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Information and Communication Technologies as Enablers for Effective Functioning of Agricultural Innovation Systems in Tanzania: Experiences of Young Farmers

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Abstract

This study presents the usefulness of Information and Communication Technologies (ICTs) in Agricultural Innovation Systems (AIS) functioning among young farmers in Tanzania. The AIS approach's preference for development results from its inclusiveness and interactions among the actors in influencing each other into learning and innovation. Young farmers in Tanzania are key actors in AIS functioning, but their ability to influence other actors using ICTs to maximize their crop productivity is contentious. This paper applied the Social Network Analysis (SNA) method to assess 90 young farmers' influence on other 38 actors to interact using ICTs for crop productivity endeavours. These actors include researchers, extension agents, input suppliers (fertilizers, seeds and pesticides), seed agencies, processors, local traders, financial institutions, NGOs, and consumers. The study revealed that young farmers were dissatisfied with the quality and frequency of interaction with key stakeholders or actors such as extension agents, researchers, and financial institutions. However, despite the low level of interaction, the study has revealed that young farmers are important actors in enhancing crop productivity. Therefore, the need for researchers, extensionists, input suppliers, financial institutions, and NGOs to interact with young farmers is recommended because young farmers are the centre of knowledge in AIS functioning.

Keywords: Agricultural Innovation System, Social Network Analysis, Knowledge Management Systems, Multi-stakeholders' Platforms, Farming, Youths

1.0 INTRODUCTION

The Tanzanian agricultural sector is characterized by new programmes such as Agricultural Sector Development Programme (ASDP) I and II and actors' relationships that influence young farmers to access and use agricultural information and knowledge. In Tanzania, young farmers are young men and women from the age of 15 to 35 years old (United Republic of Tanzania (URT), 2007) that constitute about 35.5% of the total population (URT, 2014) and majority of whom are unemployed (Roudi, 2011; Zimmermann *et al*., 2013). Engagement in crop production presents a viable means of employment for many young people (URT 2016). However, for a few decades, many African youths have increasingly abandoned farming because of its persistent negative challenges such as low productivity, less appealing characteristics of rural areas, and others (Lohento and Ajilore, 2015). For example, a study by Ruta (2012) indicates that awareness of agricultural initiative programs among the youth is very low. The youth consider agriculture an

unprofitable venture meant for the old or retired people because it takes a long time to yield results and provides no opportunity for a better life (Ruta, ibid). Hence, those engaged in agriculture are perceived to do so because of a lack of other alternatives. Based on this shortfall, the Government of Tanzania (GoT) has undertaken various interventions with a goal of making the sector as one of the major engines for the national economic development.

The agricultural policy reforms and actors' interactions are partly a result of GoT initiatives through ASDP I and ASDP II (URT, 2016). In these programmes, the issue of agricultural innovations and the effective functioning of the agricultural innovation system (AIS) has been keenly emphasized (Klerkx *et al.*, 2012). Effective functioning of AIS is the activity of learning or interactive learning of actors (Hekkert *et al.*, 2007). Generally, effective functioning approaches tend to focus on whether or not specific functions of AIS are fulfilled (Hekkert *et al.*, ibid). Fundamentally, this kind of innovation system draws upon a biological metaphor, whereby the whole body of a human being cannot function well if sub-systems such as organs and transport are lacking or do not interact amicably. For example, young farmers cannot improve their crop productivity if they work in isolation and do not interact with other actors such as researchers, creditors and extension agents. According to Klerkx *et al.* (2012), seven effective functioning innovation systems (Table 1) have been recognized as well-functioning AIS.

Table 1: Functions of effective AIS

S/N	AIS functions	Explanations
	Entrepreneurial activities	Entrepreneurs are individuals who start a new agro-enterprise by taking initiatives and risks associated with the agro-enterprise and who do so by creating something new or by using resources in unusual ways to provide value to customers. Entrepreneurs are essential for a well-functioning innovation system. The presence of active entrepreneurs is a first and prime indication of the performance of an innovation system. When entrepreneurial activity lags behind, causes may be found in the other six functions.
2	**Knowledge development**	The most fundamental resource in the modern economy is knowledge; the most important process is learning. Therefore, research and knowledge development (R&D) are prerequisites within the innovation system.
3	**Knowledge diffusion in networks**	This function encompasses the exchange of information. Learning through actors' interactions and using a particular technology is fundamental in this function. This function can be analyzed by mapping the number of workshops and conferences devoted to a specific technology topic and the network size and intensity over time.
4	**Guidance of the search**	Since resources are almost always inadequate, it is important that, when various technological options exist, specific foci are chosen for further investments. Without this selection, insufficient resources will be left for the individual options. This function can be fulfilled by focusing on a specific sector like crop productivity, the government, and/or the market. Therefore, when knowledge creation (function 2) is regarded as the creation of technological variety, this function represents the selection process.
5	**Market formation**	New technology often has difficulty competing with embedded technologies. One possibility is the formation of temporary niche markets for specific technology applications. Within such an environment, actors can learn about the new technology (functions 2 and 3) and expectations can be developed (function 4). This function can be analyzed by mapping the number of niche markets introduced, specific tax regimes for new technologies, and new environmental standards that improve the chances for new environmental technologies.
6	**Resource mobilization**	Resources, both financial and human capital, are necessary as a basic input to all activities within the innovation system. Allocating sufficient resources is essential for a specific technology to make knowledge production possible. In this sense, this function can be regarded as an important input to function 2.

7	**Overcoming resistance to change**	In order to develop well, new technology has to become part of an incumbent regime, or it even has to overthrow it. Parties with vested interests will often oppose this force of creative destruction. In that case, advocacy coalitions can function as a catalyst; they put new technology on the agenda (function 4), lobby for resources (function 6) and favourable tax regimes (function 5), and by doing so, create legitimacy for a new technological trajectory

Source: Klerkx *et al.* (2012)

This study analysed how ICTs can improve interactions among various actors of AIS to increase crop productivity. In this regard, this study is in line with function 1, whereby young farmers are engaged in crop production as one of the self-employment initiatives; function 2, whereby ICTs are considered a source of information and knowledge; and function 3, where young farmers adopt ICTs for crop productivity endeavours. The expectation of establishing effective functioning of AIS is to facilitate dissemination and information sharing of agricultural innovations and technologies among actors. This will lead to agricultural reforms, increasing crop productivity (function 4).

Various studies (see for example, Scoones and Thompson, 2009; Klerkx *et al.*, 2010) used AIS to explain the value of economic performance in some developed countries driven by a strong orientation to innovation. The AIS is a network of agents interlinking in the economic arena or sector under a certain legal framework and engaged in technology generation, diffusion, and utilization (Hekkert *et al.*, 2007). The AIS is considered multi-actor interactions and structures (infrastructures, policies, institutions) that enhance innovation, assuming that innovation is above technology development. The AIS also often requires the improvement of elements of the innovation system to enable coordination of the relevant sub-systems.

In this study, AIS is defined as a network of actors, firms, and other economic actors, including institutions and policies, with an impact on their innovative behaviour and performance in bringing new products, processes, and forms of organization into economic use (Mytelka and Goertzen, 2004). On the other hand, actors are defined as people, groups, or organizations that influence youth into using ICTs for increased crop productivity (Cadger *et al.*, 2016). These actors normally are constituted from both public and private sectors, whose interactions could initiate, adopt, modify, and diffuse new technologies related to crop productivity (Lundvall, 2007).

Drawing from the framework of AIS, interactions and ideas that promote innovation comprise knowledge production, access, and application (Hall *et al.*, 2006). Therefore, in this case, innovation is considered the product of interactive learning (Szogs, 2008), whereby new knowledge is generated when different organizations interact and share knowledge. Hence, Agricultural Innovation Systems, as a concept, are places of interactive learning and the centre of discussions on innovation, growth, and development (Lundvall, 2016). Therefore, according to Pamuk *et al.* (2014), innovation, in this case, focuses on enhancing productivity and is thus considered the ability to apply emerging knowledge or recombine existing knowledge to improve crop productivity.

In this study, productivity indicates the myriad relationship between agricultural output and major inputs (Iqbal *et al.*, 2015), whereby crop productivity per area is calculated by dividing total production by cultivated area. However, while these growing innovations in agriculture suggest opportunities for young farmers, there is inadequate literature on how ICTs can be used effectively to enhance AIS, leading to enhanced crop productivity.

Crop production and productivity trends in Tanzania have been fluctuating over time (Mkonda and He, 2016). Low crop productivity in Tanzania has mainly been attributed to the inability of smallholder farmers to take up and use modern technologies such as ICTs; and the presence of complexities associated with multiple interventions and the actors involved in agriculture and rural societies in general (Asfaw *et al.*, 2012). Moreover, information on how actors in crop productivity take advantage of ICTs through AIS interactions has often been limited. Yet, current development realities, which are multi-faceted and require different expertise to work collectively on a given or identified issue, are not well linked with ICTs use. Hence, information on how ICT use relates to AIS effectiveness in enhancing crop productivity is still scanty.

Various scholars have explained how interaction among various actors can enhance crop productivity. For instance, Emodi and Madukwe (2010), who assessed the linkage mechanisms of key actors in the rice innovation system in Southern Nigeria, found that the dissemination of knowledge and information was the major linkage mechanism among the actors. However, their study did not consider suitable mechanisms to enhance linkages/interactions among those actors. Asenso-Okyere and Mekonnen (2012) studied the importance of ICTs in providing information for improving agricultural productivity and rural incomes in Africa. They found that ICTs facilitate the dissemination of knowledge and information on agricultural production and the provision of market information to maximize the returns to agriculture. Thus, smallholder incomes can be increased with the interactions between actors such as extension agents, agricultural commodity exchange, telecommunication companies, and radio to access knowledge and information.

Luqman *et al.* (2016) assessed the impact of agricultural services provided by non-state actors in Pakistan and found that non-state actors such as extension education, training related to crop and livestock management, poultry and forestry services, vaccination for livestock and awareness campaigns regarding the latest agricultural technologies improved their overall agricultural productivity. Furthermore, a study viewed that actors' interaction played a significant role in upgrading the livelihoods of rural poor. A study done in Amhara Region in Ethiopia by Deneke and Gulti (2016) found that a fragmented and underdeveloped innovation system characterizes the agricultural research and extension system. It revealed further that farmers are perceived as passive receivers of technology. But the study did not address how research outputs could reach farmers. Moreover, ICTs are argued to enhance knowledge creation, accumulation and dissemination through interactive learning among the actors or industries (Zhang and Liang, 2012).

Hence, an analysis based on the AIS framework can address the discrepancy between the policy reforms, actors, and linkages on the one hand and crop productivity on the other. The framework draws attention to the diverse actors contributing to the agricultural innovation process. These include research, extension, input supply and credit, marketing, production, and regulation. It also underscores the roles, responsibilities, actions, interactions, and institutions that influence behaviours and practices. Investigation of the influence of ICTs as an enabler of AIS functioning is important because of the slow uptake of the ICTs as a means of disseminating agriculture-related information and knowledge to young farmers. Therefore, this study sought to answer whether ICTs can influence interactions to enable young farmers to benefit from innovations related to crop productivity dispensed by other actors.

2.0 THEORETICAL FRAMEWORK

The Social Network Theory (SNT) was used to guide this study. The SNT considers social relationships in terms of nodes and ties (Borgatti *et al.*, 2009). The nodes are individual players, people, or things in the network, and ties are the linkages or interactions that bring them together. The SNT looks at the role of social linkages in transmitting information, channelling personal or media influence, and enabling attitudinal or behavioural change.

2.1 The AIS and ICTs Framework

Agricultural Innovation System can be described in terms of sectoral innovation system (SIS), national innovation system (NIS), regional innovation system (RIS), or technology innovation system (TIS). These frameworks focus on the processes that are highly important for well-performing AIS (Figure 1).

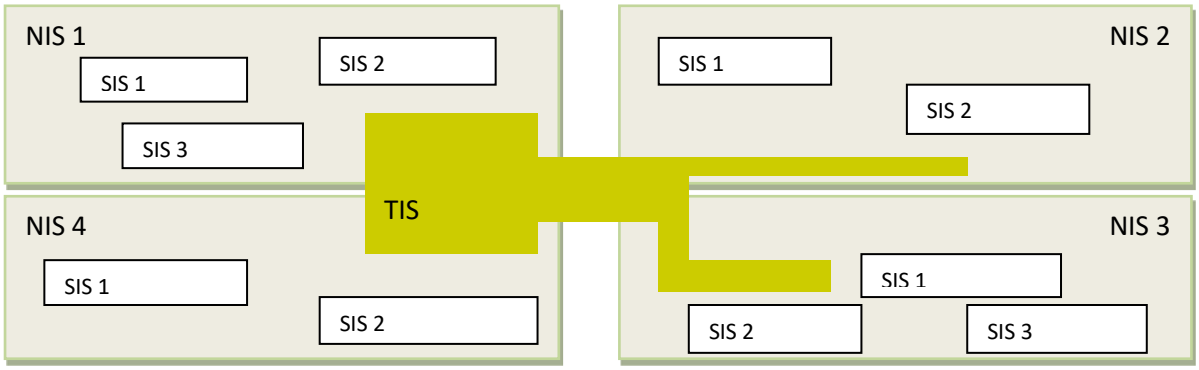

Fig. 1: Boundary relations between national, sectoral, and technology innovation systems
Source: Adapted from Hekkert *et al.* (2007)

Many national and sectoral innovation systems cause the diffusion of a particular technology. For example, figure 1 shows how TIS connects to NIS and SIS approaches. It further indicates that the TIS overlaps with some elements of NIS and other SIS, which, in turn, are embedded in the NIS.

This paper uses the concept of SIS, a network of actors interlinking in the industrial/sectoral area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology (Carlsson and Stankiewicz, 1991). In this respect, actors, links and relevant institutions in the crop production sub-sector are much smaller than the NISs and TISs. This reduces the complexity level; therefore, a dynamic analysis is appropriate for this aggregation level. The SIS presents a multidimensional, integrated, and dynamic view of the crop production sub-sector. Sectoral systems have a knowledge base, technologies, inputs, and potential or existing demand. The sectoral system enables actors at all levels of aggregation, with the specific learning process, competencies, organizational structure, beliefs, objectives, and behaviours, to interact and be shaped by institutions through the process of communication, exchange, cooperation, competition and command using ICTs. The main advantage of a sectoral system view is its better understanding of the sectoral structure, boundaries, and transformation, as well as actors and their interactions.

Three dimensions of sectoral systems affect the generation and adoption of new technologies. The first dimension is knowledge (and the related boundaries), where the crop production sub-sector is characterized by a knowledge base, technologies and inputs. The second dimension, the sector, comprises heterogeneous actors and networks such as researchers, extension agents, input supplies, creditors, marketing, production and regulation. And third, actors' cognition, action, and interactions (the essence of AIS) are shaped by institutions, namely norms, routines, common habits, established practices, rules, laws, standards and so on (Klerkx *et al.*, 2012).

3.0 METHODOLOGY

The study population is comprised of all actors in tomato, paddy and cotton innovation systems in two districts of Misungwi and Kilosa located in the Northwest and Eastern Agro-Ecological Zones (AEZ) of Tanzania respectively. The AIS actors were classified according to their related activities as follows: policymakers, researchers, technology transfer and innovation agencies, young farmers, marketers, and consumers.

Thirty-eight (38) identified AIS actors to characterize the social network, and network relations (ties) were selected purposively. These included three (3) staff from Tanzania Agricultural Research Institutes (TARI) Ilonga, two (2) staff from the Ministry of Agriculture Training Institutes (MATI) Ukiriguru, eight (8) extension agents, five (5) input suppliers, two (2) staff from government seed agencies, three (3) traders, two (2) staff from financial institutions, two (2) staff from Non-Governmental Organizations (NGOs), and two (2) consumers.

Four hundred (400) young farmer households were selected from eighteen (18) villages using the multistage sampling method. Stage one (1) was a purposive selection of two districts, stage two (2) involved the selection of three (3) administrative wards from each district, stage three (3) involved a random selection of three (3) villages from each ward, and finally, stage four (4) was a random selection of young farmers' households (15 to 35 years old). Each of the 400 sampled young farmers' households were asked to name a fellow young farmer he/she had contacts with when searching for crop productivity information using ICTs such as mobile phones or computers. There was no restriction on the number of young farmers to be listed and interviewed. After identifying the number of connections that the 400 household heads or youths hada compiled list of new focal farmers was obtained. A focal farmer had to be mentioned by at least four (4) different other respondents; this was the average number to qualify for inclusion in the list.

In the next stage, ninety (90) young focal farmers were randomly selected (5 per village) from the new list of focal farmers. The 90 young focal farmers represented the farmers' actors in the AIS. A questionnaire was then developed and administered to these actors. Each respondent (AIS players) was asked to show which actor in the given list he/she shares various information using ICTs, and to indicate the direction of the communication. Finally, the innovation system was mapped using the Social Network Analysis (SNA).

4.0 RESULTS AND DISCUSSION

4.1 Actor Centrality Measures in the AIS

Table 2 shows the mean matrix of actors' interactions with each other through ICTs. This aimed at determining how these key actors facilitate the smooth delivery of agricultural-related information that meets the diverse needs of a farmer in crop production. The actors are placed in the diagonal cells, and their connections are placed in the matrix cells. The matrix has a coded linkage with binary codes: '0' for 'no interaction' and '1' for the 'existence of interaction.

Table 2: Mean of matrix of actors' interactions through ICTs

Actors	TARI	MATI	EXT	SUP	SA	PRO	TRA	FM	FI	NGOs	CON
TARI		1	1	1	1	0	0	1	0	1	0
MATI	0		1	1	1	0	0	1	0	0	1
EXT	1	1		1	1	1	1	1	0	1	1
SUP	1	1	1		1	1	1	1	1	0	1
SA	1	1	1	1		0	1	1	0	0	1
PRO	0	0	1	1	0		1	1	0	0	1
TRA	0	0	1	1	1	1		1	1	0	1
FM	0	0	1	1	0	1	1		0	1	1
FI	0	0	0	1	0	0	1	0		0	0
NGOs	1	1	1	1	1	1	1	1	0		1
CON	0	0	1	0	0	1	1	0	0	0	

Note: **TARI** - Tanzania Agricultural Research Institutes, **MATI** - Ministry of AgricultureTraining Institutes, **EXT** - Extension Agents, **SUP** - Input supplies, **SA** - Seed Agencies, **PRO** – Processors, **TRA** – Traders, **FM** - Young farmers, **FI** - Financial Institutions, **NGOs** - Non-Governmental Organizations, **CON** - Consumers

The coded linkage matrix in Table 2 may be represented as a diagraph with 11 nodes/vertices and 64 edges (Fig 2).

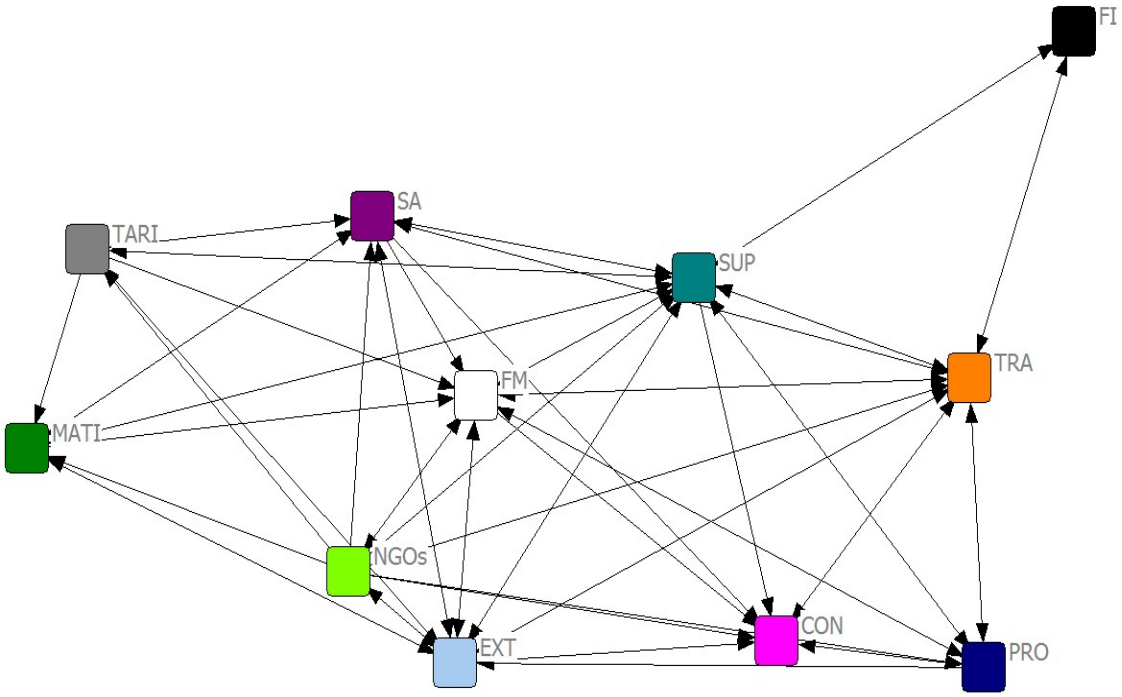

Fig. 2: Diagraph showing linkage matrix among actors

Each node is determined by either degree of centrality of the node or the number of ties that the node has in reaction to the total number of ties in the network as a whole, out-degree, in-degree, betweenness and eigenvalue (Table 3). Centrality measures are related to crop productivity information (not included in the regression estimates) regarding the crop productivity innovation system. High centralities indicate the actors' role in providing information using ICTs (Figure 2).

Table 3: Agricultural Innovation System actor-network centrality measures

Actors ($n = 11$)	**Total Connections**	**$n - 1$**	**Degree Centrality $(n - 1)/10$**	**In-degree**	**Out-degree**	**Betweeness**	**Eigen Value**
Tanzania Agricultural Research Institutes (TARI)	6	10	0.60	0.2	0.4	0.00	0.26
Ministry of Agriculture Ministry of Agriculture Training Institutes (MATI)	5	10	0.50	0.2	0.3	0.00	0.26
Extension Agents (EXT)	9	10	0.90	0.8	0.5	1.47	0.35
Input supplies (SUP)	9	10	0.90	0.8	0.2	6.47	0.36
Seed Agencies (SA)	7	10	0.70	0.5	0.2	0.80	0.33
Processors (PRO)	5	10	0.50	0.4	0.5	0.00	0.26
Traders (TRA)	7	10	0.70	0.8	0.5	3.17	0.31
Young farmers (FM)	6	10	0.60	0.8	0.5	1.47	0.35
Financial Institutions (FI)	2	10	0.20	0.4	0.1	0.00	0.86
Non-Governmental Organizations (NGOs)	9	10	0.90	0.2	0.5	1.47	0.35
Consumers (CON)	3	10	0.30	0.7	0.2	0.17	0.30

The analysis of various points of the centrality measures for the actors or the AIS indicates that actors at the most central position are extension agents, input supplies, and NGOs. First, the focus is on the in-degree centrality measures among young farmers and the other AIS actors. This indicates the actor's popularity; thus, the actor's frequency is referenced to her peers for crop productivity innovations. Young farmers have a normalized in-degree value of 0.8, indicating that 80% of the existing ties requesting information about crop productivity innovations using ICTs within the AIS are directed to young farmers. Extension agents, input suppliers, and traders (with the in-degree value of 0.8 each) were information providers (function number 2 of AIS) to young farmers in the study areas. This was confirmed during Focus Group Discussion (FGD) held at MATI Ukiriguru in Misungwi District that young farmers are the centre of any innovations related to crop productivity. These findings are in agreement with those of Magnan *et al.* (2015), who subscribe that nodes with higher in-degree values played key roles in the identification of actors to be provided with improved technologies in the network.

The calculation of out-degree centralities (the level of reach) indicates that young farmers, NGOs, extension agencies, processors, and traders had the out-degree measure of 0.5, translating to 50%. These actors play an important role in introducing technological innovations into the crop productivity innovation system, which is function number 3 of AIS. The high out-degree measure of young farmers, NGOs, extension agencies, processors, and traders is somewhat not surprising because traditionally, these actors, especially extension agents, play a vital role in extending knowledge and information from researchers to young farmers (Emodi and Madukwe 2010; Mtega and Msungu 2013; and Benard *et al.,* 2014). There was a collaboration between young farmers and companies such as Cotton Oil Co., Ltd (ICK) in farmer field trials for new, improved cotton seeds in Misungwi District. This allowed ICK to play the temporary role of the extension agent. However, these results confirm young farmers' importance in disseminating innovations in the AIS. This finding is in line with that of Wuepper *et al.* (2014), who studied the importance of actors' interaction in AIS in Ghana and found that actors such as CRI, extension agents, plantain farmers, input dealers, NGOs, marketers, and processors were important actors in the innovation system.

The betweenness centrality measures the role of actors in the delivery of information within the network. Besides, the betweenness centrality identifies actors who facilitate a flow of information or serve as a link for information transfer between other actors, which is considered function 3 of AIS. Freeman's betweenness centrality was estimated for each network player as presented in Table 3. The betweenness measure is high for input supplies representing approximately 64.2% of all the existing ties, followed by traders with the betweenness measure of 31.7% and then young farmers, extension agents and NGOs with each having a betweenness measure of 14.7% of the total ties respectively. These findings imply that if innovations are introduced into the AIS, the shortest path of disseminating such information is through input supplies, traders, young farmers, extension agents, and NGOs (function number 3 of AIS). Hence, innovations spread faster using these actors in the AIS. This finding emphasizes the importance of interactions among young farmers, extension agents, and NGOs in the innovation system. However, other researchers such as Wuepper *et al.* (2014) report the decline of the role of input supplies, traders, extension agents and NGOs in transferring innovations over time because of constraints in personnel and logistic capacities, resulting in the loss of trust in the eyes of young farmers

4.2 Actors' Influence and their Interactions' Strengths within AIS

Although the network centrality indices can be interpreted as an actor's influence and prestige in the network, the eigenvector centrality measure determines the actor's influence in the AIS. Based on the eigenvector centrality on a scale of 0-1, the study shows that financial institutions were more influential (0.86) than any other actors identified in the AIS, which is considered function number 6 of AIS. Financial institutions play a great role in AIS intervention by supporting research and development and providing credit facilities to farmers for input and output supplies (Anandajayasekeram, 2011). Although financial institutions are the most influential actors in the AIS, they are somewhat peripheral to the young farmers' innovation networks. Financial institutions consider young farmers as risk groups to provide financial credits, as remarked during FGD held in Kilosa District. The findings show that public research institutes, extension agents and financial institutions play a vital role in AIS (function number 2 of AIS). These

findings are in support of the findings by Agwu *et al.* (2008) in Nigeria, who found that public research and extension agents are the major source of innovation/knowledge required to initiate development in the agricultural sector. The emerging reforms and changes in agricultural knowledge structure imply that traditional agricultural research and extension systems alone, without financial inclusion, cannot sufficiently address the challenges of AIS. Incorporating ICTs and financial institutions to facilitate knowledge, information flow, and crop productivity offers a holistic and multi-disciplinary approach to innovation and processes.

The matrix was refined by going one step further and considering measuring the strength of the interaction among actors. After interviewing all actors, six (6) vectors were developed. The matrix in Table 4 was generated by reducing the linkage strengths to an average vector for all the actors. Thus, data were taken from all actors separately on the degree of linkages each player had developed with other system players. For example, the young farmer scale value of 1, 2, 2, 2, 1, and 2 from 6 actors were observed. The average of these scores is 1.666 (rounded to 2).

Table 4: Mean of matrix of strengths of actors' interactions using ICTs

Actors	TARI	MATI	EXT	SUP	SA	PRO	TRA	FM	FI	NGOs	CON
TARI		1	3	2	2	0	0	1	0	2	0
MATI	1		1	1	1	0	0	1	0	0	2
EXT	2	2		3	3	2	3	2	0	2	3
SUP	2	1	3		3	2	2	2	1	0	2
SA	2	1	3	3		0	2	2	0	0	2
PRO	0	0	1	1	0		3	2	0	0	3
TRA	0	0	1	1	1	1		1	1	0	3
FM	0	0	1	2	0	2	2		0	1	2
FI	0	0	0	1	0	0	1	0		0	0
NGOs	1	1	2	2	1	2	3	3	0		3
CON	0	0	0	0	0	3	3	0	0	0	

Note: 0 = no relationship, 1 = weak relationship, 2 = moderate relationship and 3 = strong relationship.

Using young farmers as a centre of knowledge in AIS, a weak relationship existed between young farmers, extension agents, and NGOs. In contrast, a moderate relationship was found between young farmers, input supplies, traders, and consumers. Extension agents had a strong relationship with input supplies and young farmers and a weak relationship with processors and traders. Many actors highly influenced Extension agents (having nine edges, see Figure 4), and their intensity of interaction varied with different key actors of the system, showing a weak relationship with agricultural training institutes and NGOs.

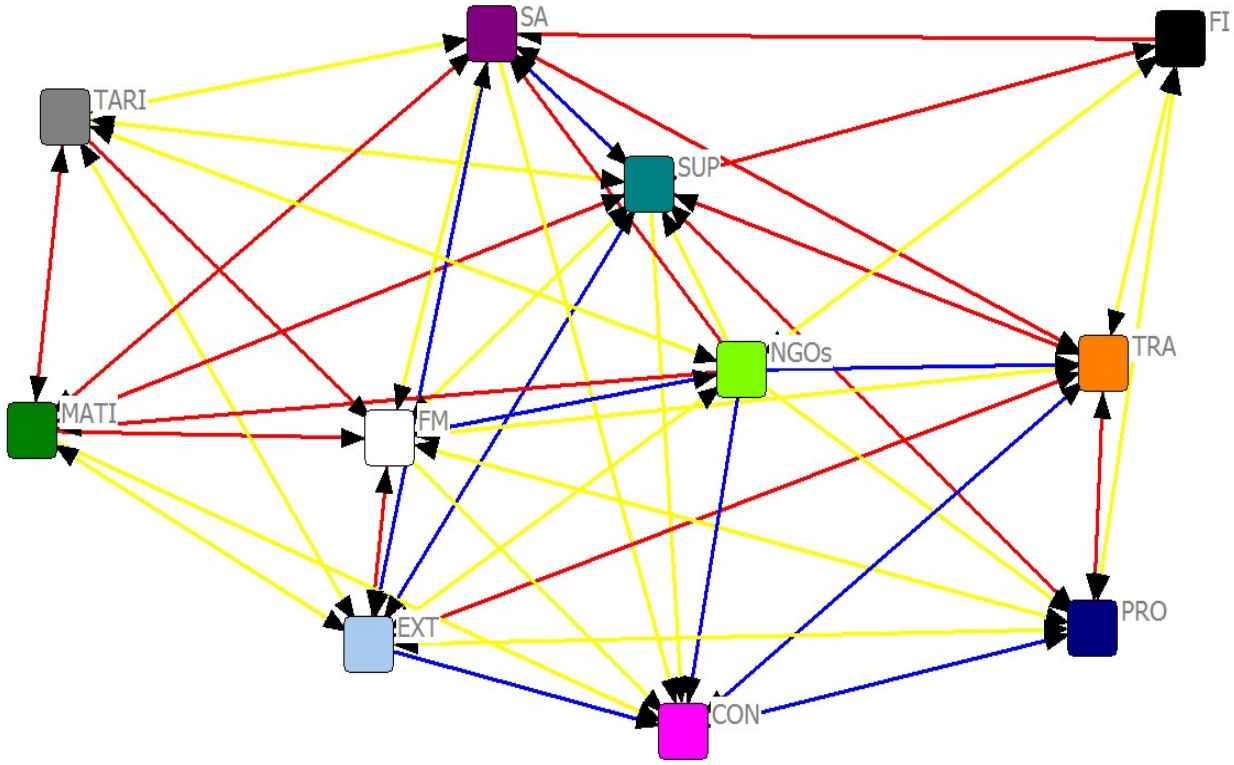

Figure 3. Diagraph showing the strength of the relationship among key actors
Key: Red edges=weak relationship, Yellow edges=Moderate relationship, Green edges =Strong relationship

Another approach used to analyze the relationship among key players was to consider the importance of each player in the system (Table 5). The bottom line was identifying which actors are key in enhancing crop productivity through the adoption of ICTs.

Table 5: Mean of Matrix of actors' importance in influencing ICT usage

Actors	TARI	MATI	EXT	SUP	SA	PRO	TRA	FM	FI	NGOs	CON
TARI		3	3	3	3	1	1	3	3	3	2
MATI	3		3	3	3	1	1	3	3	3	3
EXT	3	3		3	3	2	3	3	3	3	3
SUP	3	3	3		3	3	3	3	3	2	2
SA	3	3	3	3		1	3	3	3	3	3
PRO	1	1	2	1	2		3	3	2	2	3
TRA	2	2	2	2	2	3		3	3	2	3
FM	3	3	3	3	3	3	2		3	3	3
FI	2	2	2	2	2	3	3	2		2	2
NGOs	3	3	3	3	3	3	3	3	3		3
CON	3	3	2	2	2	3	3	1	2	2	

Keys: 1 = less important, 2 = important and 3 = very important

According to the study, young farmers rated 3 to all actors as being very important in interacting with them for crop productivity. In addition, the findings depict that despite farmers' response to having no relationship with financial institutions, farmers still considered financial institutions important players in the AIS. These findings are in concurence with thaose of Onumah *et al*. (2021) who found that local financial institutions played a minimal role in funding innovation activities among farmers.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This paper discusses how ICTs can improve interactions among various actors of AIS to increase crop productivity. The study areas were Misungwi and Kilosa districts, which are part of the Northwest and Eastern Agro Ecological Zones (AEZ) of Tanzania respectively. The study population was comprised of all actors in tomato, paddy and cotton innovation systems. The paper concludes that increased crop productivity is driven by the readily available new technologies and improved incentives for farmers and agro-enterprises supported by enabling government policies. However, despite having various responsible actors for crop production technology and innovation, interactions and linkages between these actors are not strong enough to allow better use of the technologies and knowledge because of communication asymmetry resulting from underutilization of ICTs.

The paper concluded further that the information flow was not reversed among most of the players/actors of the crop productivity innovation system. For example, there are weak linkages between young farmers and extension agents, seed agencies, and non-governmental organizations. On the other hand, there is a one-way communication mechanism between young farmers and agricultural research institutes registering limited feedback related to crop productivity. Furthermore, social network capital is crucial in enhancing the adoption of ICTs as one of the AIS perspectives. Particularly, in a situation where there is asymmetry of information on crop productivity innovation system, there is a closer connection between young farmers and other players who influence crop productivity, such as research institutes, extension agents and financial institutions. It can also be concluded that the existence of a social network increases access to proper and timely information regarding the profitability of the new and improved crop productivity innovation. In particular, the study concluded that ICTs adoption among young farmers increased the probability of increasing crop productivity by 33.31% using Propensity Score Matching (PSM) and 34.52% using the Inverse Probability Weighted Adjusted Regression (IPWRA) specifications.

5.2 Recommendations

This study has registered some policy recommendations as follows. First, support for agricultural innovations from research requires an increased focus on the interface with the rest of the agricultural sector. In particular, it requires developing links from the beginning in a way that encourages interactions with the aid of ICTs between public, private and civil society organizations. This necessitates support for service providers who can facilitate engagement between partners to create trust, cooperation and a common vision required for innovation. Second, support should be provided to encourage institutional cooperation, joint planning, implementation, analysis and learning processes rather than more traditional technology-orientated research undertaken in isolation from other crop productivity players. In turn this requires that researchers with expertise such as Tanzania Agricultural Research Institutes (TARIs) should adopt an holistic approach in their work to include a good wide knowledge of markets, agri-business and rural financial institutions that can complement specialist technical expertise.

Weak interactions identified among crop productivity sub-sector players call for special attention. Therefore, public policies and public-private partnerships are recommended to be active and work to enhance interaction by engaging all the actors in the crop productivity sub-sector to develop a platform for sharing various technologies and relevant information on the innovation system. This would improve crop productivity and explore the use of the untapped experiences among young farmers. Furthermore, the findings of the influence of financial institutions on young farmers' ties in the social network, which then enhance adoption, suggest that financial institutions need to work closely with young farmers in crop productivity endeavours.

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