the technology among their communities in order to become better known in the

area. Potential customers also receive information regarding the innovation through the annual village meetings, where researchers and village chiefs present the innovations to the community.

Leaders are important in the knowledge flow for all groups, as the have developed managerial skills that are important for the groups´ functioning. In Ilakala the *group leader* has direct contact with the transport owners therefore he has learned how to bargain their prices in order to concrete deals with them. Transport is a big challenge for all groups, therefore this skills gained by the leaders to make negotiations are vital for the groups´ success. The *secretaries* and *treasurers* are having a high indegree since they have learned how to keep the groups' records mainly. Their role is also important for bridging information and concerns from the groups to the researchers.

6.5.2 Money network for the Maize sheller & Millet thresher UPS groups

When comparing the results for the indegree centralities of the money network it can be observed that the *treasurer* is located at the top followed by the *group members* and *material providers*. The *treasurer* has the highest position since he receives the money from the groups operation and also the group fees and shares. In the case of the *group members,* they receive money every time they operate machines, and researchers also provide a small allowance to them in group meetings. Regional differences can be appreciated in Figure 14 for the *group members* and *treasurers* between sub-humid and semi-arid region. Groups in the semi-arid region have not yet started to work they do not receive the money from the machine activities, explaining their lower indegree centralities.

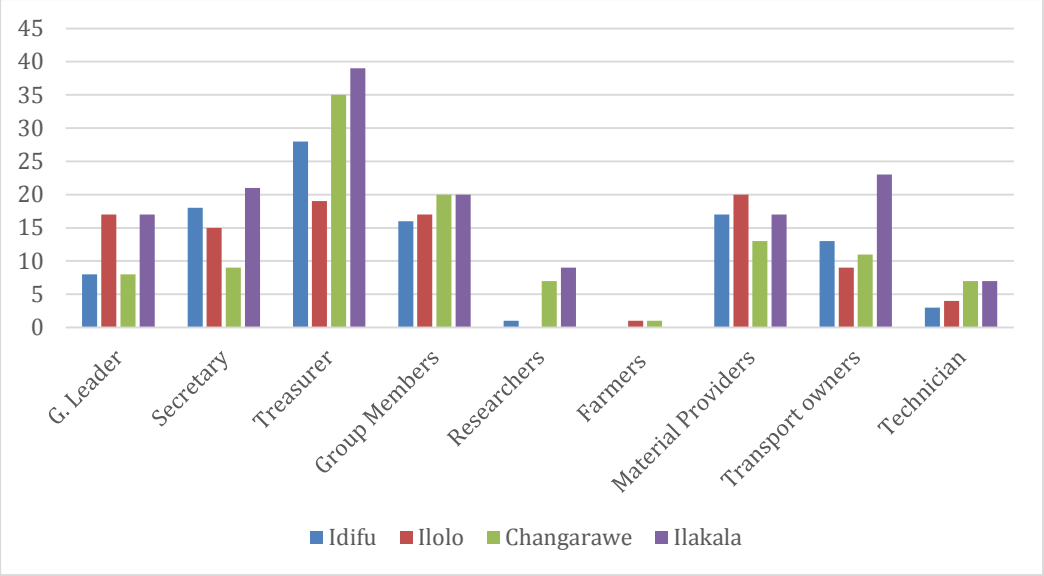


Fig. 18. *Indegree centrality money networks Millet thresher (MT) & Maize sheller (MS) UPS groups. Source: Author's data.*

The machines are given to the groups by the *researchers* as a loan and it is the responsibility of all groups to pay it back. With their activities, the group form Ilakala is close to finish paying the loan while the other groups have not yet started to pay it off. *Researchers* were mentioned to be given money by the group members for the group´s registration.

6.5.3 Materials network for the Maize sheller & Millet thresher UPS groups

For the betweenness centrality on the materials network it can be observed that *group members* are assumed to have highest value in all groups except for MT Ilolo, followed by the *researchers*. These results suggest the group members have a considerable influence on the material flow in the network as they have easy access to the materials needed for providing the service of maize shelling or millet threshing. For example, they received the machinery from the researchers and they bring the machine to the customer's field, they thresh the maize given by the customers and they fill their bags. The results for Ilolo village might be linked to their low group activities. The only betweenness centrality in the group is for the researchers suggesting that the material flow depends in a big extend on them.

Researchers are influential in the material flow of the groups as they provided the machines to the group members. In addition they link the group members with the technicians for getting spare parts and also repair service. These results reflect the influence they have on the proper functioning of the groups. However, this relation is important for the groups as they have indirect access to resources that at this point are beyond their reach.

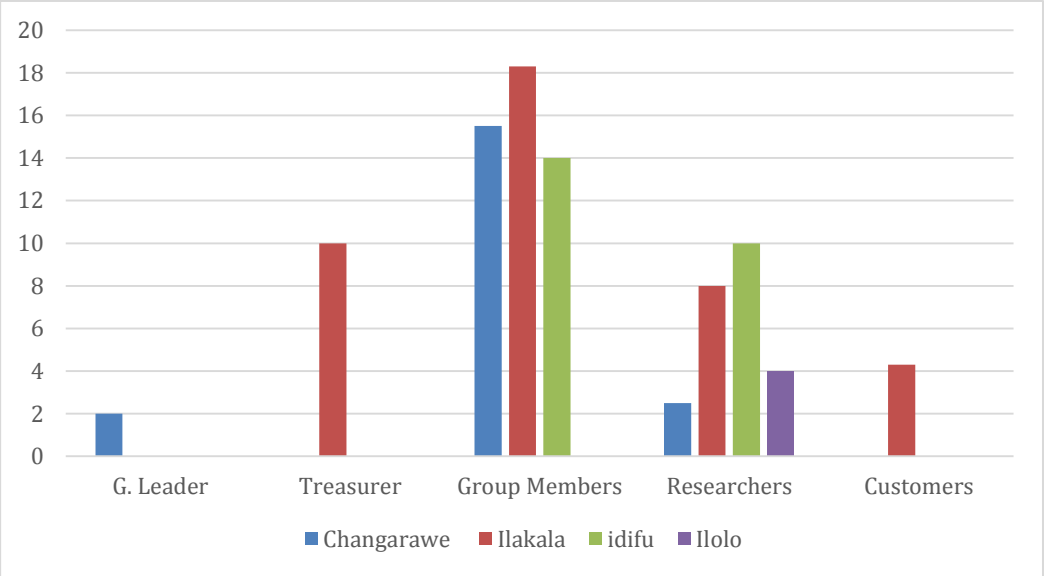


Fig. 19. *Betweenness centrality material networks Millet thresher (MT) & Maize sheller (MS) UPS groups. Source: Author´s data.*

In Ilakala village the *treasurer* is assumed to have a high indegree since was elected by the group members to be in charge of keeping the machine safe in his house. Customers in the same village are influential in the operation of the machine as they provide the group members with the bags and plastic protectors that are used when the machine is operating.

6.5.4 Influence towers for the three most important actors in the Maize sheller & Millet thresher UPS groups

Table 12 presents the results for the five different categories of influence, which were presented on chapter 6.5.4, for the three most important actors. In order to select the three most important actors of the UPS groups the average of the importance tower in all the villages was taken as parameter. For selecting the actors with the highest scores they also had to be present in all groups. In all four villages, respondents identified trust, knowledge and importance as categories with the highest ratings for all actors.

Importance: Actors identified as the most important for the implementation of the UPS are the *secretary*, *group members* and the *researchers*. Being the *researchers* the most important in all villages. These results are consistent with those of the improved cooking stoves where the actors with the highest importance scores are the *secretary*, *stove constructors* and *researchers*. Moreover, regional differences are found for the group members since in the semi-arid region ratings are lower when compared to the sub-humid groups. The results suggest there might be a lack of commitment of some group members as they have not yet started to operate. Also, another factor affecting the group members'

commitment is the seasonality of work as there is not a lot of motivation to have meetings through the not working seasons.

Trust: All of the three actors presented are highly trusted, being the *researchers* at the top, followed by the *secretary* and the *group members*. Trust is important for the success of the groups as the all can rely on each other. When comparing these results to the improved cooking stoves, it can be observed that the scores are slightly lower for the trust overall.

Income: Group members are assumed to be on top of the income distribution followed by the secretaries. Regional differences are found for both actor groups as only the groups from the sub-humid region have started to work. Moreover, the group members assumed income is significantly lower for Changarawe when compared to Ilakala. Even though both groups mentioned the transportation of the machine to be their highest challenge, Ilakala's group has been able to overcome it. *"Is hard to push the machine with people… also hiring a tractor is a challenge because we cannot make enough money to pay for it plus the wages of the members that went to work" (F5 MS CHA).* The income distribution in ICS groups is more similar between regions and villages and the ratings are slightly higher in the ICS groups.

Food: Actors assumed to receive food out of the implementation were the group members, followed by the secretaries and researchers. A clear relation between income and food can be appreciated on the table . Group members and the secretaries are able to buy more food and cultivate more extensively their fields with the income they get from their UPS participation. Additionally, when compared to Ilakala village group members in Changarawe are assumed to receive significantly lower ($p<0.05$) amounts of food. However, the distribution of food is considerably higher for the Maize Sheller groups when compared to the Improved Cooking Stoves. These results also suggest that the improvements on the food availability for the improved processing is more tangible than in the ICS groups

Knowledge: When it comes to knowledge a high distribution among the secretaries followed by group members and researchers can be observed. . When comparing the results to thus in the ICS group there is a slightly smaller perceived distribution of knowledge for all the actors. Additionally, the levels of knowledge received by the researchers is lower when compared to the group members and secretaries. They were considered to learn from the lifestyles and living philosophies of the villagers.

Table 18. *Importance, income, trust, food and knowledge towers for the three most important actors in Millet Thresher (MT) & Maize Sheller (MS) UPS groups. Source: Author's data.*

		Importance			Income			Trust			Food			Knowledge		
		N	Mean	Std. Deviation	N	Mean	Std. Deviation	N	Mean	Std. Deviation	N	Mean	Std. Deviation	N	Mean	Std. Deviation
UPS	Village	**Secretary**														
MS	Ilakala	8	4.6	0.7	8	0.6	0.9	8	4.9	0.4	8	1.4	1.8	8	4.1	1.4
MS	Changarawe	7	4.6	0.8	7	0.9	1.1	7	4.6	0.5	7	2.3	1.7	7	4.1	0.9
MT	Idifu	8	4.1	1.2	8	0.0[a]	0.0	8	4.3	1.2	8	0.0	0.0	8	4.1	1.0
MT	Ilolo	8	4.5	0.9	8	0.0	0.0	8	4.1	1.1	8	0.0	0.0	8	3.4	1.5
Group Members																
MS	Ilakala	8	4.6	0.7	8	3.9*	1.4	8	4.5	0.8	8	3.9*	0.8	8	4.3	1.2
MS	Changarawe	8	4.1	0.6	8	2.25*	0.5	8	4.0	0.8	8	2.50*	1.2	8	4.1	0.8
MT	Idifu	8	4.1	0.6	8	0.0[b]	0.0	8	4.0	0.9	8	0.0	0.0	8	3.5	1.7
MT	Ilolo	9	3.7	0.9	9	0.0	0.0	9	3.8	1.0	9	0.0[a]	0.0	9	3.3	1.4
Researchers																
MS	Ilakala	8	5.0	0.0	8	0.0	0.0	8	5.0	0.0	8	0.6	1.8	8	1.6	2.3
MS	Changarawe	8	5.0	0.0	8	0.0	0.0	8	4.5	0.8	8	0.4	1.1	8	1.9	2.1
MT	Idifu	8	5.0	0.0	8	0.0	0.0	8	4.9	0.4	8	0.0	0.0	8	2.3	2.5
MT	Ilolo	9	4.9	0.3	9	0.9	1.8	9	4.6	0.5	9	0.9[b]	1.8	9	2.4	2.4

*1. Assessment comparison between same actor role across different UPS groups: * = $p < 0.05$*

2. Assessment comparison across different actor roles in the same UPS group: a, b = $p < 0.05$

6.5.5 Motivations of actors in the Millet thresher & Maize sheller UPS groups implementation

Table 13 presents the ratings for the five most frequent motivations for the six most important actors. In order to select the six most influential actors of the UPS groups the average of the importance tower in all the villages was taken as parameter. For selecting the actors with the highest scores, they also had to be present in all groups. For MS and MT groups regardless of the actor's role we find *more food availability*, *better social relations* and *more knowledge* as the most frequent motivations followed by *more income* and *more joy*. In addition, contrasting higher results are found for all actors when compared to the improved cooking stoves groups. *Better social relations* are important as actors feel more supported in daily life and critical times (poor harvest or sick/deceased relatives), both motivations are considered vital for their success. *"Good relationship is good to their village and also its good for the success of their business so whenever if you want to succeed in any business there supposed to be good relationship"* (FDG MS Ilakala).

Better reputation was highlighted as an important motivation for the secretary in both MT groups while reputation was important in all villages for the improved cooking stoves. *"When you have a good relationship or a good interaction, you can always get a chance to be someone"* (F2 MT Idifu). For both MS groups *more income* is a frequent motivation for their participation.

For the group members in Ilolo, Ilakala and Changarawe *more knowledge* is significantly higher ($p<0.5$) rated motivation when compared to Ilolo village. Respondents expressed their interest during the interviews and FDG on learning more about business management and marketing. Other important motivations for the group members are *more income* and *enhancing food availability* in both regions. *"The maize thresh has contributed to the increase of food through the money being paid during the day when you go to work there"* (FDG MS Ilakala). Their participation in the UPS provides them with more income and this allows them to send children to school, buy more food, and cultivate their fields. "*When you get money, you can use the money to educate your kids, so first get money and the other things will follow"* (FDG MS CHA). Moreover, the assumed levels of enhancing food availability as motivations is significantly similar between the secretary and group leader in Ilakala village. When comparing these results to the ones of the group members in the ICS, it can be noticed that more knowledge and better social relations were also assumed as high motivations but more income was not. These results suggest that the money generated in the ICS stoves is not as significant as the one in the MS and MT groups.

Researchers are perceived as one of the biggest source of knowledge as they bring the innovations to the villages *"The researchers want us to get knowledge"* (F1 MT Idifu). *More joy* was assumed as a frequent motivation in the semi-arid region for the researchers, as they are perceived to feel happy about bringing the project to villages. While in the sub-humid *more income* is assumed to be a higher motivation for them. The machinery is assumed to bring benefits not only to the group members also for the community. In addition, the observed values for group leader and group members in MS Ilakala are significantly similar.

Table 19. *Motivations for participating in the Maize sheller (MS) and Millet thresher (MT) UPS groups implementation for the six most important actors. Source: Author's data.*

		More income			Enhancing food availability			More joy			Better social relations			More knowledge		
Village	UPS	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
		Researchers														
Idifu	MT	8	0.3	0.5	8	0.5	0.5	8	0.5	0.5	8	0.4	0.5	8	0.4	0.5
Ilolo	MT	9	0.1	0.3	9	0.3	0.5	9	0.4	0.5	9	0.6	0.5	9	0.7	0.5
Ilakala	MS	8	0.8	0.5	8	0.5	0.5	8	0	0	8	0.4	0.5	8	0.8	0.5
Changarawe	MS	8	0.4	0.5	8	0.4	0.5	8	0	0	8	0.6	0.5	8	0.9	0.4
		Secretary														
Idifu	MT	8	0.4	0.5	8	0.3	0.5	8	0.1	0.4	8	0.5	0.5	8	0.6	0.5
Ilolo	MT	8	0	0	8	0.4	0.5	8	0.1	0.4	8	0.8	0.5	8	0.8	0.5
Ilakala	MS	8	0.8	0.5	8	0.4[a]	0.5	8	0.1	0.4	8	0.5	0.5	8	0.8	0.5
Changarawe	MS	7	0.4	0.5	7	0.3	0.5	7	0.1	0.4	7	0.7[a]	0.5	7	0.9	0.4
		Group Leader														
Idifu	MT	8	0.3	0.5	8	0.4	0.5	8	0.6	0.5	8	0.5	0.5	8	0.5	0.5
Ilolo	MT	8	0.1	0.4	8	0.5	0.5	8	0.4	0.5	8	0.8	0.5	8	0.6	0.5
Ilakala	MS	8	0.5	0.5	8	0.4[b]	0.5	8	0.4[a]	0.5	8	0.4	0.5	8	0.6	0.5
Changarawe	MS	8	0.5	0.5	8	0.4	0.5	8	0.1	0.4	8	0.8	0.5	8	0.5	0.5
		Group Members														
Idifu	MT	8	0.5	0.5	8	0.6	0.5	8	0.3	0.5	8	0.8	0.5	8	0.0*	0
Ilolo	MT	9	0.6	0.5	9	0.4	0.5	9	0.4	0.5	9	0.7	0.5	9	0.6*	0.5
Ilakala	MS	8	0.6	0.5	8	0.5	0.5	8	0.4[b]	0.5	8	0.8	0.5	8	0.5*	0.5
Changarawe	MS	8	0.6	0.5	8	0.5	0.5	8	0.3	0.5	8	0.6[b]	0.5	8	0.5*	0.5

		Technician														
Idifu	MT	7	0.6	0.5	7	0.4	0.5	7	0.7	0.5	7	0.3	0.5	7	0.1	0.4
Ilolo	MT	5	1	0	5	0.8	0.4	5	0.6	0.5	5	0.4	0.5	5	0.2	0.4
Ilakala	MS	7	0.9	0.4	7	.06	0.6	7	0.3	0.5	7	0.4	0.5	7	0.4	0.5
Changarawe	MS	8	0.9	0.4	8	0.5	0.5	8	0.5	0.5	8	0.5	0.5	8	0.4	0.5
		Customers														
Idifu	MT	8	0.1	0.4	8	0.8	0.5	8	0.8	0.5	8	0.3	0.5	8	0.3	0.5
Ilolo	MT	9	0.2	0.4	9	0.8	0.4	9	1	0	9	0.3	0.5	9	0.1	0.3
Ilakala	MS	8	0.8*	0.5	8	0.9	0.4	8	0.3	0.5	8	0.1	0.4	8	0.3	0.5
Changarawe	MS	8	0.1*	0.4	8	0.6	0.5	8	0.8	0.5	8	0.3	0.5	8	0.1	0.4

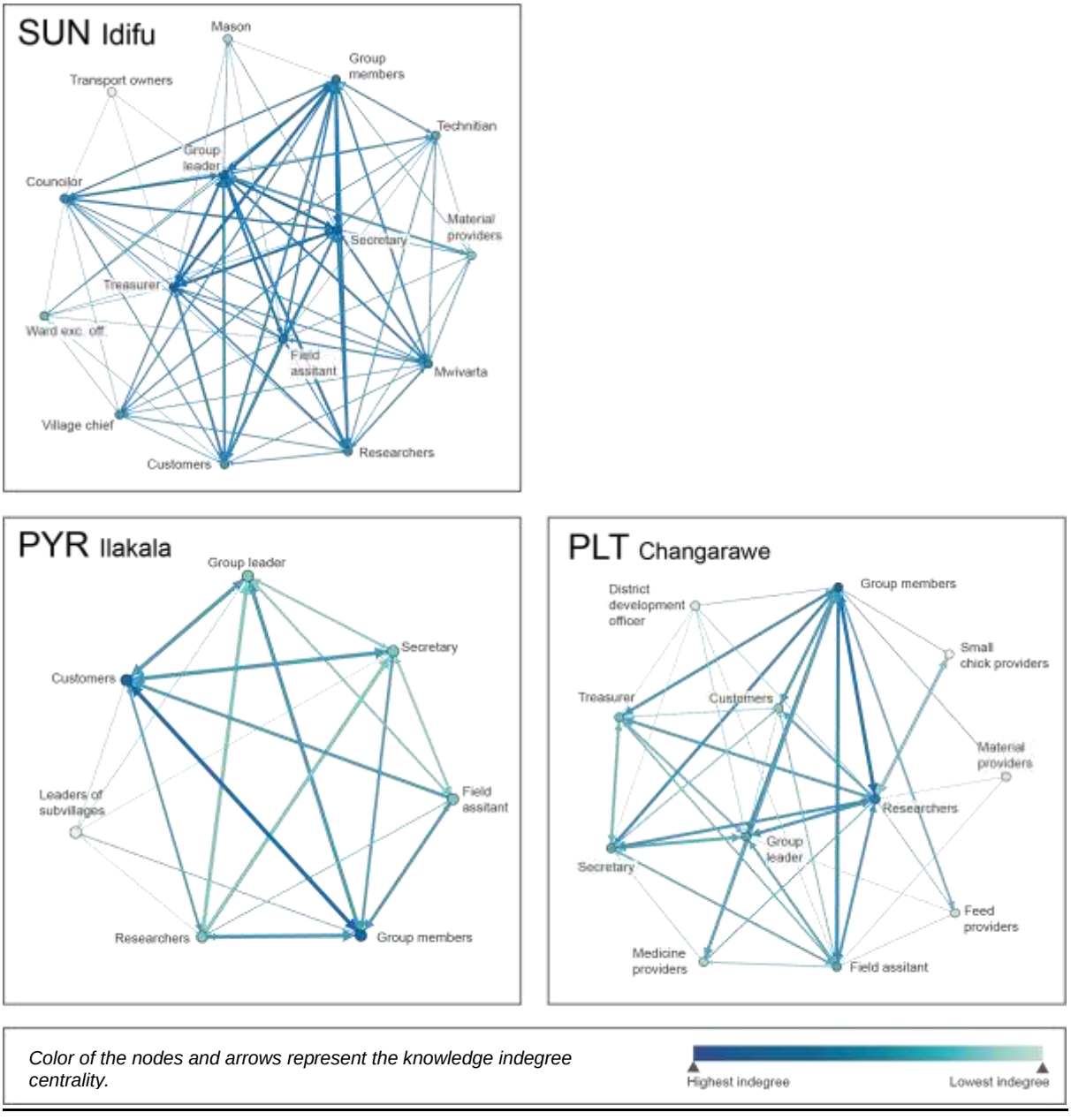
*1. Assessment comparison between same actor role across different UPS groups: * = $p < 0.05$*

2. Assessment comparison across different actor roles in the same UPS group: a, b = $p < 0.05$

6.6 Comparison between Sunflower oil production, Poultry-crop integration & marketing and By products of bioenergy UPS groups

6.6.1 Indegree knowledge network Sunflower oil production, Poultry-crop integration & marketing and By products of bioenergy UPS groups

Fig. 20. *Indegree centrality knowledge Network Maps Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author's data.*



Note: *The indegree can be visualized in the network with the arrows coming in the actor's nodes, while the arrows coming out form the nodes represent the outdegree. The amount of times this link was*

repeatedly mentioned on the interviews can be visualized with the thickness of the arrow, the bigger the arrow the higher the value.

Figure 20 shows that the group assumed with the highest numbers of important actors identified for the UPS implementation is the SUN group, closely followed by the PLT and the PYR UPSs. Additionally, the SUN group is having the highest number of governmental authorities involved in the knowledge flow. These results may be influenced by the geographical proximity of these authorities to the group, therefore enhancing their communication. The leaderships of the groups are assumed to have a more active role in the SUN group. Moreover, it can be observed that PYR group has overall lower indegree values for the actors when compared to the other groups, suggesting that network has a lower flow of knowledge. There is still a lack of understanding about the technology and group operation planning, leading to the drop-out of a large number of members.

Groups members are assumed to receive high knowledge flows across all villages. In the particular case of PLT they have the highest value in the network. These results suggest that group members seem to be equally receiving the knowledge regarding the innovations.

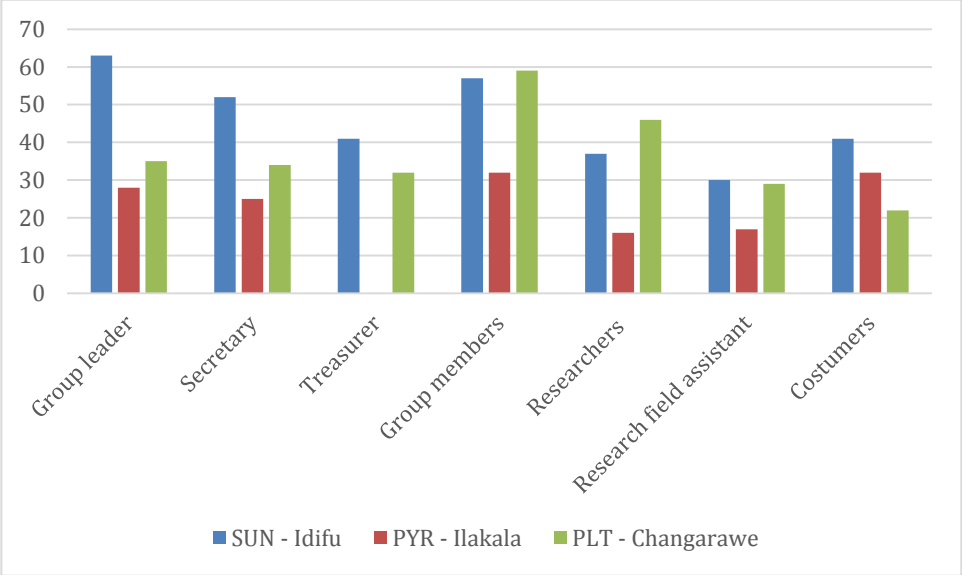


***Fig. 21**. Indegree centrality knowledge networks Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author's data.*

In the SUN and PLT groups the group leaders and the secretary are assumed to have some of the highest indegree values on their networks. They are important holders of knowledge, regarding their roles and the implementation of the UPS. The group leader in the SUN group has

the highest degree in the network explained by the high interaction he has with the researchers and customers.

Researchers receive feedback regarding the innovations from the leaders and the group members as the UPS require a lot of technical knowledge for the operation as well as a business plan. Similarly, customers who are curious about the innovation provide advices and feedback to the group members regarding prices in the SUN and PLT groups and chicken breads they prefer in the PLT group. *"Customers say it is better (with the groups' machine) because now we are going to save our time not going so far"* (F1 SUN). In the case of the PYR group the customers are assumed to learn in almost the same degree as the group members about the different uses of the bio-char. Before they used to throw away the cobs but know they collect them as they know how to use them.

6.6.2 Indegree money network Sunflower oil production, Poultry-crop integration & marketing and By products of bioenergy UPS groups

Figure 22 shows all actors present in the 3 different groups. It was necessary to present all actors; as not including them all would limit the visualization of the money flowing in the different UPS. The PLT UPS is assumed to be the group with the highest number of actors involved in the money flow, followed by the SUN and the PYR UPSs. These results suggest that there are a higher number of actors providing goods and services that are necessary for the implementation in the PLT group. Group members need purchase a broad variety of materials i.e. for wood or bricks for building the coops, small chicks, fodder and medicine treatments. This has been pointed out as a current challenge that group members face as not all of them are able to afford these expenses limiting the success and adoption of the UPS. *"People are afraid of building a coop because they think they have to build very strong coops and that requires between 200,000 to 600,000 TSCH" (F1 PLT CHA).* So far 6 group members out of 33 have received the small chicks to grow and they all have sold them to a price where they are still having a profit. Group members and leaders in the same UPS are assumed to receive money from the researchers for their participation in meetings as in the other UPS groups. Moreover researchers receive money as they provide the small chicks to the group members as a loan. The loan is paid back after the group members have sold their chickens, this money is sometimes handed in to the research field assistant.

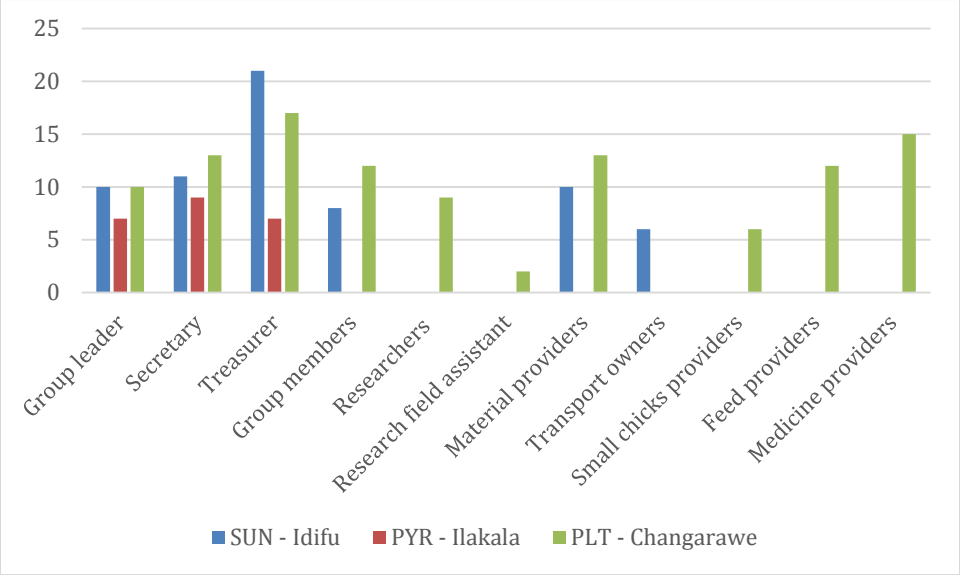


Fig. 22. *Indegree centrality money networks Sunflower oil production, Poultry-crop integration & marketing and By products of bioenergy UPS groups. Source: Author's data.*

PYR group is assumed to have the lowest number of actors receiving money from the UPS implementation. The money received by the group leader, secretary and treasurer are the small allowances they get from the researchers every time they are interviewed. Group members are not considered to receive any money, not even the small allowances provided by the researchers because they do not hold any group meetings. The organization and management of the group is poor when compared to the other UPS groups.

Similarly, to the MS groups in the SUN group, transport owners receive money for transporting stones and bricks to build the barn for the machine. Some materials bought are cement, bricks and roof for the barn. Additionally, the treasurer is assumed to have the highest indegree in the network. The money received by the treasurer is the fee group members provide on every meeting and the cooperation for constitution and group registration.

6.6.3 Betweenness materials network Sunflower oil production, Poultry-crop integration & marketing and By products of bioenergy UPS groups

From the figure 23, we can see that all of the ratings are very different for all actors in the three UPS. The group members form PLT UPS were assumed to have by far the highest betweenness values in the materials flow, followed by the PYR group leader and the feed providers. These results suggest that the group members are more likely to be influential in the materials network as they can exchange materials with other actors more efficiently, locating

them in a better position in the network. Additionally feed providers are assumed to have a high betweenness degree as they sell fodder to the group members and also to the small chick providers. Small chick providers and customers in PLT group are contacted through the researchers, hence their high betweenness values.

The group leader and the secretary in the PLT group, have the highest potential to control the flow of materials in the network. Thus, they are keeping the only pyroliser provided by the researchers in their households. The SUN group was assumed to have lowest betweenness levels, suggesting that actors have similar opportunities for accessing the materials. Moreover, there is not a big flow of materials in the two UPS as the groups have not yet started to operate.

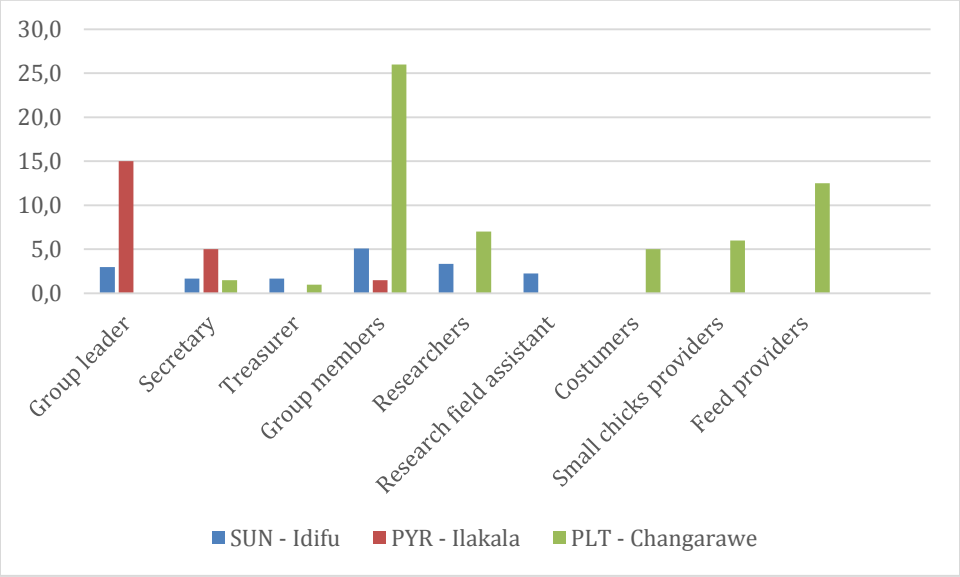


Fig. 23. *Betweenness centrality materials networks Sunflower Oil Production, Poultry-crop integration & marketing and By Products of Bioenergy UPS groups. Source: Author's data.*

6.6.4 Influence towers for the three most important actors in the Sunflower oil production, Poultry-crop integration & marketing and By products of bioenergy UPS groups

Table 14 illustrates the findings for the five influence categories (importance, income, trust, food, knowledge) measured before for all groups, in addition the bio-char influence tower was measured for the PYR group. The three most important actors are shown with their respective ratings for the different towers. In order to select the three most important actors of the UPS groups the average of the importance tower in all the villages was taken as parameter. For selecting the actors with the highest scores, they also had to be present in all groups.

Importance: The most important actors assumed for the implementation in the three UPS groups were the *researchers* followed by the *secretary* and the *group members*. All of the actors were assumed to be highly important. However, lower results for the secretary and group members are observed in the village of Changarawe in the PLT UPS group. A possible explanation is the fact that not all members have been able to build a coop for the chickens, resulting in a lack of commitment of some members. In addition, when comparing these results to the ICS, MS and MT UPS, researchers were assumed to be the most important actors across all UPS, usually followed by the secretary and the group members.

Income and food: The only income and food levels in the table are observed for the group members and secretary from the PLT UPS groups. As some of the members were able to raise and sell their chickens, benefits from participating in the implementation seemed tangible to them. *"I like keeping chickens, first of all I can generate an income and my family economy moves to another level and we can also eat chickens and eggs"* (F5 PLT). These results for the group members are similar to those of the MS groups, suggesting that on both UPS the group members were assumed to have clear benefits on their food situation. PYR UPS has not yet started to operate nevertheless therefore no income or food levels are present.

Bio-char: PYR UPS group had already a couple of trials and I wanted to measure how much bio-char the actors in the network had received. The results indicate that group members received the highest levels of bio-char followed by the secretary.

Trust: All 3 actors were assumed as highly trustworthy. Researchers are observed at the top followed by the group members and secretary. In addition, the high levels of trust for the researchers are also appreciated across all UPS including MS, MT and ICS UPS groups. The lack of participation on group meetings of some group members explains their lower ratings. Lower ratings are observed for the secretary in Changarawe as some respondents didn´t trust him completely, which can potentially influence in the performance of the group.

Knowledge: Group members are assumed to receive the highest levels of knowledge in the 3 villages. However, the levels for the group members and secretary SUN are lower when compared to the other villages. This results suggest that they are missing some important knowledge that is needed for the implementation of the UPS. "*They (researchers) came to teach us how to be persistence in the group, the group management; they were a lot of trainings but*

we had not received any training on how to operate the machine" (F3 SUN). In addition, researchers in Changarawe are assumed to receive a significant amount of knowledge as they learn about breeding chickens and the marketing strategies that are needed for the groups' success.

Moreover, the assessment comparison did not exhibit significant differences for the assumed motivations across different actors in the same UPS group neither for the same actors across the different USP groups.

Table 20. *Importance, income, trust, food, knowledge, bio-char towers for the three most important actors in the Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy(PYR) UPS groups. Source: Author's data.*

UPS	Village	Importance			Income			Trust			Food			Knowledge			Bio-char		
		N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Dev.	N	Mean	Std. Dev	N	Mean	Std. Dev
		Secretary																	
PLT	Changarawe	7	4.0	1.0	7	1.4	1.4	7	3.7	1.0	7	1.4	1.4	7	4.3	0.8	7	0.0	0.0
PYR	Ilakala	7	4.9	0.4	7	0.0	0.0	7	4.9	0.4	7	0.0	0.0	7	3.6	1.1	7	2.0	2.3
SUN	Idifu	7	4.9	0.4	7	0.0	0.0	7	4.3	1.9	7	0.0	0.0	7	2.7	2.6	7	0.0	0.0
		Group members																	
PLT	Changarawe	8	3.9	0.8	8	3.0	1.4	8	4.1	0.6	8	3.1	1.5	8	3.9	0.4	8	0.0	0.0
PYR	Ilakala	7	4.7	0.8	7	0.0	0.0	7	4.3	1.0	7	0.0	0.0	7	3.3	1.1	7	2.6	2.2
SUN	Idifu	7	4.9	0.4	7	0.0	0.0	7	5.0	0.0	7	0.0	0.0	7	2.6	2.5	7	0.0	0.0
		Researchers																	
PLT	Changarawe	8	4.9	0.4	8	0.6	1.8	8	4.5	0.9	8	0.6	1.8	8	2.3	2.5	8	0.0	0.0
PYR	Ilakala	7	5.0	0.0	7	0.0	0.0	7	5.0	0.0	7	0.0	0.0	7	1.1	2.0	7	0.0	0.0
SUN	Idifu	6	4.8	0.4	6	0.0	0.0	6	5.0	0.0	6	0.0	0.0	6	1.7	2.6	6	0.0	0.0

6.6.5 Motivations of actors in the Sunflower oil production, Poultry-crop integration & marketing and By products of bioenergy UPS groups implementation

Table 15 presents the ratings for the five most frequent motivations for the six most important actors in the PLT, SUN and PYR UPSs. In order to select the six most important actors of the UPS groups the average of the importance tower in all the villages was taken as parameter. For selecting the actors with the highest scores, they also had to be present in all groups. The results show *better social relations*, *better reputation* and *enhancing food availability* as frequently highly rated motivations in all groups. When comparing these results to the MS, MT and ICS groups it is clear that better social relations and enhancing food availability are a constant motivation for all group members in the different networks. *Better social relations* is assumed to be an important motivation for all actors except for the research field assistant in the PLT group and the customers in SUN group. Additionally, the assumed high motivation for the group members and the group leader in the PLT group is significantly similar.

In PLT UPS group *more income* is assumed to be a high motivation for all of the actors, in contrast to PYR and SUN group where more income is not frequently considered a motivation. In addition, in the PLT group researchers assumed more income motivation is significantly higher when compared to the secretary. More income is important for the researchers as they are assumed to be compromised with the improvement of the income situation of group members. In addition, the levels assumed of *more income* as a motivation is significantly similar between the group leader and secretary in the SUN UPS. Similar results are exhibited between the group members and the research field assistant in the PYR group.

Group members across the PLT and the SUN UPS groups highly rated *enhancement of food availability* as a motivation for participating in all villages. They are motivated to provide more food to their families through their participation and income generated in the UPS. However, for the group members in the PYR enhancement of food security is assumed to be a less frequent motivation. These results suggest there might be a lack of understanding among them regarding the benefits of bio-char, as the incorporation to the soil is expect to increase their yields. Enhancing food availability was also assumed as a high motivation for the field assistant in all villages, as respondents indicated he wants to help improving the food situation of the community.

More joy is an important motivation for the customers in the PLT and SUN groups. Customers of PYR consider better reputation as motivation as they are part of an innovation

that is supposed to bring high benefits to the community. They reported they feel as part of a new trend and wave of knowledge.

Table 21. *Motivations of the six most important actors for participating in the Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By Products of bioenergy (PYR) UPS groups. Source: Author's data.*

		More income			Enhancing food availability			More joy			Better social relations			Better reputation		
UPS	Village	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.
		Group leader														
SUN	Idifu	7	0.3[a]	0.5	7	0.6	0.5	7	0.3	0.5	7	0.7	0.5	7	0.6	0.5
PYR	Ilakala	7	0.1	0.4	7	0.6	0.5	7	0.1	0.4	7	0.6	0.5	7	0.7	0.5
PLT	Changarawe	7	0.6	0.5	7	0.6	0.5	7	0.1	0.4	7	0.6[a]	0.5	7	0.6	0.5
		Secretary														
SUN	Idifu	7	0.3[b]	0.5	7	0.4	0.5	7	0.7	0.5	7	0.7	0.5	7	0.3	0.5
PYR	Ilakala	7	0.1	0.4	7	0.4	0.5	7	0.4	0.5	7	0.6	0.5	7	0.6	0.5
PLT	Changarawe	7	0.7[c]	0.5	7	0.6	0.5	7	0.3	0.5	7	0.6	0.5	7	0.7	0.5
		Group members														
SUN	Idifu	7	0.3	0.5	7	0.7	0.5	7	0.4	0.5	7	0.6	0.5	7	0.7	0.5
PYR	Ilakala	7	0.3[f]	0.5	7	0.4	0.5	7	0.3	0.5	7	0.6	0.5	7	0.7	0.5
PLT	Changarawe	8	0.8	0.5	8	0.6	0.5	8	0.1	0.4	8	0.6[b]	0.5	8	0.9	0.4
		Researchers														
SUN	Idifu	6	0.3	0.5	6	0.2	0.4	6	0.5	0.5	6	0.7	0.5	6	0.5	0.5
PYR	Ilakala	7	0.1	0.4	7	0.4	0.5	7	0.6	0.5	7	0.6	0.5	7	0.7	0.5
PLT	Changarawe	8	0.9[d]	0.4	8	0.0	0.0	8	0.3	0.5	8	0.5	0.5	8	1.0	0.0
		Research field assistant														
SUN	Idifu	6	0.2	0.4	6	0.5	0.5	6	0.7	0.5	6	0.7	0.5	6	0.5	0.5
PYR	Ilakala	7	0.3[e]	0.5	7	0.9	0.4	7	0.3	0.5	7	0.4	0.5	7	0.7	0.5
PLT	Changarawe	8	0.6	0.5	8	0.9	0.4	8	0.0	0.0	8	0.3	0.5	8	0.9	0.4

		Costumers														
SUN	Idifu	6	0.3	0.5	6	0.8	0.4	6	0.8	0.4	6	0.3	0.5	6	0.5	0.5
PYR	Ilakala	7	0.1	0.4	7	0.7	0.5	7	0.6	0.5	7	0.6	0.5	7	0.7	0.5
PLT	Changarawe	7	1.0	0.0	7	0.6	0.5	7	0.9	0.4	7	0.4	0.5	7	0.0	0.0

*Assessment comparison between same actor role across different UPS groups: * = $p < 0.05$*

Assessment comparison across different actor roles in the same UPS group: a, b; c, d; f, e = $p < 0.05$

7. Discussion

In this section, the discussion takes part in order to answer the research questions posited at the beginning of this study. In the first part, the social structures and actor embeddedness of the UPS groups are analysed in relation to the different influence categories. Secondly, the motivations to participate in the implementation of the UPS are discussed. This is then followed by a review of the impacts of this implementation and possible success factors. The section finalizes with a short discussion on the methodological features and implications of this research.

7.1 Social structures and influence categories

The results from the Net-Map analysis are very insightful regarding the different interactions between actors within the UPS groups and their influence on the implementation process. Some of the influence towers (i.e. food, income and knowledge) show a clear relation between the integration of the UPS in livelihoods strategies and the impacts on the participants' livelihoods assets.

This study identified details about the actors' roles and their importance for the groups' UPS implementation from a group members' perspective. This is relevant for fostering long-term sustainability and improved performance of the UPS groups, as the assessment of the collaborative networks provide an overview of the group's development and participant's capacity of self-management. The relations drawn across the groups describe the social capital that is being built from the UPS implementation between UPS group members, their communities and different institutions (private and governmental). Moreover, from the analysis we can observe that there are diverse factors influencing the development of the social network structures of the UPS groups. These factors include:

(a) Implementation stage: Groups implementing the UPS for a longer period tend to have stronger ties and a higher number of active actors in their networks such as ICS and MS UPS, as it can be observed in Figures 12 and 16. The results of this research seemed to reaffirm the findings of the study conducted by Pretty and Ward (2001), which presents the evolution of social capital (social networks) and human capital (education and knowledge) as exhibited into groups: Reactive-Dependence; Realization-Independence; and Awareness-Independence. From this perspective, we could say that the groups of the ICS and MS have developed reaching up the Realization-Independence stage. The structures of these groups reflect that members are increasingly willing to invest their time in their groups activities, and they have started to develop stronger links with other actors from outside their UPS groups.

(b) Type of knowledge required for the UPS implementation: The different UPS require different types and levels of knowledge for their implementation; some of them require more technical knowledge than others. Some examples of the technical knowledge required include machine operations and maintenance (for MT, MS and SUN groups), chicken keeping practices in regard to fodder alternatives and disease prevention and treatment (PLT group). The results from the analysis also revealed that diverse actors are needed for providing knowledge to the aforementioned UPS groups, such as technicians, veterinary and trainers. When analyzing the structures of these UPS groups it can be observed that these ties already exist (Figures 16 and 20). However, in order for it to be disseminated, the complex knowledge network requires stronger ties and more frequent interactions (Reagans & McEvily, 2003). In the same line, Bandura (1986) developed a social cognitive learning theory emphasizing that a big part of the information people gain comes from the interaction with others. Therefore, for complex UPS requiring more technical knowledge the ties need to be strengthened for enhancing independence and sustainability of the groups.

(c) Materials and services needed for the UPS implementation: The diversity of actors in the UPS groups vary according to the materials and services required for implementing the innovations. Furthermore, the characteristics of the relations between participants and suppliers is linked to the implementation stage of the groups, as some of these relations are still dependent on researchers. An example is observed in the PLT group where the researchers are the brokers between small chick suppliers and group members (Figure 20).

7.1.1 Networks cohesiveness

The study revealed high density levels for the knowledge network in most of the UPS groups (Table 9). Overall these results provide evidence of a high knowledge flow regarding UPS implementation across most of the groups, which reflects strong actors' involvement in the exchange of ideas and advice. Previous studies held by Bodin and Crona (2009), showed that high-density levels are relevant indicators of high potential for collective action, which is important for successful UPS implementation. In addition, high-density levels can have positive impacts in the spread of information inside the networks, through increased accessibility to information (Abrahamson & Rosenkopf, 1997; Weimann, 1982). Nonetheless, too many ties can foster actor homogenization while reducing the capacity for effective collective action when dealing with changing conditions (Bodin and Crona, 2009). This happens when actors tend to have homogenized perception of issues at hand. We could consider this a risk for the sustainability of the UPS groups, as adjusting management practices is vital for overcoming the dynamic conditions of agro-ecosystems (Westley et al., 2013). In addition, the lowest density results were found for the ICS and MT UPS in Ilolo village (Table 9), indicating less knowledge exchange in their networks. An explanation to

these results could be related to the reported low participation and organization of group meetings.

Furthermore, the results revealed high reciprocity levels in the knowledge networks across most of the UPS groups (Table 9). Reciprocity is recognized for contributing to developing long-term obligations between people, which is important for achieving positive environmental outcomes (Platteau, 1997). In addition, high levels of reciprocity suggest strong levels of trust between actors (Schiffer & Hauck, 2010). This hypothesis is reinforced with the high levels of trust (measured with the trust influence tower) observed for group leaders, secretary, treasurer, group members, stove constructors and researchers in most of the UPS groups (Tables 9,12 and 14). Low levels of trust were usually related with actors outside the UPS such as customers, material providers and transport owners (see Annex C, D & E). These findings suggest that the relationships outside of the groups needs to be strengthened for a successful UPS implementation, as trust facilitates cooperation. Other benefits of building trust in relation to social capital and the environment have been explored in previous studies by Pretty and Ward (2001), which concluded that trust can potentially reduce transaction costs between groups and so liberates resources (no need for close intensive monitoring), as individuals are able to trust them to act as expected.

Some of the UPS groups have divided into subgroups for carrying out the group's activities such as stove construction (ICS) and machine operations (MS), as it can be observed in the groups' networks in the Figures 12 and 16. The organization of these UPS have led to development of different roles inside the groups, considered important from a management perspective. Some examples of these roles are the stove constructors and sub-group leaders in the ICS, machine operators in MS Ilakala and supervisor in MS Changarawe. In the MS UPS, groups are dived in two working teams and they shift the teams every couple of days to distribute the workload and profits. For all ICS groups, the increase in number of participants led to division of the group into sub-groups for a more effective construction of stoves. These sub-groups are not independent from each other, but they are intended to have their own leadership for having better management of construction activities. However, all group members still have regular meetings as a big group and the profits generated from the stoves construction are shared with the big group and not with the sub-group. The division into sub-groups has created confusion among participants, as some respondents do not perceive the benefits as they tend to be unorganized. In addition, different strategies for building the stoves is observed when comparing the semi-arid and sub-humid regions. For instance, in the sub-humid regions all UPS members of a sub-group (5-7 members) collectively build one stove, while in the semi-arid region tow members build one stove. Higher adoption rates are found in the semi-arid region; it can therefore be assumed that this could be one of the drivers of the difference in adoption rates between the regions. Furthermore, comparing the

cohesiveness attributes in the knowledge networks between groups in the semi-arid region differences are visible. For example, the density levels and reciprocity levels in Ilolo village are considerably lower than those in Idifu (Table 9). The high-density levels from Idifu village reflect the active commitment of the group members, proving that network density and reciprocity are important in the diffusion of the innovation in the community. The innovation success in Ilolo village could be linked to active engagement of a single stove constructor, who on his own has constructed more than half of the total stoves from the UPS group. He is a key actor for mobilizing its group on getting clients, *"I started asking them (group members) why only few members in the sub group build many stoves and others did not while we have a lot of customers. I thought they were not mobilizing even making follow-ups in the household asking clients to make stoves after that idea and advice like criticizing them, my subgroup started to work hard a little bit" (F3 ICS ILO)*. Even though he does not hold a leadership position in the group, his individual attributes position him as a potential social leader in the group and community. Furthermore, it can be inferred from his performance that his strong social ties within the community helps diffuse new ideas such as the use of improved cooking stoves (Crona et al. 2011). Hence, identifying and including social leaders in the diffusion of innovations within a community is important for a bigger UPS outreach. These scenarios are commonly discussed in the literature examining the role of social networks for diffusion (ibid).

UPS groups in the sub-humid region tend to have bigger networks and higher diversity of actors including governmental levels (Tables 9,10 and 11). Some factors influencing the presence of governmental actors could be related to the geography of the villages, as sub-villages are very distant from each other and groups need to contact diverse local authorities in the villages in order to implement the innovation. Nevertheless, these relations could be described as weak. Furthermore, all groups regardless of the region expressed they would like local authorities to be more involved in the implementation of the UPS. Governmental leaders are assumed to be influential in the promotion of the UPS inside and outside the villages. In the semi-arid region, the ICS and SUN UPS from Idifu village are the only groups where strong relations between local authorities and group members is observed. The councilor from the district was pointed to provide valuable advice with the UPS group regarding group registration and management (Figures 12 and 20). The inclusion of a big diversity of actors in this case is beneficial for the UPS sustainable implementation, as groups are exposed to new views from different perspectives and opinions (Crona & Bodin, 2006). Networks of dissimilar actors are expected to produce more creative ideas and solutions as compared to homogeneous ones (Newig et al., 2010). A study by Schneider et al. (2003), showed that facilitating the development of effective boundary ties among different actor kinds is feasible. In order to facilitate creation of these ties some key issues required for

accomplishing it include providing an arena for interaction, which would need coordination and facilitators (ibid).

A higher diversity of stakeholders with high outdegree centralities is identified in the material networks of the ICS, MS, MT and PLT UPS groups (Table 13). Some examples of these actors are: wood providers in ICS; transport owners and machine providers in MS; and feed and material providers in the PLT UPS. This diversity of actors in the networks could be considered as beneficial on the long run for the UPS groups and the communities, as research studies proved that having weak communication ties between dissimilar relations allow for flow of diverse information between actors enhancing the generation of new ideas (Prell et al., 2008). As a matter of fact, this is already happening in some groups like the ICS Idifu and Ilolo groups where important flows of knowledge from group members and leaders to wood suppliers is observed (Figure 12). The knowledge shared between these actors is related to forest conservation, i.e. which wood type is appropriate to fell for cooking and how to prevent deforestation. Furthermore, relational ties can evolve and the content of what is shared can also change with time (Bodin & Crona, 2009). For instance, the relations between group members and wood suppliers can evolve into deeper social relationships. This could facilitate the development of common norms and social values within their communities (McPherson et al., 2001) that lead to an improved natural resource management.

When making an in-depth comparison of the groups, differences in the development of the UPS is more visible. As a first remark, we can conclude that the development of the UPS groups has been independent from each other, additionally no connection between different UPS groups was found. Nonetheless, group members are aware of the potential cooperation across UPS groups. Therefore, it would be beneficial to facilitate simple platforms for interaction of different UPS members to foster collaboration, social learning and innovation in the communities (Reed et al., 2009).

7.1.2 Networks embeddedness

Among the relevant results of this study, we can observe that knowledge is highly dynamic inside the groups. Across all UPS groups it can be observed that group members, group leaders and secretaries are highly influential in the knowledge exchange. This is shown by their high indegree and outdegree centrality levels in Table 12. From a group management perspective, it is beneficial for the groups to have more than one influential actor, as there is less likelihood of decision making to become centralized (Abrahamson & Rosenkopf, 1997). The high centrality levels of group members are important for mobilizing the network and bringing different actors together (Prell et al., 2010). Moreover, previous studies held by Crona et al. (2011) concluded that high centrality levels are beneficial in times of change, when effective coordination of actors may be needed. This is especially important for the

UPS groups and their communities' livelihoods, as these regions are vulnerable to constantly changing climatic conditions.

Knowledge networks: The high centrality of the group members in all groups shows that knowledge has been evenly received in the UPS groups (Table 12). This assumption is confirmed with the results from the knowledge influence towers (Table 10), where it is observed that group members and leaders have high scores across all UPS groups. However, the narratives show that group members are concerned with acquisition of specific technical knowledge that is important for the UPS implementation. Some examples of this knowledge considered vital for the implementation include: repair and maintenance of machines (MT, MS, SUN); and chicken keeping for example treating diseases and feeding (PLT). Furthermore, the results for the group members' influence towers reflected that not all group members are equally important for the implementation in the UPS groups of MT (Table 12) and ICS in Ilolo (Table 9), PLT (Table 14) and MS (Table 12) in Changarawe. The scores for the importance influence tower in these UPS groups tended to be lower as not all members were perceived to be committed to the group activities.

The high indegree levels for the customers across all groups in the knowledge networks suggests that the UPS knowledge has reached various members in the communities. However, when comparing these results to the knowledge influence tower it is visible that only in the ICS groups customers are assumed to learn significantly from the innovations. Customers as adopters from the innovation are shown how to build the stoves, wood types and amount of wood required for cooking. All of the adopters are invited to join the groups in order to become stove constructors. In addition, in most of the ICS groups customers receive medium range trust scores as they show interest in the innovation but they lack commitment for adoption. An explanation for this result can be related to high social cohesion in the communities as it could obstruct external attempts to encourage stakeholders to question and rethink their practices (Crona & Bodin, 2006; Newman & Dale, 2005; Prell et al., 2010). Nevertheless, if bottleneck were broken, i.e. if a member of the community with high status can be convinced to adopt a new view or practice, strong social ties can help to diffuse new ideas as well as the adoption process (Katz & Lazardsfeld, 1955; Rogers Everett, 1995; Valente, 1996; Valente & Davis, 1999). The results for the researchers' role revealed that they are still important actors in the knowledge and material propagation in all groups. Researchers are assumed to be highly influential for the implementation of the UPS, as in all groups they were rated with the maximum scores for the importance and trust influence towers. The high levels of outdegree presented in all networks for the researchers were expected at this stage of the project, as the UPS groups are still receiving important information, trainings and materials regarding the innovations from them. However, researchers are also assumed to learn, from the communities implementing the UPS.

Furthermore, the results also revealed that overall in the sub-humid region researchers have higher betweenness levels regarding knowledge when compared to the semi-arid region. While in the material networks, researchers in the semi-arid region have higher betweenness levels when compared to the sub-humid region. The high betweenness levels for the researchers can be negative for the sustainability of the UPS in the long run, as groups are dependent on them when it comes to relating with important actors' source of knowledge, services and materials for the UPS implementation.

The UPS groups with the lowest betweenness in the knowledge and materials flows is in the ICS Idifu and Changarawe, and PYR Ilakala. Low betweenness values can be considered as beneficial from knowledge development perspective as knowledge is equally available for everyone. Moreover, when we find low betweenness and low density in the network there is a big chance for the actors in the network to assist in generating new ideas (Gloor, 2006). An example of this theory in this study is the ICS group from Idifu, which is assumed to have one of the lowest betweenness levels and high centrality levels for a large number of actors. The network relations have enhanced the innovation adoption in the village as well as generation of some novel ideas in the group regarding improvements for the stove construction and ecosystem protection.

Interesting results is observed for the group leaders, as they hold high betweenness centrality levels in the knowledge flows regardless of the agro-climatic region. Their high influence suggest that they are key actors for the UPS implementation. Through their brokering position, group leaders have a high potential to pick up information and trends from a number of different actors that can be introduced to the UPS groups. Nevertheless, their influence in the groups is assumed to be limited as there is lack of knowledge regarding the tasks they are supposed to perform as leaders. In addition, the results for the importance influence towers and the qualitative discussions, revealed that secretaries are usually perceived as more influential for the UPS implementation than group leaders, as they have acquired knowledge that is important for the group management such as record keeping which is important in the management of their groups.

Materials networks: The results of this study also revealed that group members are assumed to be highly influential in the material flows of the UPS and their communities, as they receive the highest amount of materials in the networks and have the highest betweenness levels in all groups. Actors' holding high betweenness centrality are important for long-term resource management planning. These actors perform a broker role of bridging together disconnected segments of the network, thus bringing diversity and new ideas to the network (Bodin et al., 2006; Brass, 1992; Prell, 2003). The influential position of the group members defines them as change agents in natural resource management on shifting to more sustainable practices in their communities (Olsson et al., 2006). In addition, group leaders also hold high

betweenness levels in the material flows in some of the UPS groups as they are in charge of keeping the tools and making them available to group members when needed.

In the particular case of the materials network of ICS Ilakala, customers have a high betweenness degree, as they are in charge of buying bricks for stove construction and the husk for the soil mixture. This is a limitation for the groups operation as customers are not always willing to get materials necessary for the construction. It can be inferred from the results that the knowledge flow is somehow related to the availability and management of natural resources. This assumption can be explained with a couple of examples. Firstly, the participants form the semi-arid region recognize the importance of the research field assistant in the UPS implementation as he provides knowledge to farmers regarding improved farming practices. Secondly, there are more ties to the material and wood suppliers in the ICS groups from the semi-arid region as group members and leaders share with them knowledge about ecosystem conservation.

Money networks: The results from the study revealed a clear connection between the money and materials networks. Overall, it is observed that the UPS implementation stimulates the money flows inside the communities. Treasurers have an influential role in the money networks, which is reflected on their high betweenness levels in most of the groups. Thus, it can be assumed that they are acting according to their roles. Nevertheless, group leaders influence on the UPS implementation is perceived as limited as they are only in charge of keeping money for the groups. Group members expressed they expect more involvement from them in the group management tasks.

The UPS groups having more participation of actors in the money networks are the PLT, MS and ICS. When comparing the money networks to the income influence towers we can observe that the actors perceived to have the highest incomes from the implementation are also found in the same UPS. These actors are: group members (ICS, MS, and PLT), stove constructors (ICS), customers (PLT and MS), material providers (MS, ICS, PLT), wood sellers (ICS), laborers (MS Ilakala) and transport owners (MS Ilakala). However, the income scale is different between the groups i.e. for the group members the income generated from the ICS construction is lower than when participating in the MS activities where group members reported that they can get money having a full-time job.

Overall, we can say that these results reflect characteristics of a decentralized knowledge networks, which is important for the UPS implementation the long term (Crona & Bodin, 2006). Centralized networks can be beneficial in an initial face of forming groups and building support for collective action (Crona & Bodin, 2006; Olsson et al., 2004).

7.2 UPS Groups' motivations to participate in the implementation of the innovations

When analyzing the motivations of the actors to participate in the different UPS, we can observe a relation between motivations and important capital assets in a community, group and individual levels. Furthermore, the motivations have to be taken into account for improving management and performance of the UPS groups (Freeman, 1984).

The study revealed that the motivations for participating in a UPS group differ to some extent between all UPS groups and all types of actors, whereby *improved social relations* and *more knowledge* were the most frequently mentioned for the group members followed by enhancing *food availability, more income* and *better reputation* These motivations overall are related to the impacts they are expecting in their livelihoods through their participation in the UPS groups. The results from the motivations of the group members revealed some patterns drawn across all groups, same UPS groups and between regions.

Social relations: Firstly, we can observe that *better social relations* are frequently important for all UPS participants. These findings are consistent with those of Misra et al. (2014), who studied the importance of social relations for the rural poor as a vital part of their survival strategies. Through social relations small farmers are able to cope with diverse challenges that threaten their livelihoods. The UPS groups are a platform for the small farmers to interact with one another. Regular interaction allows them to gradually build up their networks through these ties (Jana & Chaudhuri, 2013). Moreover, increasing the social capital in the groups bring lots of benefits that result in mutual support, collective representation and recognition. For instance, all UPS groups took the initiative to be registered in order to have legal recognition. This allows them to have better access to financial support as it is better for getting loans and grants.

Knowledge and enhanced food security: Secondly, from a regional comparison the results show that knowledge is overall the most frequent motivation in the semi-arid region, while enhance food security is in the sub-humid. These findings suggest that for participants in the sub-humid region direct impacts on natural assets resulting in improved food security are highly important. While in the semi-arid region, knowledge in regard to their livelihood systems is highly important. Through this knowledge, group members can develop skills that allow them to enhance their livelihood strategies, resulting in more diverse livelihood outcomes including *improved food security, more income* and *reduced vulnerability*. These results are consistent with the studies of Reed (2008), who found that connecting local knowledge and scientific knowledge provides a more comprehensive understanding of complex and dynamic systems and processes. Thus, producing more relevant and effective practices for enhancing participants' livelihood outcomes. Knowledge increases the human

capital of the participants in the groups. In this line, recent research proved that both social and human capital is indispensable for the implementation of sustainable natural resource practices (Pretty & Ward, 2001). UPS groups are platforms where individuals can work together to increase their knowledge and skills, their leadership capacity and their motivation to act (ibid). Moreover, knowledge and social learning is important as societies tend to become reflexive towards risk management, including environmental, in the constant changing context (Blackmore, 2007).

More Income: Thirdly, we can observe that income is a highly frequent motivation in the improved processing groups (MT and MS) and the poultry crop integration group (PLT). As aforementioned in last chapter, group members can afford more quantity and more diverse food through the income earned from their group activities. This is particularly important in the semi-arid region, as the region is more prone to long droughts and money allows members to buy food in the off-season. In addition, participants expressed their intention to send their children to school and cultivate larger fields with their income. These results suggest that increasing the financial capital of participants' results in larger impacts and diversification of their livelihoods strategies.

Furthermore, comparing the results from this study with those of Schindler et al. (2016), we can observe that there are similar links between the motivations of actors and the impacts on food security perceived from the UPS. In most of the cases the correlation is positive. For instance, the MS group from Changarawe reported that the three highest expected implementation impacts were firstly social (social relations, food diversity, working conditions, agronomic knowledge), second economic (market participation, yield, income) and third environmental (agro diversity, soil fertility, water availability). The four most important motivations for the group members were *better social relations, more income, enhanced food availability* and *more knowledge*. These results provide confirmatory evidence that the motivations and expected impacts are aligned in the UPS.

The study revealed that group leaders assumed motivations do not differ considerably across the different UPS groups. This includes *better reputation* in their communities, improving their *social relations* and receiving more *knowledge*. Furthermore, these motivations are also highly frequent for the secretaries and treasurers. The motivations of group leaders to receive more knowledge reveals the interest for the groups' leadership to improve their managerial skills.

Analyzing the motivations for the researchers is important as it provides insights on how participants perceive the goals of the project. Across all UPS groups, the results revealed that the most frequently assumed motivations for the researchers are *more knowledge* (for the group members and themselves), *improved social relations* (for themselves) and *more joy* (they want group members to be happy). Moreover, the results did not show *improved*

food security as a frequent motivation for the researchers. However, through the knowledge received from researchers participants enhance their livelihoods strategies, which results in better livelihoods outcomes including *improved food security*. These results revealed there is a possibility that the main goal of the project is not clearly perceived from the participants.

7.3 Perceived impacts on food security, livelihoods and possible success factors for sustainable UPS adoption

The Sustainable Livelihoods Framework clearly draws a connection between the UPS implementation and its impacts on the livelihoods of the participants, as its integration in their livelihoods strategies. Starting with the illustration of the vulnerability context and important factors affecting the success of the UPS. Followed by the description of the improvements in the livelihood assets (social capital, human capital, natural capital, physical capital and financial capital), strategies and livelihood outcomes. This study revealed that the food security impacts and success factors vary according to the UPS type, and stage of implementation. Moreover, some of these factors are linked to the particular climate vulnerability context such as climate shocks (droughts and floods), deaths in the family, seasonality, technology and markets among others. "*Capacity building to better cope with constrains and opportunities of the climate variability must be enhanced in order to adapt and predict the future increase in climate variability is vital for the communities in the SSA region (Cooper et al., 2008)"*. The droughts and floods in the region partially paralyze the activities of the groups as farming still remains a priority for food source *"Climate destroyed everything even the maize, so there was no time to think about the group" (FDG MS CHA).*

Impacts on food security as part of the improved livelihoods outcomes are visible in the UPS groups that have started to work properly such as ICS and MS. However, the groups that have not yet started with their activities are also expecting impacts on their food security. Moreover, the results from the study revealed that groups with the highest impacts on food availability, measured by the influence food towers of group members are the MS from Ilakala followed by the PLT Changarawe (Tables 18 and 20). Overall, the impacts on food security reported by the UPS groups can be divided into 3 main categories: quality, amount and diversity of food.

a) Quality of food: ICS groups reported that the food cooked in their stoves has less sand and smoke, which improves the health of the family. Also, group members from the millet and maize sheller UPS mentioned that using the machine for processing their seeds has big benefits on their health as it keeps food clean and food is not mixed with sand from the ground.

b) Amount: The time saved in looking for wood and cooking allows the UPS members from the ICS to expand their fields or carryout other activities that allows them to earn money to buy food. Members of the MS and MT UPS reported that with the money they earn from the group activities they are able to purchase more food that is diverse. Moreover, members from this group are also planning to individually and as a group expand their fields. PYR members expect to have better yields on their vegetable gardens after they have incorporated the ashes from the maize cobs pyrolysis to the soil.

c) Diversity: The income earned by the group members allows them to purchase more diverse food such as vegetables or meat. In addition, PLT group members mentioned to have a constant source of food when they raise chickens as they consume the meat and the eggs from it. Also, the income earned from selling the chickens is invested in raising more chicks or/and buying more food.

This study revealed that some of the factors positively affecting the development and sustainability of the UPS groups are: the enhancement of the social and human capital (such as knowledge and education) of the participants, more time for their families and personal business, better working conditions, better health and access to financial assets among others. Furthermore, comparing these factors with the results from the impact assessment of Schindler et al. (2016) we can observe a positive correlation with the results from this study. For instance, in the improved cooking stoves in Idifu the highest positive impacts were; working conditions, social relations and income. In our study respondents expressed that since they are using the stoves they are able to improve the health of their households (human capital), share more quality time with their families (social capital), get extra income from the construction of the stoves and save money buying wood (financial capital). With the stoves farmers can invest more time in their fields or in activities that allow them to get extra income. A participant having a small general shop in the village reported *“For that I am thankful, because when I put my beans in the stove I don’t have to worry about them, and I can focus on my activities to attend to customers” (FDG ICS ILA).*

In addition, ICS Idifu participants recognized the potential of having more adopters as it can reduce high deforestation rates in the area. The protection of forest ecosystems presents positive impacts in the livelihoods of the communities as it benefits the diverse natural capital such as biomass production and improved watershed functions. One of the factors limiting the participation of group members in the construction of the stoves is the physical condition, as women and the elderly are usually relegated from the construction activities. "*Mixing the soil and water for the stoves construction is very laborious and risky "*, a woman reported in the ICS FGD in Ilolo. However, women play a significant role in the diffusion of the innovation, as they have a big influence on the household decision of adopting the technology. Other challenges are related to the climate conditions, as group members from the sub-humid region reported that the dry materials are hard to find during the rainy season. Money is another limiting factor in some cases for the adoption of the innovation in the communities. "*Because of the economic situation in the village people cannot afford to pay for the stoves" (FDG ICS ILA)*. Related to this is the fact customers in the region usually have to invest on building external roofs to protect the stoves from the rain.

Overall, groups concede that the project provides them with valuable knowledge that improves their livelihoods (human capital). Moreover, through their participation in the UPS they have strengthened their social relations within their communities. *"I am a construction expert now; I can educate people about the technology" (F1 ICS CHA)*. Also, UPS groups are important for the participants as they can exchange ideas and skills together. *"The ideas we get here are very different than if I stay at home" (FDG MS CHA).* Other benefits of being recognized as a group as mentioned before are related to the possibilities of the groups to open bank accounts, get loans and grants from the government that may not available for individuals. Furthermore, the majority of the UPS group reported that after getting a loan they can invest it in cultivating fields together or in animal husbandry thus, enhancing their food security.

Furthermore, group members consider it very important to receive more trainings regarding marketing in order to have a successful outreach in their communities and regions (Tables 11 & 13). Regularly the decision of adopting or not adopting an innovation depends on the benefits of the adoption. In a rural context, social interaction is important in the diffusion process, according to Feder and Slade (1985), the dynamics of the diffusion process depend on horizontal process among farmers, however opinion leaders are a good source of new information and advices. In addition, from a social perspective the position of the farmer in the community's social network determines how they can access the information in the use of knowledge and technology (Isaac et al., 2007).

In the case of the MS and MT groups, important success factors of the UPS groups are the improved working conditions, the improved quality of the food and the income. *"From the*

machine, you will get work… and money to save the family" (FDG MT IDI). Furthermore, as mentioned before technical knowledge is vital for the implementation of the groups such as MT, MS, PYR, and SUN. Knowledge about repair and maintenance is essential, as it represents a potentially high expense that groups might not be able to afford. Other types of knowledge important for these groups is related to the development of entrepreneurial skills that leads to better performance of the group. "*We need business knowledge because the machine is for business. For us the group members the first thing to learn is business. In addition, use of machine is not bad; this machine does not show oil. It has many hours grease you can see after how many times it has to be there so as to put grease again …" (F5 MS CHA).* The role of entrepreneurs has been studied and it is recognized to play a significant role in the structural transformation of economies especially in developing countries, including less developed countries in Sub-Saharan Africa (Naudé, 2010).

Specifically, for the PYR UPS more training about the use of the technology and definition of group goals is needed. Moreover, the large number of dropouts is related to the geography of the region and the fact that there is no income generated from the groups´ activities. *"People live far, and some members are just lazy to come for meetings… people say that unless they have pyroliser in their sub-village they will join" (FDG PYR ILA); "As the group is not generating any income a lot of members have droped out" (FDG PYR ILA).* Geography is an important factor altering the diffusion and adoption of the innovation within the village. Recent studies held by Isaac et al. (2007), indicate that geographic proximity allowed knowledge sharing through observation and promotion of discussions which results in higher possibilities of adoption. Therefore, different strategies are needed for its diffusion. Transportation for the MS and MT groups is the biggest challenge the groups are facing. The situations are different in both regions, in the semi-arid region the machines can be transported with the help of animals such as ox, while in the sub-humid region a power tiller or tractor is needed for the reason of geography of the villages and technical characteristics of the machines. Hiring transportation was reported to be challenging, as there are not many people providing the service and at the same time a big expense. However, the group of MS Ilakala has overcome this challenge. Group members have been active throughout the harvesting seasons and they were able to rent a tractor to move the machine between the customers' fields. *"The highest percentage of the earnings from the groups' activities goes to the transport that's why we haven't finished paying for the machine loan" (FDG MS ILA).*

The narratives also revealed that the improvement of the UPS groups' organizational skills is considered important for the sustainability of the groups, especially for the leadership of the groups. *"We need training about leadership responsibilities, to determine the tasks for the different roles… now we (the leaders) are doing things randomly… we need these skills" (F4 ICS ILA).* The integration organizational skills and local knowledge in all of the UPS groups is

fundamental during the built-up during planning and implementation. Different studies have proved that when these elements are integrated groups are more likely to sustain their activities after the project completion (Pretty, 1991; Pretty et al., 1995; Uphoff et al.,1998; Pretty & Ward, 2001).

The results of this study also reflect the many factors that impact the success of the PLT group. The first is the high cost of chicken keeping. Many UPS members are not able to build a coop and fodder and medicines are expensive, therefore they are not active in the group. Moreover, the dependence of the group members on the researchers in getting small chicks and clients limits the independence of the group. In addition, other obstacles in the implementation is miscommunication with the small chick providers, and the chicken breed. The chicks which they were offered did not match the local market expectations, hence it was hard to commercialize the chickens inside the villages.

7.4 Methodological features and implications

The use of Net-Map in combination with the FGDs turned out to be great complementary tools for this kind of participatory action research (PAR). This approach enabled drawing a picture of the current status of each UPS group in terms of knowledge generated and the avenues of how it is co-created, while increasing the ability of participants to understand their roles in the social networks which can lead them to improve their capacities (Greenwood & Levin, 2007). In this regard, the participatory methods used in this research were important as knowledge generated in the sessions led to better understanding on the livelihoods situations that enables these communities to mobilize their diverse and complex resources as fully as possible (ibid).

Discussing the social networks outcomes with the group members was important for clarifying relations among actors that are not equally perceived by all participants. In addition, through the visualization of the links between relevant actors in the UPS implementation, participants were able to learn more about the structure of their groups while recognizing their strengths and limitations in the social network. FGDs were an important platform for discussing the potential relations that groups could build or enhance that would result in great benefits for the UPS implementation. In PAR, the collaborative work enables the creation of a better picture for all participants as they *"grow to appreciate how their interrelatedness created power greater than the sum of individual powers (Kasl & Yorks, 2002)*".

The qualitative data from the narratives was of relevant importance for the interpretation of the centralities of the actors as the measures by their own could be misleading (Schiffer &

Hauck, 2010). This allowed a more realistic interpretation of the current state of the social relations of the rural livelihoods of the participants.

The visualization of the networks has been pointed out as critical for the improvement of the social network capabilities for small farmers (Douthwaite et al., 2006). In the Net-Map sessions, it was evident that it was easier for respondents to find the links between actors when having visual aid of the map. For the participants that were not able to read, the use of icons to represent actors was a key element in the sessions for keeping them engaged through the session. Furthermore, the use of interactive elements such as the motivation cards and the wood towers was well received by the participants as it gave the session a different dynamic which most of the time was good.

The individual sessions allowed the participants both men and women to express their personal perspectives of who the important and influential actors in the implementation of the UPS were (Jakobsen, 2012). However, some respondents considered that the questions were challenging, as they required a lot of abstract thinking. *"These questions are challenging" (F6 MT IDI).* For the groups having large networks the sessions tended to be more complicated, as the activity required more time and participants found it tiring. This study revealed that participants tend to loss interest and concentration after one hour of session. Another limitation of the tool was the inability of some interviewees to talk about other actors' relation on which they are not directly involved.

Some important considerations at the start of the session were to properly explain the procedure and the tool. Furthermore, in order to create stronger engagement of the interviewees it was important to explain the value of how their participation in the session will bring to their livelihoods, the research, and the expected outcomes from the research. This approached helped overcome the feeling of "being at school"; they felt more comfortable sharing their views as they felt they were contributing in a meaningful way to the project. In a PAR, in order to comprehend the complexity of the local situations and the role of knowledge in everyday life, is important to respect what people think and want (Brydon-Miller et al., 2003).

The participation of the local translators as moderators was important in the FGDs, for creating a more empathetic atmosphere. In addition, the constant involvement of the moderator in the discussions resulted in a livelier participation of more group members. However, some challenges in the FGDs were the constant participation of group leaders that were the majority men. Thus, woman and other group members had to be constantly encouraged to participate in the discussions. A possible explanation for these might have been related to the presence of researchers as it might have caused the participants to be hesitant and intimidated in expressing their personal views (Jakobsen, 2012).

8. Conclusions and Recommendations

This study presents an analysis of the social networks of different UPS groups in four villages in rural Tanzania. Through the use of the Net-Map tool and FGD, it was possible to describe the structures of the UPS groups, revealing who are the perceived important actors for the implementation of the innovations from a farmers' perspective. The social network analysis displayed a clear picture of how these groups are developing, which is important for implementing an evaluating the performance of the UPS groups. The integration of the narratives on the analysis was important as the centrality measures by their own could be misleading. Furthermore, the results of the study show how participants integrate the UPS as part of their livelihoods strategies and their impacts on their food security and other livelihoods outcomes such as more income, improved wellbeing (improved health and better working conditions) and more sustainable use of natural resources (wood harvesting). The social networks were Net-Mapped for the knowledge, materials and money flows for all of the groups, including a description of the motivations for participants taking part in the UPS implementation.

Findings demonstrate how network structures influence the knowledge, materials and money flows in the UPS. The groups have developed different network structures between the different UPS, villages and regions. Furthermore, no connection between different UPS groups was found. However, group members are aware of the potential benefits of relating and cooperating with other UPS groups. Therefore, it is recommended to integrate platforms that facilitate interaction across them.

The diversity of actors identified and the size of the social networks depend on different factors such as implementation stage, type of knowledge and materials necessary for the UPS implementation. The more advanced the implementation stage the stronger the ties and the more diverse the role of actors are. Having a bigger diversity of actors is important for enhancing the development and propagation of UPS related ideas and material exchange that benefits the livelihoods of the stakeholders' communities. Moreover, the connections with actors outside of the groups are recognized as important as the communication ties which are central in the innovation diffusion process.

Furthermore, the networks' structures revealed the possible bottlenecks within the UPS groups that could potentially hinder the flow of resources, such as the dependence of group members on researchers to contact technicians for the repair and training on the machines operation. Interestingly the UPS groups have also developed different roles and structures inside the groups in order to manage and facilitate the implementation of the innovations for example machine operators and supervisors in the MS groups. Overall, the results from the

network structures did not present centralization in the relations of knowledge, which is good for the management and sustainability of the groups.

The results indicated high-density network levels for the knowledge flows in almost all groups. It can be assumed that is was the high levels of trust among actor group that positively influenced the development of the networks. The results from the centralities of group members showed that knowledge is highly dynamic in the UPS groups as actors are actively receiving and providing knowledge inside and outside the groups. Another interesting result from the study is that knowledge flows is somehow related to the availability of natural resources, as stronger ties with members outside of the groups were visible in the semi-arid region. This was usually used to share information regarding natural resource management.

UPS group members in all networks show an important active participation in the different relations (knowledge, materials and money flows), which are reflected by their high centrality levels reflecting cooperation and engagement inside the groups. Researchers are still important actors for the UPS implementation in most of the groups, as they provide trainings and materials for the innovations. UPS groups having implemented the innovation for a longer time, a lower influence of researchers in their networks is observed as it is the case of ICS Idifu and MS Ilakala. Moreover, the performance of group leaders in general is considered limited as they lack managerial skills. To enhance the sustainability and performance of the UPS groups it is advised to build capacities for group management through effective leadership, marketing strategies and creating direct linkages between UPS groups and service and material suppliers.

Relations between the groups and governmental authorities were found. However, these ties can be described as most of the time weak. Therefore, it is recommended to strengthen the ties between local governmental authorities and the UPS groups' networks, as well as identify the benefits for the diffusion of the innovations. Moreover, for increasing the diffusion and promotion of the innovation it is further required to improve communication regarding benefits of the innovations adoption at households and community levels within the CSS. In this line, identifying and enrolling community leaders in the adoption of the technology can be beneficial for the outreach of the innovation

Some of the most frequent motivations for the group members to participate in the project were; *more knowledge, improved social relations, enhancing food availability, more income* and *more joy*. It is important to recognize the motivations of the actors in order to improve the management and performance of the UPS groups. Overall, participants feel joyful when participating in the group's activities. Enhancing the social capital of the farmers is of vital importance as it provides mutual support collective representation and recognition inside their communities. Knowledge and income increases the human and financial capital, and it

is important for participants as it allows the diversification of their current livelihood strategies. Income was also recognized to be important for the participants as they have bigger possibilities to send their children to school. The motivation of *enhancing food security* of the participants' households is an important indicator that the goals of the project and the participants are aligned.

The SNA helps align connection between the implementation of the UPS and the impacts in the livelihoods assets of the participants as individuals, groups and communities. Furthermore, it is clear that these factors are linked to the vulnerability context of the communities such as climate shocks, deaths in the family and seasonality. Groups like the ICS, MS and PLT have started to experience impacts on their food security. These impacts are related to the quality, amount and diversity of food. Other important identified success factors are enhancement of social and human capital of participants, improved working conditions, improved health, more time for their families, farming and personal business and access to financial assets among others. While limiting factors in the UPS groups are related to the weak organizational skills of leaders in all groups, limited knowledge and expenses related to the repair and maintenance of the machines (SUN, MS, MT), physical condition of participants (ICS), high cost of building coops and keeping chickens (PLT) among others. Internal or external assessment of the groups in the framework of PAR is important for the development of the UPS as group members show their concern. It is vital to build these skills that allow UPS groups to have a better picture of their performance. Moreover, in the especial case of the ICS groups it is important to understand and explore collaborative approaches that integrate the equal participation of women and men in the UPS implementation.

Findings presented in this study were possible due to the active stakeholder involvement in the social network mapping, the narratives were vital for interpreting data describing the networks of UPS groups. The results of this study help to understand relevant stakeholder management and stakeholder processes in fostering the sustainability of the UPS groups and enhancement of its capacities for self-management. Social networks evolve with time; therefore, it is expected that the structural characteristics of the UPS groups presented in this study will change over time and require being revisited. For future Net-Maps and FGD´s, it is recommended to engage participants in leading the sessions for example letting them explain the maps to their peers and less interaction of researchers. In addition, it would be interesting to organize discussions for women and men separately, in order to explore the different outcomes of the perspectives of both genders.

The use of the Net-Map tool is highly recommended in projects related to resource management and innovations diffusion for understanding the role of social networks in these processes from a stakeholder's perspective. Moreover, I encourage research studies that

explore the attributes of the social structures that enhance cooperation and collective action in rural communities.

References

AbdulRahim, M., Shehu, D., Mensah, S. A., Hartemink, A. E., Ruf, F., Uprety, K., . . . Johnston, P. (2008). *Experts address the question:"What are the most important constraints to achieving food security in various parts of Africa?".* Paper presented at the Natural Resources Forum.

Abrahamson, E., & Rosenkopf, L. (1997). Social network effects on the extent of innovation diffusion: A computer simulation. *Organization science, 8*(3), 289-309.

Adekunle, A., & Fatunbi, A. (2012). Approaches for setting-up multi-stakeholder platforms for agricultural research and development. *World Applied Sciences Journal, 16*(7), 981-988.

Adger, W. N. (2003). Social capital, collective action, and adaptation to climate change. *Economic geography, 79*(4), 387-404.

Arndt, C., Farmer, W., Strzepek, K., & Thurlow, J. (2012). Climate Change, Agriculture and Food Security in Tanzania. *Review of Development Economics, 16*(3), 378-393. doi:10.1111/j.1467-9361.2012.00669.x

Arslan, A., Belotti, F., & Lipper, L. (2017). Smallholder productivity and weather shocks: Adoption and impact of widely promoted agricultural practices in Tanzania. *Food Policy, 69*, 68-81. doi:https://doi.org/10.1016/j.foodpol.2017.03.005

Arun, S., Heeks, R., & Morgan, S. (2004). Researching ICT-based enterprise for women in developing countries: A livelihoods perspective.

Ayuku, D., Odero, W., Kaplan, C., De Bruyn, R., & De Vries, M. (2003). Social network analysis for health and social interventions among Kenyan scavenging street children. *Health policy and planning, 18*(1), 109-118.

Bandura, A. (1986). Social foundation of thought and action: A social-cognitive view. *Englewood Cliffs*.

Bank, T. W. (2015). Tanzania overview. Retrieved 15 January 2017 http://www.worldbank.org/en/country/tanzania/overview

Barrett, C. B. (2008). Smallholder market participation: Concepts and evidence from eastern and southern Africa. *Food Policy, 33*(4), 299-317. doi:https://doi.org/10.1016/j.foodpol.2007.10.005

Barrios, S., Ouattara, B., & Strobl, E. (2008). The impact of climatic change on agricultural production: Is it different for Africa? *Food Policy, 33*(4), 287-298.

Battisti, D. S., & Naylor, R. L. (2009). Historical warnings of future food insecurity with unprecedented seasonal heat. *Science, 323*(5911), 240-244.

Bodin, Ö., Crona, B., & Ernstson, H. (2006). Social networks in natural resource management: what is there to learn from a structural perspective? *Ecology and Society, 11*(2).

Bodin, Ö., & Crona, B. I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global environmental change, 19*(3), 366-374.

Borgatti, S. P., & Foster, P. C. (2003). The network paradigm in organizational research: A review and typology. *Journal of management, 29*(6), 991-1013.

Brass, D. J. (1992). Power in organizations: A social network perspective. *Research in politics and society, 4*(1), 295-323.

Brydon-Miller, M., Greenwood, D., & Maguire, P. (2003). Why action research? : Sage Publications.

Burchi, F., & De Muro, P. (2016). From food availability to nutritional capabilities: Advancing food security analysis. *Food Policy, 60*, 10-19. doi:https://doi.org/10.1016/j.foodpol.2015.03.008

Burt, R. S. (2004). Structural holes and good ideas. *American journal of sociology, 110*(2), 349-399.
Chambers, R., & Conway, G. (1992). *Sustainable rural livelihoods: practical concepts for the 21st century*: Institute of Development Studies (UK).
Chung, K., Haddad, L., Ramakrishna, J., & Riely, F. (1997). Identifying the food insecure: The application of mixed method approaches in India. International Food Policy Research Institute, Washington, DC, USA. *Washington, DC, USA*.
Chung, K. S. K., & Crawford, L. (2016). The Role of Social Networks Theory and Methodology for Project Stakeholder Management. *Procedia-Social and Behavioral Sciences, 226*, 372-380.
Coleman, J. (1990). Foundations of Social Theory. Cambridge, Mass.: Belknap Press of Harvard University Press.
Collier, P., & Dercon, S. (2014). African Agriculture in 50 Years: Smallholders in a Rapidly Changing World? *World Development, 63*, 92-101. doi:https://doi.org/10.1016/j.worlddev.2013.10.001
Conceição, P., Levine, S., Lipton, M., & Warren-Rodríguez, A. (2016). Toward a food secure future: Ensuring food security for sustainable human development in Sub-Saharan Africa. *Food Policy, 60*, 1-9.
Conway, G. (1998). *The doubly green revolution: food for all in the twenty-first century*: Cornell University Press.
Cooper, P. J. M., Dimes, J., Rao, K. P. C., Shapiro, B., Shiferaw, B., & Twomlow, S. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems & Environment, 126*(1), 24-35. doi:https://doi.org/10.1016/j.agee.2008.01.007
Crona, B., & Bodin, Ö. (2006). What you know is who you know? Communication patterns among resource users as a prerequisite for co-management. *Ecology and Society, 11*(2).
Crona, B., Ernstson, H., Prell, C., Reed, M., & Hubacek, K. (2011). Combining social network approaches with social theories to improve understanding of natural resource governance. *Social networks and natural resource management: Uncovering the social fabric of environmental governance*, 44-71.
Cross, R. L., & Parker, A. (2004). *The hidden power of social networks: Understanding how work really gets done in organizations*: Harvard Business Review Press.
Devereux, S. (2006). Desk Review: Distinguishing between Chronic and Transitory Food Insecurity in Emergency Need Assessments. *Rome: SENAC/WFP*.
Devereux, S. (2016). Social protection for enhanced food security in sub-Saharan Africa. *Food Policy, 60*, 52-62. doi:https://doi.org/10.1016/j.foodpol.2015.03.009
Djalante, R., Holley, C., Thomalla, F., & Carnegie, M. (2013). Pathways for adaptive and integrated disaster resilience. *Natural Hazards, 69*(3), 2105-2135.
Douthwaite, B., Carvajal, A., Alvarez, S., Claros, E., & Hernández, L. A. (2006). Building farmers' capacities for networking (Part I): Strengthening rural groups in Colombia through network analysis. *Knowledge Management for Development Journal, 2*(2).
Ellis, F. (2000). *Rural livelihoods and diversity in developing countries*: Oxford university press.
Ellis, K., & Keane, J. (2008). *A review of Ethical Standards and labels: is there a gap in the market for a new'Good for Development'label?* : Overseas Development Institute.
Emirbayer, M., & Goodwin, J. (1994). Network analysis, culture, and the problem of agency. *American journal of sociology, 99*(6), 1411-1454.
FAO. (2008). Introduction to the Basic Concepts of Food Security. *Food Security Information for Action, Rome*.
FAO. (2009). *Declaration of the world summit on food security*. Retrieved from Rome:
FAO, & IFAD. (2014). WFP (2014) The state of food insecurity in the world 2014: strengthening the enabling environment for food security and nutrition. *FAO, Rome*.

FAO, IFAD, & WFP. (2015). *The State of Food Insecurity in the World 2015.* Retrieved from Rome:
FAOStat. (2014). United Republic of Tanzania. Retrieved 12 January 2017 http://faostat3.fao.org/browse/area/215/E
Feder, G., & Slade, R. (1985). The role of public policy in the diffusion of improved agricultural technology. *American Journal of Agricultural Economics, 67*(2), 423-428.
Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., . . . West, P. C. (2011). Solutions for a cultivated planet. *Nature, 478*(7369), 337-342.
Freeman, L. C. (1978). Centrality in social networks conceptual clarification. *Social networks, 1*(3), 215-239.
Freeman, R. E. (1984). *Strategic management: A stakeholder approach*: New York: Basic Books.
Friedkin, N. E. (1998). *A structural theory of social influence* (Vol. 13): Cambridge University Press.
Frija, A., Zaatra, A., Frija, I., & AbdelHafidh, H. (2017). Mapping Social Networks for Performance Evaluation of Irrigation Water Management in Dry Areas. *Environmental Modeling & Assessment, 22*(2), 147-158. doi:10.1007/s10666-016-9527-1
Gasparatos, A., von Maltitz, G. P., Johnson, F. X., Lee, L., Mathai, M., Puppim de Oliveira, J. A., & Willis, K. J. (2015). Biofuels in sub-Sahara Africa: Drivers, impacts and priority policy areas. *Renewable and Sustainable Energy Reviews, 45*, 879-901. doi:https://doi.org/10.1016/j.rser.2015.02.006
Gloor, P. A. (2006). *Swarm creativity: Competitive advantage through collaborative innovation networks*: Oxford University Press.
Graef, F., Schneider, I., Fasse, A., Germer, J. U., Gevorgyan, E., Haule, F., . . . Yustas, Y. M. (2015). Assessment of Upgrading Strategies to Improve Regional Food Systems in Tanzania. *Outlook on Agriculture, 44*(3), 179-186. doi:doi:10.5367/oa.2015.0209
Graef, F., Sieber, S., Mutabazi, K., Asch, F., Biesalski, H., Bitegeko, J., . . . Elly, N. (2014). Framework for participatory food security research in rural food value chains. *Global Food Security, 3*(1), 8-15.
Granovetter, M. S. (1973). The strength of weak ties. *American journal of sociology, 78*(6), 1360-1380.
Greenwood, D. J., & Levin, M. (2007). Introduction to action research, 2. *Aufl., Thousand Oaks et al*.
Hauck, J., & Schiffer, E. (2012). Between intuition and indicators–Using Net-Map for visual and qualitative social network analysis. *Knoten Und Kanten 2.0. Soziale Netzwerkanalyse in Der Medienforschung Und Der Kulturanthropologie*, 231-257.
Hauck, J., Schmidt, J., & Werner, A. (2016). Using social network analysis to identify key stakeholders in agricultural biodiversity governance and related land-use decisions at regional and local level. *Ecology and Society, 21*(2).
Hernandez, E. (2016). *IMPACT ASSESSMENT OF UPGRADING STRATEGIES FOR FOOD SECURITY: CASE STUDY TANZANIA.* (Erasmus Mundus International Master of Science in Rural Development Master's Thesis), Humboldt University of Berlin, Ghent University, Agrocampus Ouest, Slovak University of Agriculture in Nitra, University of Pisa.
Höhne, M. (2015). *A participatory situation analysis of Tanzanian smallholder farming systems: Identifying points of entry for innovation from the farmer's perspective.* (Master's Thesis), German Institute for Tropical and Subtropical Agriculture (DITSL), Kassel, Germany.
Ikelle, I. I., & Ivoms, O. S. P. (2014). Determination of the Heating Ability of Coal and Corn Cob Briquettes. *IOSR Journal of Applied Chemistry, 7*(2), 77-82.
Iram, U., & Butt, M. S. (2004). Determinants of household food security: An empirical analysis for Pakistan. *International Journal of Social Economics, 31*(8), 753-766. doi:10.1108/03068290410546011

Isaac, M., Erickson, B., Quashie-Sam, S., & Timmer, V. (2007). Transfer of knowledge on agroforestry management practices: the structure of farmer advice networks. *Ecology and Society, 12*(2).
Jakobsen, H. (2012). Focus groups and methodological rigour outside the minority world: Making the method work to its strengths in Tanzania. *Qualitative Research, 12*(2), 111-130.
Jana, R., & Chaudhuri, A. K. (2013). Studying various aspects of social networks with socio-economic changes in a rural area: A case study from West Bengal. *Guru Nanak Journal of Sociology, 34*(1-2), 1-29.
Jansen, D. (2006). *Einführung in die Netzwerkanalyse: Grundlagen, Methoden, Forschungsbeispiele*: Springer-Verlag.
Kaplinsky, R., & Morris, M. (2001). *A handbook for value chain research* (Vol. 113): IDRC Ottawa.
Kaplinsky, R., & Readman, J. (2001). How can SME producers serve global markets and sustain income growth? *University of Sussex and University of Brighton, mimeo*.
Kasl, E., & Yorks, L. (2002). An extended epistemology for transformative learning theory and its application through collaborative inquiry. *Teachers College Record, 2*, 1-17.
Kassie, M., Ndiritu, S. W., & Stage, J. (2014). What Determines Gender Inequality in Household Food Security in Kenya? Application of Exogenous Switching Treatment Regression. *World Development, 56*, 153-171. doi:https://doi.org/10.1016/j.worlddev.2013.10.025
Katz, E., & Lazardsfeld, P. F. (1955). *Personal Influence: The Part Played by in the Flow of Mass Communications*: Free Press.
Kilelu, C., Klerkx, L., Omore, A., Baltenweck, I., Leeuwis, C., & Githinji, J. (2017). Value Chain Upgrading and the Inclusion of Smallholders in Markets: Reflections on Contributions of Multi-Stakeholder Processes in Dairy Development in Tanzania. *The European Journal of Development Research*, 1-20. doi:10.1057/s41287-016-0074-z
Kollmair, M., & Juli, S. (2002). The Sustainable Livelihoods Approach Input Paper for the Integrated Training Course of NCCR North-South Aeschiried. *Development Study Group, University of Zurich, Zurich*.
König, H. J., Sghaier, M., Schuler, J., Abdeladhim, M., Helming, K., Tonneau, J.-P., . . . Wiggering, H. (2012). Participatory impact assessment of soil and water conservation scenarios in Oum Zessar Watershed, Tunisia. *Environmental management, 50*(1), 153-165.
Kshirsagar, M. P., & Kalamkar, V. R. (2014). A comprehensive review on biomass cookstoves and a systematic approach for modern cookstove design. *Renewable and Sustainable Energy Reviews, 30*, 580-603.
Lotze-Campen, H., Popp, A., Beringer, T., Müller, C., Bondeau, A., Rost, S., & Lucht, W. (2010). Scenarios of global bioenergy production: the trade-offs between agricultural expansion, intensification and trade. *Ecological Modelling, 221*(18), 2188-2196.
Martin, K. S., Rogers, B. L., Cook, J. T., & Joseph, H. M. (2004). Social capital is associated with decreased risk of hunger. *Social science & medicine, 58*(12), 2645-2654.
Maxwell, S. (1996). Food security: a post-modern perspective. *Food Policy, 21*(2), 155-170. doi:http://dx.doi.org/10.1016/0306-9192(95)00074-7
Maxwell, S., & Smith, M. (1992). Household food security: a conceptual review. *Household Food Security: concepts, indicators, measurements. Edited by S. Maxwell and T. Frankenberger. Rome and New York: IFAD and UNICEF*.
McOmber, C., Panikowski, A., McKune, S., Bartels, W., & Russo, S. (2013). Investigating climate information services through a gendered lens.
McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual review of sociology, 27*(1), 415-444.
Mejía, D. (2003). Post Harvest Compendium, Maize.(ed.) Danilo, Mejía. and Emanuela Parrucci Information Network on Post-harvest Operations. *Food and Agriculture Organization of the United Nations (FAO)*.

Mills, M., Álvarez-Romero, J. G., Vance-Borland, K., Cohen, P., Pressey, R. L., Guerrero, A. M., & Ernstson, H. (2014). Linking regional planning and local action: Towards using social network analysis in systematic conservation planning. *Biological Conservation, 169*, 6-13.

Misra, S., Goswami, R., Basu, D., & Jana, R. (2014). Application of social network analysis in livelihood system study.

Mitchell, D. (2010). *Biofuels in Africa: opportunities, prospects, and challenges*: World Bank Publications.

Mlozi, M., Kakengi, A., Minga, U., Mtambo, A., & Olsen, J. (2003). Marketing of free-range local chickens in Morogoro and Kilosa urban markets, Tanzania. *Livestock Research for Rural Development, 15*(2), 2003.

Mnenwa, R., & Maliti, E. (2010). *A comparative analysis of poverty incidence in farming systems of Tanzania*: Research on Poverty Alleviation.

MOFEA. (2008). *The economic survey 2007*. Retrieved from Dar es Salaam, Tanzania:

Mutabazi, K. D., Amjath-Babu, T., & Sieber, S. (2015). Influence of livelihood resources on adaptive strategies to enhance climatic resilience of farm households in Morogoro, Tanzania: an indicator-based analysis. *Regional Environmental Change, 15*(7), 1259-1268.

Nations, U. (2014). *The Millennium Development Goals*. Retrieved from New York:

Naudé, W. (2010). Entrepreneurship, developing countries, and development economics: new approaches and insights. *Small business economics, 34*(1), 1.

Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., . . . Batka, M. (2009). *Climate change: Impact on agriculture and costs of adaptation* (Vol. 21): Intl Food Policy Res Inst.

Newig, J., Günther, D., & Pahl-Wostl, C. (2010). Synapses in the network: learning in governance networks in the context of environmental management. *Ecology and Society, 15*(4).

Newman, L., & Dale, A. (2005). Network structure, diversity, and proactive resilience building: a response to Tompkins and Adger. *Ecology and Society, 10*(1).

Olsson, P., Folke, C., & Hahn, T. (2004). Social-ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. *Ecology and Society, 9*(4).

Olsson, P., Gunderson, L., Carpenter, S., Ryan, P., Lebel, L., Folke, C., & Holling, C. S. (2006). Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. *Ecology and Society, 11*(1).

Orchard, S. E., Stringer, L. C., & Quinn, C. H. (2015). Impacts of aquaculture on social networks in the mangrove systems of northern Vietnam. *Ocean & Coastal Management, 114*, 1-10. doi:http://dx.doi.org/10.1016/j.ocecoaman.2015.05.019

Ostrom, E. (1990). *Governing the commons*: Cambridge university press.

Paavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science & Policy, 11*(7), 642-654.

Pauw, K., & Thurlow, J. (2011). Agricultural growth, poverty, and nutrition in Tanzania. *Food Policy, 36*(6), 795-804. doi:https://doi.org/10.1016/j.foodpol.2011.09.002

Platteau, J. P. (1997). Mutual insurance as an elusive concept in traditional rural communities. *The Journal of Development Studies, 33*(6), 764-796.

Poulsen, M. N., McNab, P. R., Clayton, M. L., & Neff, R. A. (2015). A systematic review of urban agriculture and food security impacts in low-income countries. *Food Policy, 55*, 131-146. doi:https://doi.org/10.1016/j.foodpol.2015.07.002

Prell, C. (2003). Community networking and social capital: early investigations. *Journal of Computer‐Mediated Communication, 8*(3), 0-0.

Prell, C., Hubacek, K., Quinn, C., & Reed, M. (2008). 'Who's in the network?'When stakeholders influence data analysis. *Systemic Practice and Action Research, 21*(6), 443-458.

Prell, C., Hubacek, K., & Reed, M. (2009). Stakeholder analysis and social network analysis in natural resource management. *Society and Natural Resources, 22*(6), 501-518.

Prell, C., Reed, M., Racin, L., & Hubacek, K. (2010). Competing structure, competing views: the role of formal and informal social structures in shaping stakeholder perceptions. *Ecology and Society, 15*(4).
Pretty, J. (2003). Social capital and the collective management of resources. *Science, 302*(5652), 1912-1914.
Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability, 9*(1), 5-24. doi:10.3763/ijas.2010.0583
Pretty, J., & Ward, H. (2001). Social capital and the environment. *World Development, 29*(2), 209-227.
Pretty, J. N. (1991). Farmers' extension practice and technology adaptation: Agricultural revolution in 17–19th century Britain. *Agriculture and Human Values, 8*(1), 132-148.
Pretty, J. N., Thompson, J., & Kiara, J. (1995). Agricultural regeneration in Kenya: the catchment approach to soil and water conservation. *Ambio. Stockholm, 24*(1), 7-15.
Putnam, R. D. (1995). Bowling alone: America's declining social capital. *Journal of democracy, 6*(1), 65-78.
Radcliffe-Brown, A. R. (1952). *Structure and function in primitive society: essays and addresses by AR Radcliffe-Brown*.
Reagans, R., & McEvily, B. (2003). Network Structure and Knowledge Transfer: The Effects of Cohesion and Range. *Administrative Science Quarterly, 48*(2), 240-267. doi:doi:10.2307/3556658
Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation, 141*(10), 2417-2431. doi:https://doi.org/10.1016/j.biocon.2008.07.014
Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., . . . Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of environmental management, 90*(5), 1933-1949.
Riisgaard, L., Bolwig, S., Ponte, S., Du Toit, A., Halberg, N., & Matose, F. (2010). Integrating poverty and environmental concerns into value‐chain analysis: a strategic framework and practical guide. *Development Policy Review, 28*(2), 195-216.
RLDC, R. L. D. C. (2008). *Sunflower Sector-Market Development Strategy*. Retrieved from Dodoma, Tanzania:
Rogers Everett, M. (1995). Diffusion of innovations. *New York, 12*.
Rosillo-Calle, F., & Johnson, F. X. (2010). *Food versus fuel: an informed introduction to biofuels*: ZED books.
Sander, K., Gros, C., & Peter, C. (2013). Enabling reforms: analyzing the political economy of the charcoal sector in Tanzania. *Energy for Sustainable Development, 17*(2), 116-126.
Sandström, A., & Carlsson, L. (2008). The performance of policy networks: the relation between network structure and network performance. *Policy Studies Journal, 36*(4), 497-524.
Schiffer, E. (2007). Net-map toolbox: Influence mapping of social networks.
Schiffer, E., & Hauck, J. (2010). Net-Map: collecting social network data and facilitating network learning through participatory influence network mapping. *Field Methods, 22*(3), 231-249.
Schindler, J., Graef, F., & König, H. J. (2015). Methods to assess farming sustainability in developing countries. A review. *Agronomy for sustainable development, 35*(3), 1043-1057.
Schindler, J., Graef, F., König, H. J., Mchau, D., Saidia, P., & Sieber, S. (2016). Sustainability impact assessment to improve food security of smallholders in Tanzania. *Environmental Impact Assessment Review, 60*, 52-63.
Schneider, M., Scholz, J., Lubell, M., Mindruta, D., & Edwardsen, M. (2003). Building consensual institutions: networks and the National Estuary Program. *American Journal of Political Science, 47*(1), 143-158.

Scholz, J. T., & Wang, C. L. (2006). Cooptation or transformation? Local policy networks and federal regulatory enforcement. *American Journal of Political Science, 50*(1), 81-97.
Scoones, I. (1998). Sustainable rural livelihoods: a framework for analysis.
Scott, J. (2012). *Social network analysis*: Sage.
Servon, L. J., & Bates, T. (1998). Microenterprise as an exit route from poverty: Recommendations for programs and policy makers. *Journal of Urban Affairs, 20*(4), 419-441.
Sieber, S., & Graef, F. (2013). Trans-SEC: Innovating pro-poor Strategies to safeguard Food Security using Technology and Knowledge Transfer

OBJOBJOBJOBJOBJ. In L. C. f. A. L. R. (ZALF) (Ed.). Müncheberg, Germany.
Smith, M., Pointing, J., & Maxwell, S. (1993). *Household Food Security: Concepts and Definitions : an Annotated Bibliography*: Institute of Development Studies.
Smith, M. D., Rabbitt, M. P., & Coleman- Jensen, A. (2017). Who are the World's Food Insecure? New Evidence from the Food and Agriculture Organization's Food Insecurity Experience Scale. *World Development, 93*, 402-412. doi:https://doi.org/10.1016/j.worlddev.2017.01.006
Stein, C., Ernstson, H., & Barron, J. (2011). A social network approach to analyzing water governance: The case of the Mkindo catchment, Tanzania. *Physics and Chemistry of the Earth, Parts A/B/C, 36*(14), 1085-1092.
UNPD. (2012). *Africa Human Development Report 2012: Towards a Food Secure Future*. Retrieved from UNPD, New York:
Uphoff, N. E., & MJ Krishna, A. (1998). *Reasons for success: Learning from instructive experiences in rural development*: Kumarian Press.
URT. (2005). National strategy for growth and reduction of poverty (NSGRP).
URT. (2012). *National Sample Census of Agriculture 2007/2008*. Retrieved from Tanzania:
USAID. (2008). *Tanzania's Agenda for Action, February 2008*. Retrieved from Dar es Salaam:
USAID. (2010). *Staple foods value chain analysis. Country Report Tanzania*. Retrieved from Washington, DC:
Valente, T. W. (1996). Social network thresholds in the diffusion of innovations. *Social networks, 18*(1), 69-89.
Valente, T. W., & Davis, R. L. (1999). Accelerating the diffusion of innovations using opinion leaders. *The Annals of the American Academy of Political and Social Science, 566*(1), 55-67.
Von Braun, J. (2007). *The world food situtation: new driving forces and required actions*: Intl Food Policy Res Inst.
Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications* (Vol. 8): Cambridge university press.
Weimann, G. (1982). On the importance of marginality: One more step into the two-step flow of communication. *American Sociological Review*, 764-773.
Westley, F., Tjornbo, O., Schultz, L., Olsson, P., Folke, C., Crona, B., & Bodin, Ö. (2013). A theory of transformative agency in linked social-ecological systems. *Ecology and Society, 18*(3).
WFP. (2013). *Comprehensive Food Security & Vulnerability Analysis (CFSVA), Tanzania, 2012*. Retrieved from Rome:
Wheeler, T., & von Braun, J. (2013). Climate Change Impacts on Global Food Security. *Science, 341*(6145), 508-513. doi:10.1126/science.1239402
Ziervogel, G., & Ericksen, P. J. (2010). Adapting to climate change to sustain food security. *Wiley Interdisciplinary Reviews: Climate Change, 1*(4), 525-540.

Annex

Annex A. Methodological Research Approaches/Methods

Net-Map preparation

- **Make a pool of the possible important actors, thinking who is important for the implementation of the UPS.**

- **Make a pool of the possible important motivations for the actors to be taking part into the implementation.**

- **Prepare the post-it cards with the actor names and motivations for the session.**

- **Prepare the recorder and markers with different colors to draw the links.**

Beginning of Net-Map: There is no wrong or right answer. U may interrupt once in a while. It will be recorded and used only for the desired purpose

1) Individual interviews with Net-Map

1.1 Individual interview

- tell us more about your role in the group.

-Do you think something can be improved with the implementation of the UPS?

- How do you feel about your food security (i.e. more food availability) now that you are involved in the UPS?

1.2 Net-map

1st step

-Who is important in terms of linkage within the group (ask the group assistant and field assistant), on which scale level do the actors operate (e.g. do piki piki operate out of the village

-Who is important in the implementation of the UPS (e.g. implementation of stoves) at the moment?

-Let them choose among the prepared post-it (actor cards), and ask for other actors to be included, e.g. how did u pick your group leader

2nd step

-Is actor A communicating with actor B (how are they linked (e.g. **materials, money, knowledge/info** Ask for examples, how they do it, how often?

Or does chicken keeper exchange knowledge with group members or does he provide his expertise to grp members

-Is Actor A exchanging resources (e.g. food, money and material) with actor B. Ask for examples, how they do it, how often?

Our links are:

-**Knowledge:** are you providing/sharing and getting knowledge on the UPS implementation?

- **Materials** and any other resources but not money e.g. seeds, machinery, tools:

-**Money:** are you giving money to the field assistant or is the field assistant giving money to the farmer?

3rd step

-what is the motivation for each actor to participate in the implementation of the UPS

-Can you tell me for each actor? (We do a round, verbally)

- We were thinking about these 8 images

-If there is a very strong motivation mentioned before we make a new card for it, "You already mention before…" (Have extra cards with you)

- Please, can you tell me for each actor the 3 most important motivations and rank them (asking for each actor group)?

Examples of Motivations (use icons)

-availability of food in the household

-the joy of participating in the UPS implementation and group activities (fun, happiness

-family, friends, others are participating (they should explain if it's positive or negative)

-recognition/reputation (ask for examples) /Strengthen social relations (in the family, group)

-growth in knowledge and skills on UPS (ask for examples)

-Being better prepared for any kind of shocks (security, adaptive capacity, resilience)

-Better living conditions and less workload (enough time for other activities, work quality)

-wealth/income

4th step

Explain to them they have to build a tower for each actor group (the limit is 5 with 5 being the maximum).

First tower: How **strong is the influence** of each actor on the implementation? How strongly do u feel the chicken keeper influences the UPS implementation?
-who is the **most influential** in the implementation or who has the most influence

5th step

2nd tower: We want to know **how much more income** each actor gets out of the implementation? Or who is getting the most income out of the poultry implementation
-who gets the most money out of the implementation

3rd tower: How **much more food each** actor gets out of the implementation? Does the leader get more food out of the implementation?
- Who gets the most food out of the implementation of the millet thresher?

4th tower: How much **each actor learns** out of the implementation?
-who gets the most knowledge or who learns the most out of the implementation
-How much do you learn from chicken keeping or implementation of the UPS?

-5th tower (Final tower): who do u think is the **most trust worthy** or who is more honest?

Towers:

-influence
-Income
-food availability
-Learning or knowledge
-Trust

1.3 Additional questions after net-map

- Does your involvement in the UPS change your daily life, habits, attitude? If so, how? Has it changed something else
- Do you think the UPS is done in a fair way (why or why not)?
- Do you think there should be someone within the village who should be included in the implementation? If yes, who?
- Do you think someone from outside the village should be included in the UPS implementation?

- would it make a difference if you did not take part in the keeping of the chickens to the group? Or for the group Or How did your involvement change in the implementation of the UPS?
-what are u going to do when the project is over?
-do you have any conflicts within the group? Who is having conflict within the group?

Finally: Thank him

2) Focus Group Discussion (FGD)

-Introduce our selves, aim of the exercise, give a feedback and clarify some open questions.
-Show the net-map which is representative for the whole group and explain.
Estimation with a map of all actors, showing the main motivations, and one tower the one with the most interesting results.
-Do you agree? Would you add any other actor? Would you add any other motivation?
- Does your involvement in the UPS change your daily life, habits, attitude? If so, how?
-Is there anything you think would be beneficial to add to the group?
- Is there any unforeseen benefit that you get from implementing the UPS?
-What are the links outside the group and the links with other UPS groups?
- Do you think the UPS is done in a fair way (why or why not)?
-How does this implementation change the balance of man and woman or male and female?
- Do you think there should be someone within the village who should be included in the implementation? If yes, who?
- Do you think someone from outside the village should be included in the UPS implementation?
-would it make a difference if you did not take part in the keeping of the chickens to the group?
- How do you feel about your food security (i.e. more food availability) now that you are involved in the UPS?
-Would you prefer other motivations?
-Do you think you are helpful/ important in the group? How
-Do you think this actor is important in the net-map?
-What are u going to do when the project is over?
-What other activities do you carry out as a group?
-How do the UPS members manage and facilitate themselves in order to reach their goals?

-What are the activities that enhance the proper functioning of and engagement in the UPS groups and the UPS?

Annex B. Net-Map data analysis in Trans-Sec

Most Similar Cases Design: comparing very similar cases (ICS, MS and MT) which only differ in the *dependent variable (any value or index)*, on the assumption that this would make it easier to find those *independent variables* which explain the presence/absence of the dependent variable.

Most Different Cases Design: it consists in comparing very different cases (SUN, PLT, PYR), all of which however have in common the same *dependent variable (e.g. group members influence towers,)*, so that any other circumstance which is present in all the cases can be regarded as the *independent variable*.

1a. Networks' oversight attributes (density, reciprocity, average & longest distance) (3 tables: Knowledge, Money, material)

	Morogoro						**Dodoma**					
	Ilakala			Changarawe			Ilolo			Idifu		
UPS	Distance	Reciprocity	Density	Reciprocity	Distance	Density	Reciprocity	Distance	Distance	Density	Reciprocity	Distance
all	Table	Table	Table	Table	Table	Table	Table	Table	Table	Table	Table	Table

1b. Networks' oversight: All UPS groups networks' 3 most important actors per UPS network, ending in 6-9 different actors altogether per table (2 tables: Knowledge, Money) (1 table for Material → Annex)

	Morogoro						**Dodoma**					
	Ilakala			Changarawe			Ilolo			Idifu		
UPS	Betweeness	Indegree	Outdegree	Betweeness	Indegree	Outdegree	Betweeness	Outdegree	Betweeness	Indegree	Outdegree	Betweeness
all	Table	Table	Table	Table	Table	Table	Table	Table	Table	Table	Table	Table

2. In-depth comparison: both regional and village level ICS. For the influence towers and motivations use averages SD, and N.

	Morogoro					**Dodoma**		
	Ilakala					Changarawe	Ilolo	Idifu
UPS	All 3 centralities in Knowledge Network (10 most important actors)	indegree centrality in money network (10 most important actors)	Betweennes s centrality in material network (10 most important actors)	1 table with "importanc e tower" showing all actors. 5 influence towers for three most important actors	three most important motivation s for 6 most important actors	idem	idem	idem
ICS	1 visualized network (+ figures for all three)	1 visualized network	Figures	Tables	Tables			

3a. Less measures comparison: Both regional and village level (MS & MT) For the influence towers and motivations use averages

SD, and N.

	Morogoro					Dodoma		
	Ilakala					Changarawe	Ilolo	Idifu
UPS	Indegree centrality in Knowledge Network	indegree centrality in money network	Betweenness centrality in material network	all 5 towers for three most important actors	three most important motivations for all actors	idem	idem	idem
MS & MT	1 visualized network (+ figures)	Figures	Figures	Tables	Tables			

3b. Less measures and UPS specific comparison (SUN, PLT, PYR). For the towers and motivations use averages SD, and N.

UPS	Indegree centrality in Knowledge Network	Indegree centrality in money network	Betweenness centrality in material network	all 5 towers for three most important actors	three most important motivations for all actors
SUN, PLT & PYR	1 visualized network (+ figures)	figures	figures	Tables	Tables

4. Narratives:

Information from the narratives is used as citation to support results to stress actor's importance and motivations and their position in the network.

The question about improvements of the UPS and about how they feel about their food security is used for the discussion part of the thesis.

Annex C. Table of influence towers for all actors in Improved cooking stoves UPS Groups

Importance, income, trust, food and knowledge towers for all actors in Improved cooking stoves UPS groups. Source: Author's data.

	Importance			Income			Trust			Food			Knowledge		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Secretary															
Idifu	8	4.9	0.4	8	0	0	8	4.5	1.1	8	0	0	8	4.9	0.4
Ilolo	8	4.1	0.8	8	0.4	1.1	8	3.9	1.4	8	1.1	2.1	8	3.9	1.1
Ilakala	8	4.9	0.4	8	0	0	8	4.6	0.7	8	0.5	1.4	8	4.9	0.4
Changarawe	8	4.4	0.9	8	0	0	8	4.6	0.5	8	0.5	0.9	8	4.3	1
Stove Constructors															
Idifu	8	5	0	8	3.5	1.7	8	5	0	8	3.6	1.8	8	5	0
Ilolo	8	4.6	1.1	8	3.3	2.1	8	4.8	0.7	8	3.5	1.9	8	4.8	0.7
Ilakala	8	4.5	0.8	8	2.9	1.2	8	4.6	0.7	8	3.1	0.8	8	4.9	0.4
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Researchers															
Idifu	8	5	0	8	0.6	1.8	8	5	0	8	1.1*	2.1	8	2.5	2.7
Ilolo	8	5	0	8	2.6	2.6	8	5	0	8	3.3*/***	1.9	8	3.9	1.9
Ilakala	8	5	0	8	0	0	8	5	0	8	0.00***	0	8	1.9	1.9
Changarawe	8	5	0	8	0	0	8	5	0	8	0.00***	0	8	2	2.3
Group members															
Idifu	8	4.8	0.5	8	3.6*	0.9	8	4.6	0.7	8	0.4	1.1	8	4.1	1.4
Ilolo	8	3.8	1.6	8	3.8**	1.7	8	3.5	1.3	8	1.9	2.2	8	4.3	1.4
Ilakala	8	4.1	0.8	8	2.5	1.6	8	4.4	0.7	8	0.9	1.6	8	4.6	0.7

Changarawe	8	3.5	1.2	8	1.6*/**	1.1	8	4.4	0.9	8	1.3	1.9	8	3.9	1
Customers															
Idifu	8	3.1	2	8	0	0	8	3	2	8	0	0	8	2.6	2.3
Ilolo	5	4.4	1.3	5	1	2.2	5	2.8	2.3	5	1	2.2	5	2.8	1.9
Ilakala	8	4.1	1	8	0	0	8	4.6	0.7	8	0.5	1.4	8	3.6	1.3
Changarawe	8	2.5	1.3	8	0.3	0.7	8	2.9	1.6	8	0.4	0.7	8	2.4	1.3
Group leader															
Idifu	8	4.8*	0.7	8	0.0	0.0	8	4.6	1.1	8	0.0	0.0	8	4.8	0.5
Ilolo	8	3.8	1.8	8	0.4	1.1	8	3.6	1.8	8	1.1	2.1	8	3.9	1.1
Ilakala	8	4.5	0.8	8	0.0	0.0	8	4.4	1.1	8	1.0	1.9	8	4.6	0.7
Changarawe	6	2.8*	1.5	6	0.0	0.0	6	4.8	0.4	6	0.3	0.8	6	4.0	1.5
Treasurer															
Idifu	8	4.9**	0.4	8	0.0	0.0	8	4.8	0.7	8	0.0	0.0	8	4.1	1.2
Ilolo	6	2.8**	1.5	6	0.5	1.2	6	3.0	2.1	6	0.5	1.2	6	2.7	1.2*
Ilakala	8	4.5	0.8	8	0.0	0.0	8	4.9	0.4	8	0.5	1.4	8	4.6	0.7*
Changarawe	8	3.6	1.5	8	0.0	0.0	8	4.4	1.4	8	0.3	0.7	8	3.5	1.6
Sub-group leader															
Idifu	3	3.0	1.7	3	0.0	0.0	3	2.7	1.2	3	0.0	0.0	3	3.3	1.5
Ilolo	5	2.4	1.5	5	0.8	1.8	5	2.0	1.9	5	1.0	2.2	5	2.2	1.9
Ilakala	7	2.7	1.8	7	0.4	1.1	7	2.9	2.0	7	0.6	1.0	7	4.1	1.9
Changarawe	8	3.5	1.7	8	0.5	1.4	8	3.5	2.0	8	0.3	0.7	8	4.0	1.2
Sub-group secretary															
Idifu	4	3.5	1.9	4	0.0	0.0	4	3.3	2.1	4	0.0	0.0	4	3.8	1.5
Ilolo	5	2.8	1.9	5	0.0	0.0	5	2.4	2.1	5	1.0	2.2	5	2.2	2.2
Ilakala	5	3.4	1.9	5	0.0	0.0	5	3.8	2.2	5	0.0	0.0	5	4.0	2.2

Changarawe	7	3.6	1.3	7	0.0	0.0	7	4.6	0.8	7	0.3	0.8	7	4.1	1.2
Sub-group treasurer															
Idifu	4	2.0	2.2	4	0.0	0.0	4	2.0	2.2	4	0.0	0.0	4	2.3	2.1
Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilakala	5	3.8	2.2	5	0.0	0.0	5	3.0	2.1	5	1.2	1.6	5	3.8	2.2
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Research field assistant															
Idifu	4	4.3	1.0	4	0.0	0.0	4	4.8	0.5	4	2.3	2.6**	4	3.8	2.5
Ilolo	1	3.0	-	1	1.0	-	1	5.0	-	1	1.0	-	1	1.0	-
Ilakala	6	3.7	2.0	6	0.0	0.0	6	4.2	2.0	6	0.0	0.0**	6	2.7	2.6
Changarawe	8	4.6	0.5	8	0.0	0.0	8	5.0	0.0	8	0.3	0.7	8	3.9	1.4
Material providers															
Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilolo	5	4.0	1.2	5	3.0	2.1	5	3.2	2.0	5	3.0	1.9	5	2.6	1.5
Ilakala	4	4.0	1.4	4	4.8**	0.5	4	4.5	1.0	4	3.3	2.4	4	1.0	2.0
Changarawe	7	3.0	1.5	7	1.9**	1.1	7	4.6	0.8	7	1.9	0.7	7	1.4	1.4
Wood suppliers															
Idifu	6	2.7	2.1	6	0.8**	2.0	6	2.7	2.0	6	0.8	2.0*	6	1.7	2.0
Ilolo	8	3.9	1.8	8	4.1**	1.0	8	3.6	1.1	8	3.9	1.2*	8	2.8	1.8
Ilakala	5	3.0	1.2	5	2.8	.8	5	4.6	0.9	5	3.8	.8	5	1.0	2.2
Changarawe	8	2.8	1.5	8	2.8	1.0	8	3.5	1.4	8	3.1	1.1	8	1.3	1.3
Village chief															
Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilakala	2	3.5	0.7	2	0.0	0.0	2	3.5	0.7	2	0.0	0.0	2	0.0	0.0
Changarawe	4	3.5	1.9	4	0.0	0.0	4	4.8	0.5	4	0.5	1.0	4	1.3	1.9

Councilor															
Idifu	6	4.7	0.8	6	0.0	0.0	6	4.7	0.8	6	0.0	0.0	6	2.2	2.5
Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilakala	2	3.5	2.1	2	0.0	0.0	2	3.0	0.0	2	0.0	0.0	2	0.0	0.0
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leaders of sub-villages															
Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilakala	3	4.3	1.2	3	0.0	0.0	3	3.7	1.5	3	0.0	0.0	3	.7	1.2
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Village executive officer															
Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilakala	2	3.5	.7	2	0.0	0.0	2	3.00	1.41	2	0.0	0.0	2	0.00	0.00
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monitoring group															
Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilolo	3	3.3	1.2	3	0.0	0.0	3	2.0	1.7	3	0.0	0.0	3	2.7	1.2
Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Assessment comparison between same actor role across different UPS groups: *p < 0.05; **p < 0.01; ***p < 0.001*

Annex D. Table of influence towers for all actors in Maize sheller and Millet thresher UPS Groups

Importance, income, trust, food and knowledge towers for all actors in Millet thresher (MT) & Maize sheller (MS) UPS groups. Source: Author's data.

		Importance			Income			Trust			Food			Knowledge		
		N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Devi
UPS	Village	**Secretary**														
MS	Ilakala	8	4.6	0.7	8	0.6	0.9	8	4.9	0.4	8	1.4	1.8	8	4.1	1.4
MS	Changarawe	7	4.6	0.8	7	0.9	1.1	7	4.6	0.5	7	2.3	1.7	7	4.1	0.9
MT	Idifu	8	4.1	1.2	8	0.0[a]	0	8	4.3	1.2	8	0	0	8	4.1	1
MT	Ilolo	8	4.5	0.9	8	0	0	8	4.1	1.1	8	0	0	8	3.4	1.5
Group Members																
MS	Ilakala	8	4.6	0.7	8	3.9*	1.4	8	4.5	0.8	8	3.9*	0.8	8	4.3	1.2
MS	Changarawe	8	4.1	0.6	8	2.25*	0.5	8	4	0.8	8	2.50*	1.2	8	4.1	0.8
MT	Idifu	8	4.1	0.6	8	0.0[b]	0	8	4	0.9	8	0	0	8	3.5	1.7
MT	Ilolo	9	3.7	0.9	9	0	0	9	3.8	1	9	0.0[a]	0	9	3.3	1.4
Researchers																
MS	Ilakala	8	5	0	8	0	0	8	5	0	8	0.6	1.8	8	1.6	2.3
MS	Changarawe	8	5	0	8	0	0	8	4.5	0.8	8	0.4	1.1	8	1.9	2.1
MT	Idifu	8	5	0	8	0	0	8	4.9	0.4	8	0	0	8	2.3	2.5
MT	Ilolo	9	4.9	0.3	9	0.9	1.8	9	4.6	0.5	9	0.9[b]	1.8	9	2.4	2.4

Group Leader																
MS	Ilakala	8	5.0*	0.5	8	2.5***	0.5	8	4.6	0.5	8	3.0	0.8	8	4.6	0.7
MS	Changarawe	8	4.1*	0.8	8	0.3***	0.5	8	4.3	0.7	8	2.1	1.9	8	3.9	1.0
MT	Idifu	8	4.5	0.9	8	0.0	0.0	8	4.1	1.4	8	0.0	0.0	8	4.0	1.2
MT	Ilolo	8	3.8	1.3	8	0.0	0.0	8	3.8	1.4	8	0.0	0.0	8	3.3	1.4
Treasurer																
MS	Ilakala	8	4.6	0.7	8	4.0*	1.1	8	4.9	0.4	8	4.3*	0.7	8	4.9*	0.4
MS	Changarawe	8	3.9	1.0	8	1.5*	1.2	8	4.4	0.7	8	2.5*	1.5	8	3.8*	1.4
MT	Idifu	8	4.3	1.2	8	0.0	0.0	8	4.6	0.7	8	0.0	0.0	8	3.9	1.5
MT	Ilolo	6	3.0	1.3	6	0.0	0.0	6.0	4.0	1.3	6.0	0.0	0.0	6.0	3.7	1.2
Customers																
MS	Ilakala	8	4.1	1.8	8	3.4	2.2	8	4.1	1.7	8	4.5	0.8	8	3.0	2.3
MS	Changarawe	8	4.8	0.5	8	1.9	1.7	8	4.4	0.7	8	3.1	1.7	8	2.8	1.8
MT	Idifu	8	4.3	1.4	8	0.0	0.0	8	3.0	2.0	8	0.0	0.0	8	1.3	1.4
MT	Ilolo	9	2.9	2.2	9	0.0	0.0	9	1.9	2.0	9	0.4	1.3	9	1.6	1.7
Material providers																
MS	Ilakala	8	4.5	1.1	8	3.1	1.2	8	4.5	0.8	8	4.0	0.9	8	1.3	1.8
MS	Changarawe	8	4.8	0.5	8	3.5	0.9	8	3.9	1.4	8	3.1	1.2	8	0.0	0.0
MT	Idifu	7	4.4	1.1	7	3.9*	1.7	7	4.3	1.0	7	4.1	1.2	7	1.6	2.1
MT	Ilolo	9	3.6	1.4	9	1.8*	1.5	9	3.4	1.5	9	2.4	1.9	9	0.6	1.7
Technician																
MS	Ilakala	7	4.7	0.5	7	3.3*	1.5	7	4.3	1.1	7	4.0*	1.2	7	0.9*	1.5
MS	Changarawe	8	4.0	0.9	8	1.5*	1.4	8	4.4	1.2	8	2.0*	1.7	8	4.4*	.5
MT	Idifu	7	4.1	1.5	7	1.3	1.3	7	3.9	1.5	7	1.4	1.4	7	1.4	2.0
MT	Ilolo	5	3.8	1.8	5	2.0	2.0	5	3.4	2.1	5	3.0	2.7	5	1.0	1.4
		Transport Owners														

MS	Ilakala	8	4.3	1.2	8	4.9*	0.4	8	3.8	1.6	8	5.0*	0.0	8	2.1	2.4
MS	Changarawe	8	3.4	1.8	8	2.0*	1.4	8	3.3	1.8	8	2.6*	1.5	8	0.1	0.4
MT	Idifu	8	4.5	0.9	8	2.0	1.6	8	3.9	1.2	8	3.0	1.7	8	1.1	1.6
MT	Ilolo	8	3.5	1.7	8	3.3	1.3	8	3.8	1.2	8	3.5	1.5	8	0.0	0.0
		Research field assistant														
MS	Ilakala	7	3.9	1.9	7	0.0	0.0	7	4.3	1.9	7	.7	1.9	7	1.9	2.4
MS	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Idifu	8	4.5	0.8	8	0.0	0.0	8	4.5	0.8	8	.0	.0	8	2.0	2.3
MT	Ilolo	7	4.3	1.0	7	0.7	1.9	7	4.7	0.8	7	1.3	2.2	7	2.3	2.4
		Machine operator														
MS	Ilakala	7	4.1	1.9	7	3.7	1.8	7	3.9	1.9	7	3.8	1.8	7	4.3	1.9
MS	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Village executive officer														
MS	Ilakala	2	1.0	1.4	2	0	0	2	1.0	1.4	2	0.0	0.0	2	1.5	2.1
MS	Changarawe	3	3.0	0.0	3	0	0	3	4.0	0.0	3	0.0	0.0	3	1.3	1.5
MT	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Councilor														
MS	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Idifu	5	4.2	1.3	5	0.0	0.0	5	4.0	1.2	5	0.0	0.0	5	1.8	2.2
MT	Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Villa chief														

MS	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Idifu	3	4.3	1.2	3	0.0	0.0	3	4.3	1.2	3	0.0	0.0	3	0.0	0.0
MT	Ilolo	3	4.3	0.6	3	1.0	1.7	3	4.7	0.6	3	1.3	2.3	3	0.3	0.6
Piki piki																
MS	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Ilolo	1	5.0		1	3.0		1	5.00		1	4.00		1	0.00	
Laborers																
MS	Ilakala	6	3.5	1.4	6	3.0	1.7	6	4.3	0.8	6	3.2	1.5	6	3.3	1.9
MS	Changarawe	8	3.0	1.1	8	1.9	0.8	8	3.8	1.2	8	1.8	1.0	8	3.1	0.8
MT	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Machine providers																
MS	Ilakala	8	4.6	0.7	8	5.0	0.0	8	4.8	0.7	8	4.9	0.4	8	1.4	1.9
MS	Changarawe	7	5.0	0.0	7	5.0	0.0	7	4.0	1.3	7	4.6	0.8	7	0.6	1.5
MT	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MT	Ilolo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*1. Assessment comparison between same actor role across different UPS groups: * = *p < 0.05; **p < 0.01; ***p < 0.001*

2. Assessment comparison across different actor roles in the same UPS group: a, b = p < 0.05

Annex E. Table of influence towers for all actors in Sunflower oil production, Poultry-crop integration & marketing, and By products of bioenergy UPS groups

Importance, income, trust, food, knowledge, bio-char towers for all actors in the Sunflower oil production (SUN), Poultry-crop integration & marketing (PLT) and By products of bioenergy (PYR) UPS groups. Source: Author's

UPS		Importance			Income			Trust			Food			Knowledge			Bio-char		
		N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Dev	N	Mean	Std. Dev.	N	Mean	Std. Dev	N	Mean	Std. Dev
Secretary																			
PLT	Changarawe	7	4	1	7	1.4	1.4	7	3.7	1	7	1.4	1.4	7	4.3	0.8	7	0	0
PYR	Ilakala	7	4.9	0.4	7	0	0	7	4.9	0.4	7	0	0	7	3.6	1.1	7	2	2.3
SUN	Idifu	7	4.9	0.4	7	0	0	7	4.3	1.9	7	0	0	7	2.7	2.6	7	0	0
Group members																			
PLT	Changarawe	8	3.9	0.8	8	3	1.4	8	4.1	0.6	8	3.1	1.5	8	3.9	0.4	8	0	0
PYR	Ilakala	7	4.7	0.8	7	0	0	7	4.3	1	7	0	0	7	3.3	1.1	7	2.6	2.2
SUN	Idifu	7	4.9	0.4	7	0	0	7	5	0	7	0	0	7	2.6	2.5	7	0	0
Researchers																			
PLT	Changarawe	8	4.9	0.4	8	0.6	1.8	8	4.5	0.9	8	0.6	1.8	8	2.3	2.5	8	0	0
PYR	Ilakala	7	5	0	7	0	0	7	5	0	7	0	0	7	1.1	2	7	0	0
SUN	Idifu	6	4.8	0.4	6	0	0	6	5	0	6	0	0	6	1.7	2.6	6	0	0
Group leader																			
PLT	Changarawe	7	3.7	1.1	7	.7	1.9	7	4.3	0.8	7	.7	1.9	7	3.6	1.0	-	-	-

PYR	Ilakala	7	4.6	0.8	7	.0	.0	7	4.7	0.5	7	.0	.0	7	3.6	1.1	7.0	2.0	2.3
SUN	Idifu	7	4.6	0.8	7	.0	.0	7	4.7	0.8	7	.0	.0	7	2.7	2.6	-	-	-
Treasurer																			
PLT	Changarawe	7	3.7	1.6	7	.7	1.9	7	4.1	1.5	7	.7	1.9	7	3.7	0.8	-	-	-
PYR	Ilakala																-	-	-
SUN	Idifu	7	4.7	0.5	7	.0	.0	7	5.0	0.0	7	.0	.0	7	1.9	2.4			
Researchers																			
PLT	Changarawe	8	4.9	0.4	8	.6	1.8	8	4.5	0.9	8	.6	1.8	8	2.3	2.5	-	-	-
PYR	Ilakala	7	5.0	0.0	7	.0	.0	7	5.0	0.0	7	.0	.0	7	1.1	2.0	7	0.0	0.0
SUN	Idifu	6	4.8	0.4	6	.0	.0	6	5.0	0.0	6	.0	.0	6	1.7	2.6	-	-	-
MVIWATA																			
PLT	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	5	5.00	0.000	5	0.0	0.0	5	5.0	0.0	5	0.0	0.0	5	3.00	2.739	-	-	-
Research field assistant																			
PLT	Changarawe	8	4.5	0.8	8	0.0	0.0	8	4.4	1.4	8	0.0	0.0	8	1.1	2.1	-	-	-
PYR	Ilakala	7	5.0	0.0	7	0.0	0.0	7	5.0	0.0	7	0.0	0.0	7	1.7	1.9	7	0.0	0.0
SUN	Idifu	6	4.2	1.0	6	0.8	2.0	6	4.5	1.2	6	0.3	0.8	6	2.2	2.5	-	-	-
Customers																			
PLT	Changarawe	7	2.7	1.5	7	3.6	1.7	7	2.7	0.8	7	3.1	1.8	7	0.4	1.1	-	-	-
PYR	Ilakala	7	4.3	1.0	7	0.0	0.0	7	4.7	0.8	7	0.0	0.0	7	2.7	1.8	7	1.0	1.5
SUN	Idifu	6	4.2	1.6	6	0.0	0.0	6	3.2	2.1	6	0.0	0.0	6	1.8	2.5			
Mason																			
PLT	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SUN	Idifu	3	5.0	0.0	3	4.7	0.6	3	4.7	0.6	3	4.7	0.6	3	1.7	2.9			
Small chicks provider																			
PLT	Changarawe	8	3.3	1.8	8	4.6	.7	8	2.8	1.6	8	4.0	1.6	8	0.6	1.8	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Feed providers																			
PLT	Changarawe	8	3.6	1.4	8	3.0	1.8	8	4.1	1.0	8	3.8	1.7	8	.6	1.8	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Medicine providers																			
PLT	Changarawe	8	4.5	0.8	8	4.0	0.8	8	4.5	0.8	8	3.9	1.6	8	.9	1.6			
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
District development officer																			
PLT	Changarawe	4	3.3	1.5	4	.3	.5	4	3.3	2.1	4	0.0	0.0	4	0.0	0.0			
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villa chief																			
PLT	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	3	2.3	.6	3	1.7	2.9	3	1.3	2.3	3	.3	.6	3	2.0	2.7	-	-	-
Councilor																			
PLT	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	6	4.0	1.3	6	0.0	0.0	6	3.3	2.3	6	0.0	0.0	6	1.8	2.5	-	-	-
Leaders of sub-villages																			

PLT	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYR	Ilakala	4	4.5	1.0	4	0.0	0.0	4	4.0	1.1	4	0.0	0.0	4	2.5	2.0	-	-	-
SUN	Idifu	-	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	-
Villa executive officer (VEO)																			
PLT	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	2	4.0	1.4	2	0.0	0.0	2	2.5	3.5	2	0	0	2	0	0			
Transport owners																			
PLT	Changarawe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYR	Ilakala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN	Idifu	3	5.0	0.0	3	4.3	1.2	3	5.0	0.0	3	5.0	0.0	3	1.3	2.3	-	-	-

Declaration of Originality

I declare that this thesis is my own work and that, to the best of my knowledge, it contains no material previously published, or substantially overlapping with material submitted for the award of any other degree at any institution, except where due acknowledgment is made in the text.

Estephania Delgadillo Jaime

26th of November 2017