TRANSFORMATION OF AGRICULTURAL TECHNOLOGY DEVELOPMENT APPROACHES IN TANZANIA

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EXTENDED ABSTRACT

This study aimed at analyzing the transformation of agricultural innovation approaches in Tanzania, from a ‘linear’ to ‘system’ mode of innovation, responding to reform measures and new heterogeneous demands from the agricultural sector. The Agricultural Innovation System (AIS) approach allows multiple actors to participate in agricultural chains and also accommodate the institutional and organizational innovation. Using the perceptions of researchers and their experiences from technologies generated from agricultural Research and Development (R&D) institutions and organizations, the research study provides the answer of why the adapted features of system mode of innovation by the National Agricultural Research System (NARS) over time, have not sufficiently enhanced the impact of technological innovation in Tanzanian agriculture, particularly on reaching the majority smallholder resource-poor farmers that are weakly linked to the market. The research applied mixed methods approach involving quantitative and qualitative methods, including survey of 100 researchers and 87 technologies, and in-depth key informant interviews. Analysis of the quantitative data indicated that, awareness of features of AIS is limited to about half (50%) of researchers. However, quantitative data and qualitative information form the technologies, identified various features of AIS that are incorporated in NARS. Further analysis identified that about 69% of the agricultural technologies from R&D are potentially public goods hence are managed through innovation intermediation / brokerage roles performed in a project set-up by R&D institutions and NGOs. The inadequate involvement of private sector in agricultural innovation was mainly due to lack of viable commercial market for this type of agricultural technologies. The study concluded that a number of institutional features of agricultural innovation system have been incorporated in the current NARS in Tanzania, however, present limited delivery of innovations. All stakeholders should promote, support and sponsor research using the ‘system’ approaches of agricultural innovation at all levels. In order for this to happen, it demands on policy re-orientation regarding modes of operation, management style, and the legal framework. Enabling environment for wider stakeholders participation in research and extension should also be adopted and the indicators of performance for agricultural research should capture not only technical innovations, but also institutional, organizational and managerial innovations.

DECLARATION

I, **ATHMAN HAMZA MGUMIA** do hereby declare to the Senate of Sokoine University of Agriculture that the work presented here is my original work done within the period of registration and that it has neither been nor concurrently being submitted for a higher degree award in any other institution.

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

AFO	Agricultural Field Officer
AI	Agricultural Innovation
AIS	Agricultural Innovation System
ARI	Agricultural Research Institute
ASA	Agricultural Seed Agency
ASDP	Agricultural Sector Development Programme
AKIS	Agricultural Knowledge and Information System
ASLM	Agriculture Sector Lead Ministry
ATTC	Agricultural Technology Transfer Centre
BTC	Belgium Technical Cooperation
CSMF	Cassava Seed Multiplication Farm
CRS	Catholic Relief Services
CFFO	Community Family Farmers' Organization
CORDEMA	Client Oriented Research and Development Management Approach
COSTECH	Tanzania Commission of Science and Technology
CPTP	Cassava Processing Technology Project
DADP	District Agricultural Development Plan
DAICO	District Agricultural Irrigation and Cooperative Officer
DFT	District Facilitation Team
DC	District Commissioner
DED	District Executive Director
DMBC	District Marketing Bulking Centre
DONATA	Dissemination of New Agriculture Technologies in Africa
FAO	Food and Agricultural Organization

FFS	Farmer Field School
FSR	Farming Systems Research
IITA	International Institute for Tropical Agriculture
IIPI	Innovation Intermediary Projects Interventions
IPAT	Innovation Platforms for Technology Adoption
IPR	Intellectual Property Rights
LGAs	Local Government Authorities
LGRP	Local Government Reform Programme
MAFC	Ministry of Agriculture, Food Security and Cooperatives
MALFD	Ministry of Agriculture Livestock and Fisheries Development
MGLPP	Misungwi Grain Legume Pilot Project
MHRP	Mwanza Rural Housing Project
MUCCOBS	Moshi University College of Cooperative and Business Studies
MKUCAPCOJE	Mkuranga Cassava Processing Cooperative Joint Enterprises
MKUKUTA	*Mkakati wa Kukuza Uchumi na Kuondoa Umasikini Tanzania*
MVIWATA	*Mtandao wa Vikundi vya Wakulima Tanzania*
NARI	National Agricultural Research Institute
NARS	National Agricultural Research System
NAEP II	National Agricultural Extension Project Phase II
NALERP	National Agricultural and Livestock Extension Rehabilitation Project
NFRA	National Food Reserve Agency
NGOs	Non Governmental Organizations
NIS	National Innovation System
NRI	Natural Resource Institute,
OECD	The Organization for Economic Co-operation and Development
OFSP	Orange Fleshed Sweet Potato

OPVs	Open Pollinated Varieties
PBR	Plant Breeders Right
PBRA	Plant Breeders Right Act
PPP	Public Private Partnership
QDS	Quality Declared Seed
QPM	Quality Protein Maize
R&D	Research and Development
SILC	Saving and Internal Lending Communities
SMEs	Small and Medium Enterprises
SSA	Sub-Saharan Africa
SPSS	Statistical Product and Service Solution
SUA	Sokoine University of Agriculture
TaCRI	Tanzania Coffee Research Institute
TARP	Tanzania-Agricultural Research Project
TANSEED	Tanzania Seed Company
TBS	Tanzania Bureau of Standards
TC	Tissue Culture
TFDA	Tanzania Food and Drug Authority.
TFNC	Tanzania Food and Nutrition Centre
TFSP	Tanzania Food Security Project
TIS	Technological Innovation System
TOSCA	Tanzania Official Seed Certification Agency
TORITA	Tobacco Research Institute of Tanzania
TTO	Technology Transfer Office
UMADEP	Uluguru Mountains Agricultural Development Project
URT	United Republic of Tanzania

VECO	Vredeseilanden Country Office
VC	Value Chain
WDC	Ward Development Council
ZARF	Zonal Agricultural Research Fund
ZARDEF	Zonal Agricultural Research and Development Fund
ZIELU	Zonal Information and Extension Liaison Unit

CHAPTER ONE

1.0 General Introduction

This thesis deals with transformation in agricultural innovation approaches in Tanzania. Comparable to many other sub-Saharan African (SSA) countries, Tanzania has reformed the agricultural research system to allow multiple actors to participate in agricultural innovation and also to accommodate the institutional and organizational dimensions of agricultural innovation (Sumberg, 2005; Sempeho, 2004; Rutatora and Mattee, 2001; Chema *et al*., 2003). Apart from a vast literature on the adoption of agricultural technologies during and after the Green Revolution (Gollin *et al*., 2005), the trend of the studies on innovation particularly in Tanzania, however, have been mainly on industrial technologies with regard to exploring innovation systems and intermediary organizations, for example, Szogs and Wilson (2006); Szogs (2008); Szogs *et al*. (2011) and Diyamett (2009), with the exception of few studies particularly on sectorial innovation (Malerba and Mani, 2009) and commission studies on specific crops (Larsen *et al*., 2009).

This thesis expands the scope of agricultural innovation studies to include crop and livestock-based innovations and to analyze the innovation system not only on the structural and process perspectives as it has been always the case (Klerkx *et al.,* 2012; Wieczorek and Hekkert, 2012), but also to include the dimension of characteristics of technologies. Hence, specifically this study is about the changes that have taken place in the set of actors, their roles, outcomes of their interactions and relationships among the players of agricultural innovations, particularly crop based (seeds, seed multiplication techniques, fertilizers and food processing technologies) in responding to the challenges facing agricultural development in sub-Saharan Africa, particularly Tanzania. The challenges are related to the ambiguous innovation systems and inadequacy of capacities of key players, particularly in the context of smallholder dominated farming systems, poorly linked to the market.

The following sections of this introductory chapter briefly describe the background information about the research problem for the subsequent studies, the broader objectives and provide a reflection on the methods used.

1.1 Background of the Study

Tanzania, like many other SSA countries, during 1980s created the National Agricultural Research Systems (NARS) (Taylor, 1991), purposely to conduct applied research and to adjust imported technologies to fit relevant ecological and production conditions, and pass them through extension agencies to the ultimate users (Pineiro, 2007). It is through this approach, that the beneficiaries who are mostly subsistence farmers could be reached. However, for a number of reasons the system has not performed well (Norman, 2002; Sumberg, 2005; Simpson, 2006; Agwu *et al*., 2008). On the research side, the studies highlighted some general reasons for poor performance of NARSs particularly in SSA to include: scientific orientation thus isolation from economic production, lack of organizational structure that focuses on interdisciplinary problems faced by the farmers, and underfunding (Norman, 2002). On the extension side, the reasons include inadequacy in quantity and quality of trained personnel to deal effectively with the complexities of new technological packages in such a way that a reasonable proportion of the targeted farming population could be reached (Sumberg, 2005; Simpson, 2006; Agwu *et al.,* 2008).

In this regard, a more system oriented mode of agricultural innovation has gained popularity as a framework for understanding constraints and identifying opportunities for enhancing the innovation capacities of agricultural systems particularly in SSA (Chema, *et* *al*., 2003; Hall, *et al*., 2005). Among the reported approaches include innovation platforms (Hounhonnou *et al.,* 2012); innovation intermediaries (Klerkx and Leeuwis, 2008a); innovation brokers (Klerkx and Gildemacher, 2012; Perez *et al*., 2010); commodity innovation system (Ortiz, *et al*., 2013); and public-private partnerships (Ayyappan *et al.,* 2007; Hartwich, *et al.,* 2007a; Hartwich *et al.,* 2007b; Ferroni and Castle, 2011 and Ngaiza, 2012). Thus, scholars have conceptualized this transition through a number of paradigms with each one being more comprehensive on innovation than the previous one, such as from the NARS, Agricultural Knowledge and Information System (AKIS) to the current Agricultural Innovation System (AIS) (Hall *et al.,* 2005, Hall *et al.,* 2006). Table1 below provides institutional features of the early (NARS) and latest (AIS) paradigms for comparison purposes.

Thus for the R&D institutions and extension providers to achieve impact of new technologies, they should give more attention to institutional and organizational innovations not only operationally but also in the priority for capacity building including indicators for measuring the outcomes and impacts.

Table 1. Similarities and differences between National Agricultural Research Systems (NARSs), Agricultural Information Knowledge Systems (AIKS) and Agricultural Innovation Systems (AISs)

Defining feature	**NARS**	**AIKS**	**AIS**
Purpose	Planning capacity for agricultural research, technology development, and technology transfer	Planning capacity for agricultural research, technology development, and technology transfer	Strengthening the capacity to innovate throughout the agricultural production and marketing system
Actors	National agricultural research organizations, agricultural universities or faculties of agriculture, extension services, and farmers	National agricultural research organizations, agricultural universities or faculties of agriculture, extension services, and farmers	Potentially all actors in the public and private sectors involved in the creation, diffusion, adaptation, and use of all types of knowledge relevant to agricultural production and marketing
Outcome	Technology invention and technology transfer	Technology invention and technology transfer	Combinations of technical and institutional innovations throughout the production, marketing, policy research, and enterprise domains
Organizing principle	Use of science to create inventions	Use of science to create inventions	New uses of knowledge for social and economic change
Mechanism for innovation	Transfer of technology	Transfer of technology	Interactive learning
Degree of market integration	Nil	Nil	High
Role of policy	Resource allocation, priority setting	Resource allocation, priority setting	Integrated component and enabling framework
Nature of capacity strengthening	Infrastructure and human resource development	Infrastructure and human resource development	Strengthening interactions between actors; institutional development and change to support interaction, learning, and innovation;

Source: Hall *et al*. (2005: 3)

1.2 Research Problem and Justification Of Study

Conventionally, agricultural research system in Tanzania is characterized by mixed approaches top-down, centralized and isolated institutional structures (URT, 2011). Mechanisms for enhancing linkages, interactions and learning among the components (actors) are weak due to various factors including missing links (Daniel, 2013; Larsen, *et al.,* 2009). For example; universities and agricultural research institutions in some cases innovate in isolation or collaborate through informal engagements, and research conducted at any level (national or international) is poorly linked to the produces or end-users. Initiatives such as the World Bank-supported National Agriculture and Livestock Extension Rehabilitation Project (NALERP) and National Agricultural Extension Rehabilitation Project (NAEP II), strongly emphasised demand–driven research. However, at the end of the project, it was reported that technology transfer was more of linear, supply–driven than demand-driven (Rutatora and Mattee, 2001).

A more recent agricultural reform in Tanzania was initiated through the Agricultural Sector Development Programme (ASDP) (URT, 2003). The programme aimed to transform the agricultural sector from subsistence to export agriculture through the active involvement of the private sector. The ASDP used a variety of R&D approaches: client and farmer empowerment; demand driven and market-led technology development; increased range of service providers and approaches to service provision; division of labor between local, district, and national governments; focus on economics, technical solutions; and increased accountability and transparency of processes (Gordon, 2008). In addition, ASDP endeavored to transform Zonal Agricultural Research Funds (ZARFs) to become Zonal Agricultural Research and Development Funds (ZARDEFs). ZARFs were established in 1997 aiming at having zonal research funds managed at each of the seven designated zones, with the common desire by donors to concentrate their limited assistance in small geographic areas where local impact is easier to be achieved (Gavian, *et al.,* 2001).

The aimed of changes were to make the research agenda demand driven and also supporting technology transfer interventions (URT, 2011).

However, it was reported that private sector involvement did not reduced reliance on government extension services for necessary service provision to smallholder farmers (Thornton, *et al.,* 2011). On the other hand, the participation of NGOs in research and extension has not only increased but also shifted to a process-oriented, demand-driven style of rural development, including local organizational capacity building and empowerment themes (Simpson, 2006). The reforms are discussed in more detail in the following sections.

1.2.1 Trends and reforms in the current National Agricultural Research System

In Tanzania, the changes and reforms guiding agricultural research and development are mainly dealing with governance structure, incentive mechanism, funding and changing approaches with regard to the type of actors, relationships and mechanisms (Table 2).

Table 2. Major reforms and changes in policies, national program and strategies on the crop sub- sector in Tanzania

Year	Reforms and changes	Outcomes with emphasis on innovation aspects
1973	Seed Act No. 29 of 1973 launched	Establishment of TANSEED and TOSCA to multiply and disseminate seeds
1989	National Seed Industry Development Program	Private seed companies allowed to operate
1989	National Agriculture and Livestock Extension Rehabilitation Project (NALERP) and National Agricultural Extension Rehabilitation Project (NAEP II) was launched	Adopting Farming System Research (FSR), strongly emphasise demand – driven research.
1997	Local Government Reform Programme (URT, 1998)	Extension services shifted from central government to LGAs
2001	Agricultural Sector Development Strategy (ASDS) adopted	Forms basis for public-private partnership in support of agricultural growth and rural poverty reduction.
2002	Plant Breeders Right Act (PBRA)	Protection of new varieties
2003	Seed Act of 2003, to replace the seed Act of 1973	Allows seed trade through promotion of plant breeding, multiplication and distribution of quality seed and other planting materials
2003	Agricultural Sector Development Programme (ASDP) launched	Public – private sector actions in support of agricultural growth and rural poverty reduction
2003	Client Oriented Research and Development Management Approach (CORDEMA)	Strengthening demand-driven research and extension
2005	Launch of SUA- IPR Policy	Establishment of TTO in 2007
2006	Agricultural Seed Agency (ASA) established	Produce, process and market both basic and certified seeds
2010	National Research and Development Policy of 2010	Emphasizes on commercialization and dissemination of research results.
2010	Southern Agricultural Growth Corridor of Tanzania (SAGCOT)	partnership of farmers, agri-business, the Government of Tanzania, and development agencies
2011	Ministerial circular on licensing of protected public varieties of plants (URT, 2011)	Allows private seed companies to access pre-basic seed of protected public bred varieties through licensing
2013	National Agricultural Policy of 2013	Provides enabling environment to attract private sector investment and particularly on value addition

However, the reforms and changes can easily be visualized through privatization of public agricultural knowledge especially from public research institutions, mainly crop varieties. Thus, in the current NARS, agricultural research is mainly conducted in government and private R&D institutions, and in universities. Agricultural research has largely been a public undertaking over the past several decades (Rutatora and Mattee, 2001), but following the provision for private sector based research, the current NARS is now a loose collection of multiple public, NGO and private institutions (Sempeho, 2004). These conglomerations of stakeholders do support both research and technology transfer but with different goals and through different approaches. Technologies generated from research are also diverse in nature from simple agronomic practices such as fertilizer rates to highly sophisticated technologies such as product of bio-technology. The end users also vary from small scale to large-scale producers.

The integration of multiple actors, market dimension and enabling environment within the NARS as indicated in the above trends (Table 2), confirms the observation by Anandajayasekeram and Gebremedhin (2009), that the reforms of agricultural R&D institutional systems in many SSA countries have already incorporated elements of the evolving Agricultural Innovation System (AIS). How these elements are perceived by researchers and have influenced the extent of economic use of technologies from agricultural R&D institutions in Tanzania are the questions investigated by this study.

1.2.2 The drivers of change and the emerging challenges and opportunities

Two major drivers of reforms can be observed from the above trends (Table 2). These are purposefully induced reform through the privatization process and the spontaneous reform stimulated by the different characteristics of the technologies generated from R&D institutions. As a consequence of public-private relationships emerging within the NARS following privatization reforms, the number of actors and stakeholders of the agricultural innovation have increased to include regulators of quality and safety standards as well as organizations responsible for the management and protection of intellectual property rights. Hence, apart from the believed benefits of privatization such as increased efficiency, effectiveness, accountability and reduced bureaucracy and corruption (Van de Walle, 1989), two economic risks have also become apparent including exclusion and substitutability risk.

The first is marginalization of resource-poor farmers in the innovation process due to high costs of inputs and inability to meet the demand of the market (big volumes of products and stringent quality and safety standards along the value chain). Kahn and Kamerman (1989) referred to this phenomenon as exclusion risks. On the supply side (research institutions), Starr (1988) alternatively defines privatization as the substitution of private goods for public goods (substitutability risk). In that case, taking an example of supplying of seeds of Open Pollinated Varieties (OPVs) to the end-users, the private companies are likely to replace OPVs with seeds that have higher market potentials such as hybrid varieties. OPVs, in economic sense are considered a public good since one can select seed from the previous harvest instead of buying new ones yearly. The trend of seed production in Tanzania illustrates the point, for example, the availability of hybrid maize seed in tons per year, has increased by 58% from about 35% in the years 2007/08 to 93% in 2011/12, compared to increase of less than 10% for OPV varieties like paddy (1% to 6%) and beans (0.5% to 2%) (Appendix 1). Also, about 80% of all maize varieties supplied by registered seed companies in the year 2013 were hybrid (Appendix 2).

The other driver of the reforms, which is also related to privatization, is the characteristics of technologies (particularly physical and economic characteristics) generated from public research institutions. The physical characteristics of the technologies (physical product and knowledge of use) necessitated more than one actor to deal with one technology. Taking an example of a new variety of maize, the physical part (seed), needs the private sector for mass production and dissemination while the associated recommended agronomic practices can be taken care of by agricultural extension services (mostly public). Therefore, the study will contribute to an understanding of how these two actors, which are operating under different domains (public and private), will be facilitated to ensure that a complete package is delivered to the intended end users at the right time and place.

The other physical characteristic of technologies is degree of complexity. This can be expressed in two forms: one is the level of complexity in terms of highly sophisticated facilities and expertise needed for development and mass production, for example biotechnological protocols; and two, the required devices to deliver the intended products such as food formulations, which need specialized processing machines for grinding, mixing, shaking etc. Thus, packaging for these kinds of technologies demand not only combinations of more than one technology but also linking different sources of these technologies. For the highly sophisticated technologies, due to the lack of specialized entrepreneurs equipped with sophisticated facilities and skills, the possible practical option is the establishment of spin-off companies where the facilities and experts from the source (R&D institutions) can easily be accessed with special agreement such as attachment, consultancy or lease arrangements. However, this requires conducive institutional policies.

The economic characteristics of technologies on the other hand determine the appropriability (excludability, rivalry/subtractibility) of goods (Hall *et al.*, 2001; Van den berg and Margee, 2001). This calls for facilitators to deal with non-appropriable technologies due to the unwillingness of the private sector to deal with them (Alston *et al.,* 1999). Again, experience from the seed industry in Tanzania is that, even though most of the seeds developed from R&Ds are OPVs (cereals and legumes); only few private companies are interested in these crops and none in vegetatively propagated crops. According to the list of seed production and importation for 2013 available at the Seed Unit of the Ministry of Agriculture Food Security and Cooperatives (MAFC), about 65% of the released varieties from R&D institutions were not taken up by seed companies, majority being legumes, vegetatively propagated crops and OPVs (Appendix 2). Vegetatively propagated crops are facing the same challenge as OPVs in that farmers can select seed from previous seasons, which limits participation of entrepreneurs in multiplication and dissemination (Appendix 2). Thus, the study provides evidence on how these types of technologies such as OPVs and vegetatively propagated seeds are reaching the end users and how the situation can be innovatively improved ie addressing the controversy of technology availability vs knowledge of use to end-users.

Moreover, the recent literature on agricultural innovation systems recognizes the new organizational arrangements that have emerged to balance the interests of both the supply and the demand side as a way of dealing with market or system failures. Different names are given to these organizations depending on their organizational set-up and contribution to the innovation including innovation intermediaries; innovation brokers; and knowledge brokers (Klerkx and Leeuwis, 2008a, b; Howells, 2006). A critical question to be answered by this study is how these types of organizations, which appear to be essential for the dissemination of agricultural technologies with diverse characteristics, exist in Tanzania and what is their contribution with regard to agricultural innovation. Contrary to the countries of mature innovation systems where these organizations have emerged and are recognized (Klerkx and Leeuwis, 2008a), in Tanzania, the Intellectual Property Rights

(IPR) regime is still immature, majority of technologies are produced by government R&D but both private and public organizations are involved in multiplication and dissemination and the intermediary organization recognized by NARS is the agricultural extension service dealing mainly with transfer of knowledge of use in more of a linear mode.

1.3 Objectives of the Study

Grounded on the developments in the crop sub-sector outlined above, particularly on the approaches of putting the technologies (new seed varieties) generated from R&D, into economic use, the following are the objectives of the study:

1.3.1 The general objective

To examine the implication of agricultural transformation focusing on adoption of agricultural innovation system in Tanzania.

1.3.2 Specific objectives:

(i) To determine the degree of awareness of researchers in R&D institutions of the features of the system mode of agricultural innovation.

(ii) To determine the influence of agricultural technologies characteristics on the adopted features of the agricultural innovation system approaches.

(iii) To assess the emerging innovation intermediary arrangements within the agricultural knowledge infrastructure by exploring their position and roles in relation to the traditional actors such as R&D institutions, extension service providers and end-users (farmers).

1.3.3 Research questions

(i) How are the features of the system mode of agricultural innovation, particularly key actors and their roles which have been incorporated in NARS, perceived by the researchers in the R&D institutions?

(ii) What are the influences of the characteristics of agricultural technologies on the innovation process? Focus points related to this question are the types of actors and their roles for technologies of different characteristics.

(iii) What are the types and contributions of the new types of organizational arrangements that have emerged in the process of putting new agricultural knowledge into economic use?

1.4 Relevance of the Study

The study questions are meant to contribute clarification to the ongoing debate in the field of agriculture (specifically in the crop sub-sector) regarding the best mode of putting agricultural technologies from R&D into economic and sustainable use. The study has specifically contributed to the following knowledge and policy debates:

From a practical point, the insights from this study are useful in highlighting the components (actors) of agricultural innovation that are necessary to ensure the balance of supply and demand of a commodity. Hence, it contributes to the debate on whether the technologies generated from R&D are effectively transferred to the targeted end-users as believed by many of researchers (MLFD, 2011; URT, 2009), or are shelved as generally maintained by the majority: Scientists at the African Green Revolution Forum 2012 (Panapress, 2014) maintain that:

> '*Many technologies have been kept "on the shelf" in African countries and could be more widely adopted if some of the enabling conditions – such as better markets*

> *and infrastructure as well as access to fertilizer and seeds – were improved' (Prof. Gebisa Ejeta, Executive Director of Purdue Centre for Global Food Security at Purdue University in the united States*).

> '*Technologies are available on the shelves of our universities but never go outside the gate to reach farmers' (Prof. Jumanne Magembe, Tanzania's Minister for Water and Irrigation and former staff at Sokoine University of Agriculture*).

Another contribution of the study is on the practical-oriented contradiction regarding organizational arrangements of the actors within agricultural knowledge infrastructure and what is transferred within the transfer arrangements. Taking an example of seed technology, two major strands of technology transfer arrangements can be observed: actors responsible for the transfer of knowledge-of-use (appropriate recommendations such as seeding rate and other agronomic practices) and the actors responsible for multiplication and dissemination of the physical products (seeds). However, while the agricultural extension system that is responsible for the knowledge part of technology is mainly government driven (public), the physical part is managed by private sector actors, driven not only by market factors (demand and supply) but also by the appropriability nature of the commodity (seed). In addition, the source (R&D institutions) and the intermediary organization (extension services) being in different ministries with different mandates and priorities bring controversy on the effectiveness of the flow of knowledge. Hence, how these two but associated parts of the technologies (seed and its knowledge of use) generated from R&D institutions reach the end user at the right time and without distortion will be discussed in the subsequent chapters.

Secondly a policy-based debate prevalent in the reports, which this study contributes to, is on the operationalization of demand–driven service provision. Demand refers to the desire or preference to purchase an affordable product or service. The controversy is on how the interest of both private and public sectors can be fulfilled within the existing supply driven institutional set-up, dominated by agricultural technologies that are mostly public goods. For example according to the list of seed production and importation of 2013, out of 22 crops (excluding vegetables and cash crops) only two crops (maize and barley) have hybrid varieties, the rest are OPVs (cereals and legumes) and vegetatively propagated crops (Appendix 2). Hence, as indicated above 65% of crop varieties (OPV/Legumes) are not considered by private companies for multiplication and dissemination.

The contribution of the study on policy debate stems from the trends of initiatives towards demand-driven R&D institutions and extension providers implemented over time. A number of programmes including the National Agricultural and Livestock Extension Rehabilitation Project phase one and two (NALERP and NAEP II), Tanzania Agricultural Research Project phase one and two (TARP I&II) and Client Oriented Research and Development Management Approach (CORDEMA), were introduced aiming at strengthening demand-driven research and extension. Though the implementation of these program was important particularly in strengthening research systems and increasing availability of knowledge (Sumberg, 2005; Rajalahti, 2009), they could not impart the knowledge to the majority of the expected end-users and the technology transfer was more of traditional linear, supply-driven than demand-driven (Rutatora and Mattee, 2001). Similarly with the currently ended Agricultural Sector Development Programme (ASDP), despite the efforts of engaging private sector in dissemination of agricultural technologies, the situation has not sufficiently changed from traditional reliance on extension services (Thornton, *et al*., 2011).

Lastly, systematic studies on AIS especially for least developed countries, especially the SSA, have been very limited. With current realization that innovation is context specific, only context specific studies will yield good policies.

1.5 Definition and Discussion of the Key Concepts

1.5.1 Innovation

The term innovation is widely used but with different perspectives, in Tanzania and particularly in the crop subsector, reference is made to the use of the concept in relation to the activities of R&D and farmers' novel ideas, where innovation is used in the place of invention. According to Mutlu and Er (2003), invention is the first step in the long process of bringing a good idea to widespread and effective use; and invention cannot be termed as innovation unless it has been put in the market or any other effective use.

Innovation has been studied in different contexts, including in relation to technology, social system, economic development, and policy formulation. Innovation is also referred in the education system. This study is mainly concerned with innovation in economic context. Innovation in this perspective is referred to successful creation, development, and marketing of new goods or successful applications of new techniques or ways of working that improve the effectiveness of an individual and organization (World Bank 2006). Therefore, while invention refers to creation of something new, innovation is actually a process of putting the new thing into the market place.

Four types of innovations are reported in the literature: products, process, organizational and marketing innovations. However, the technological innovations (such as product and process), are considered as core (Diyamett, 2009), while marketing and organizational innovation are related to product or process innovations. For example, market innovation includes activities such as introduction of a new product or process in the market (OECD, 2004), similar to organizational innovations, which include establishment and arrangements of supportive organizations (Smits and Kuhlman, 2004). However, Tanzania and particularly crop subsector being in transition towards ‘systemic’ phase of innovation (Chema *et al*., 2003; URT, 2003; URT, 2013), the difference between actors along the innovation process (i.e. development, multiplication, dissemination and utilization of knowledge) is becoming insignificant (Smits and Kuhlman, 2004) and distinction basing on their roles in the innovation process is not useful. Thus, it signifies the view of innovation as a process that recognizes multiple sources of knowledge and interaction that are guided by social and economic institutions such as values, norms and legal frameworks (World Bank 2006). In addition, the performance of the innovation process in systemic mode of innovation is determined by institutional context rather than technical change (Hall *et al*., 2005). Hence, for effective agricultural innovation, the changes required, be their institutional, managerial or/and organizational should be well institutionalized and internalized by developers of technologies in this case the R&D institutions.

1.5.2 Innovation system and Agricultural Innovation System (AIS)

Innovation system is a concept that emphasizes the flow of technology and information among people, enterprises and institutions as a key to an innovative process. It comprises of actors and their interactions, which are needed in order to turn an idea into a process, product or service in the market. Thus, systems of innovation are frameworks for understanding innovation. The frameworks have become popular particularly among policy makers and innovation researchers first in Europe, but now anywhere in the world (World Bank, 2006). Lundvall introduced the concept of a ‘system of innovation’ in 1985 (Lundvall, 1985). Innovation systems have been categorized into: national innovation systems, regional innovation systems, local innovation systems, technological innovation systems and sectoral innovation systems. Hall *et al.* (2006) introduced the concept in agriculture as Agricultural Innovation System (AIS), which is focusing mainly on technological innovation.

According to Hall, AIS is defined as a network of organizations, enterprises and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way different agents interact, exchange and use knowledge. This definition of AIS fits well with the objective of this study as it provides a framework that enables an analysis of complex relationships among the agents, social and economic institutions involved in agricultural (crop based) innovations from a diverse background.

1.5.3 Agricultural Knowledge Infrastructure

Knowledge infrastructure according to the literature is a complex of public and private organizations and institutions that are engaged in production, maintenance, distribution, management and protection of knowledge (Smith, 1997). In this context, the Tanzanian agricultural knowledge infrastructure has been subjected to several reforms that marked its evolution from linear (Research-Extension–Farmer) (URT, 1997) to system mode of innovation. However, the major challenge has been the weak linkages between the actors within and outside the Ministry of Agriculture (URT, 2013).

1.5.4 Commercializable agricultural technologies

These are technologies that need investments after invention for their multiplication before dissemination (sold). In this study they also include process technologies that are accompanied or associated with processing machines, which need to be manufactured.

1.6 Theoretical Framework

This research was carried out based on two sets of theoretical frameworks: those of Agricultural Innovation System and those on characteristics of technologies, to assess the features of the 'system' mode of innovation that has been adopted in the current National Agricultural Research System in Tanzania and their contributions to agricultural innovation.

1.6.1 The concept of agricultural innovation systems

Apart from the introduced concept of 'system of innovation', the AIS approaches can also be traced to other sources including: inadequacy of the linear model to explain the actual process of innovation in the real world; the inadequacy of the existing organizational frameworks to be all inclusive in terms of coverage of the various actors; and the increasing demand for demonstrated development impacts and the expanded mandate and expectations from the research for development (R&D institutions) communities (Anandajayasekeram and Berhamu, 2005).

AIS is defined as a network of organizations, enterprises and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way different agents interact, exchange and use knowledge (Hall *et al*., 2006: vi-vii).

1.6.2 Conceptualization and operationalization of AIS: In search of an appropriate analytical framework

The origin and definition of AIS indicated a number of salient features of AIS concept. Clark (2002) summarized them as follows: Innovation process involves not only formal scientific research organizations, but also a range of other organizations and non-research tasks; linkages, making contracts, partnerships, alliances and conditions and the way these assist information flow; the innovation is essentially a social process involving interactive learning by doing and that the process can lead to new possibilities and approaches inevitably leading to a diversity of organizational and institutional change; innovation process depends on the relationships between different people and organizations and lastly, is that knowledge production is a contextual affair, such that innovation is conditioned by the system of actors and institutional context at particular location.

Together with the shared understanding on the above elements within AIS conducive to innovation, different perspectives of AIS exist. Four different theoretical perspectives of innovation systems (particularly technological) have been reported in the literature including: Structural (Lundvall, 1992; Malerba, 2002; Carlson *et al.,* 2002), and functional (Hekkert *et al*., 2007, Johnson, 2001). Other scholars have analysed innovation systems from the view of systemic problems (Smith, 2000; Klein-Woolthus *et al.,* 2005) or systemic instruments (Smits and Kuhlman, 2004). Nevertheless, the systemic problems were limited within the description of system, which include the component, relationship, and attributes of components, and also attributes of relationship as argued by Wieczorek and Hekkert (2012). The following subsections discuss each of the perspectives briefly:

Structural perspective of AIS

The success or failure of innovation systems have for a long time been measured by comparing their structures. The presence and interactions of actors, and the infrastructure that governs the behaviours of actors in the innovation process are the prerequisites of the system performance. Thus, four structural elements of technological innovation system that exercise direct influence on the innovation outcomes can be identified from the literature: actors, institutions, interactions and a specific infrastructure. Categorized according to economic activities the elements comprise of the following:

(i) Actors including: Civil society, Companies, knowledge institutes, government, NGOs and other such as legal and financial intermediaries, knowledge brokers and consultants (Wieczorek and Hekkert, 2012).
(ii) Institutions including both soft institutions (rules, laws, regulations) organized by hard institutions (customs, habits, routines.) (Crawford and Ostorom, 1995) and their set-up and capacities as determined by specificity in location and social-cultural environments.
(iii) Interactions being dynamic it may not appear to fit into the structural category but looking at the level of relationships even individuals in a network qualify to be organizational. (Wieczorek and Hekkert, 2012).
(iv) Infrastructure with regard to availability of finance for innovation in form of subsidies, funds or programmes (O' Sullivan, 2005). Others connect infrastructure with the importance of physical instruments, machines, roads and knowledge (knowledge, expertise, knowhow.) (Smith, 1997; Klein-Woolthuis *et al*., 2005).

Functional perspective of AIS

The functional perspective is a more dynamic analysis, focusing on the processes that are essential for a well performing innovation system. Empirically, the literature suggested seven functions: entrepreneurial, knowledge development, knowledge dissemination, guidance of the search, market formation, resource mobilization and creation of legitimacy (Hekkert *et al.,* 2007). However, functions alone are not sufficient to measure performance of innovation system because functions can not be influenced without altering the structure elements (Wieczorek and Hekkert 2012). Therefore, these two features of innovation system are measured together (Table 3). The argument is that the presence or weakness of any function is determined by the structural elements. Likewise, strategic alteration of the structural elements can create conducive conditions for function to either take place or be enhanced. However, the description of relationship between functions and structure regarding performance of innovation system seems to assume that all technologies are uniform. This may be possible in industrialized countries where agricultural technologies are regarded similar to industrial technologies. But for the case of agricultural technologies in developing countries where IPR regime is still immature, and research is a public undertaking, the characteristics of technology may also have influence on structure (presences/absence) and functions of innovation system, as we shall see later in this chapter.

Table 3: Functions viewed through structural elements of innovation system

System function	Structural elements
F1: Entrepreneurial activities	Actors Institutions Interactions Infrastructure
F2: Knowledge development.	Actors Institutions Interactions Infrastructure

Source: (Wieczorek and Hekkert, 2012)

Systemic Problems

Systemic problems or failures refer to problems that hinder the development of innovation (Wieczorek and Hekkert, 2012), or factors that negatively influence the direction and speed of the innovation process (Klein-Woolthuis *et al*., 2005). Several lists of proposed system problems are available in the literature, however, the recently revised list consists of four general categories: infrastructure (physical), institutional (hard and soft), interaction (network failure) and capabilities problems (Klein-Woolthuis *et al.,* 2005). Linking the systemic problem and structural elements, Wieczorek and Hekkert (2012) conceptualized the problems that arise in the context of an innovation system as related to issues of presence (presence or absence of structural elements) or capability (capacity or lack of capacity of structural elements).

Systemic instruments

Other scholars view innovation system in the perspective of tools or instruments needed for successful performance of innovation system. However, this is only possible when the systemic problems are identified which in turn will guide the proper selection of strategies and tools that will effectively influence the functions of the innovation system. Therefore, following the establishment of possible systemic problems (discussed above), Wieczorek and Hekkert (2012) suggested eight goals that the systemic instruments should focus on, to ensure a successful innovation system: (1) Stimulate and organise the participation of various actors (NGOs, companies, government.); (2) Create space for actors' capability development (e.g. through learning and experimenting); (3) Stimulate the occurrence of interaction among heterogeneous actors (e.g. by managing interfaces and building a consensus); (4) Prevent ties that are either too strong or too weak; (5) Secure the presence of (hard and soft) institutions; (6) Prevent institutions being too weak or too stringent; (7) Stimulate the physical, financial and knowledge infrastructure and (8) Ensure that the quality of the infrastructure is adequate (strategic intelligence serving as a good example of specific knowledge infrastructure.

1.6.3 The concept of technology characteristics

Theoretically, characteristics of agricultural technologies (particularly physical and economic characteristics) appeared to be able to influence the structural elements of innovations systems. In a physical perspective, majority of agricultural technologies (particularly planting materials) have two parts, physical product (hard) and knowledge of use (soft), which necessitates more than one actor to deal with one technology (Bozeman, 2000). The degree of complexity is another physical characteristic which can influence structural dimension of innovation. For example a protocol for a certain food or feed may demand accompanied technologies (e.g. processing devices) for its multiplication or for the technology to deliver its intended output.

The economic characteristics on the other hand, determine the appropriability (excludability, rivalry/subtractibility) of goods (Hall *et al.,* 2001; Van den berg and Margree, 2001). Hence, call for facilitators to deal with non-appropriable technologies due to unwillingness of private sector to deal with them (Alston *et al*., 1999). Conceptualizing the above experience we find that, the agricultural technologies generated by R&D institutions being mainly public goods, are rendered unattractive to entrepreneurs hence they are likely to experience market failure (Alston *et al*., 1999). Likewise, when private sector is either not willing or is unable to invest in the agricultural sector because of the inability of the private sector to adopt new technologies (such as a highly sophisticated technologies), is referred as system failure (Smith, 2000). Referring to the description of systemic problems mentioned above, characteristics of technology may as well be considered as a systemic problem which may have influence on AIS through both structural (presence/capacity) and functional elements (Table 4). Therefore, while the structural (presence/capabilities) and functional elements determine the performance of innovation system, the characteristics of technologies envisage for structural elements and functions that are favorable for a particular innovation system.

Table 4: Dimensions of characteristics of agricultural technology in an innovation system perspective

Characteristics	Subcategories
Physical	Knowledge (Soft / hard part or mixed) Level of sophistication: simple or complex or needs associated technology
Economic	Private: excludable (access can be denied to those who have not paid for the product) and or rivalry (one person's use reduces the availability of a good or service to others) Public: non excludable and non rivalry Mixed: technologies with potential of expressing both public and private features

1.6.4 Application of the theoretical frameworks: Conceptual framework of the study

The subsequent empirical chapters of this thesis apply one or a combination of the above perspectives of AIS in order to assess the adopted features of AIS (specifically for commercializable agricultural technologies), their contribution in agricultural innovation and to determine policy implications for future improvements. In Chapter 2 (Paper manuscript 1) the study used structural and functional dimension of the innovation system to identify the actors and their relationships. A combination of characteristic of technology - structural - functional was used as the analytical framework in Chapter 3 (Paper manuscript 2) to identify and examine each technological innovation system (for agricultural technologies) to determine the influence of the characteristics on the structural dimension (e.g. the need of several actors for dissemination of one technology having two parts) and to explain why functions (e.g. entrepreneurial activities) are not taken up by private sector as expected, hence identify systemic problems (e.g. missing or weak links for the source of technology and the sources of its associated technologies). Chapter 4 (Paper manuscript 3) applies the framework for technology characteristics to map structural elements appropriate for technologies with specific character and use functional dimensions to unpack functions specific for innovation intermediaries. The functional elements are also used in Chapter 5 (Paper manuscript 4) to describe the contribution of an innovation broker (as a case study) and use a set of goals of systemic instruments to measure the impact of the same.

1.7 Research Methodology

1.7.1 Description of study sites

This thesis consists of four different parts focusing on four units of analysis: (1) researchers from agricultural R&D institutions, (2) commercializable agricultural technologies from R&D institutions, (3) innovation intermediaries and (4) a case study of an innovation broker. The study was conducted in Tanzania mainland. Two parts were conducted at agricultural R&D institutions and the other one were cases of different agricultural technologies generated from R&D and their associated facilitators (innovation intermediaries/brokers) and a case study. In Tanzania, there are three categories of R&D institutions that are involved in researching for crop-based technologies: 16 government Agricultural Research Institutions (ARIs) located in seven different ecological zones, dealing with different kinds of agricultural technologies suitable for each zone; three private R&D institutes dealing with three major cash crops and one University (Table 5).

Table 5: Categories of agricultural R&D institutions and centers, and their operating zones

Categories of R&D	Zones/crop	Location	Agricultural Research Institutions/ centers
ARI – Government	Eastern zone	Morogoro, Tanga, Coast, Dar es salaam	Ilonga, Mlingano, Kibaha, Mikocheni, Katrin and Tanga
	Southern highlands zone	Mbeya, Iringa, Ruvuma, Rukwa, Katavi	Uyole
	Western zone	Tabora	Tumbi
	Central zone	Dodoma	Mpwapwa and Makutopora
	Northern zone	Kilimanjaro and Arusha	Selian and Tengeru
	Lake zone	Mwanza, Mara, Shinyanga, Geita and Kagera	Ukiriguru, Maruku and Mabuki
	Southern zone	Mtwara, Lindi	Naliendele
Private R&D – crops	Coffee research	Kilimanjaro, Kigoma, Ruvuma and Kagera	TaCRI
	Tea research	Iringa, Tanga, Kagera	TRIT
	Tobacco research	Tabora, Ruvuma	TORITA
Universities			SUA

1.7.2 Research design

This study, like other empirical studies, has a research design. Research design is defined as a plan that guides the researcher in the process of collecting analyzing and interpreting data (Yin, 2003). Considering the need of in-depth understanding of dynamics at the interfaces between several actors that are involved in the process of making economic use of agricultural technologies, a more of qualitative approach was deemed more appropriate. However, both quantitative (survey questionnaires) and qualitative methods were used to collect and analyze data. The principle research methods used in this study were surveys using questionnaires, semi-structured interviews and document analysis (including business plans, project proposals, progress reports, monitoring and evaluation reports and annual reports). Furthermore, systematic observation was undertaken during key informant interviews and site visits (Table 6).

Table 6: Methods used and number of respondents by unit of analysis

Unit of analysis (Studies)	Chapter of the thesis	Questionnaire (Number of respondents)	Semi -structured interviews (Number of respondents)	Document analysis (Number of documents)
• Researchers	2	100	24	8
• Technologies	3	87*	30*	6
• Twelve Innovation intermediaries**	4	--	24	34
• Innovation broker (NGO)	5	--	18	14

* Respondents were researchers involved in developing the technologies

** Twelve innovation intermediary organizations include six R&D institutions, SUA and three NGOs

Unity of analysis indicated in Table 6 were identified as follows: 100 researchers purposefully selected from public and private agricultural R&D institutions. The criteria for the selection included work experience of at least 5 years. Regarding technologies, the study aimed at all commecializable technologies generated from R&D. However, out of the 134 technologies identified, only 87 technologies were surveyed. The responsible researchers who were supposed to respond to the questionnaires for the remaining technologies could not be easily accessed. In the process of analyzing the responses from the questionnaires, some respondents (24 researchers and 30 for technologies) were further interviewed to clarify some of the issues mentioned in their questionnaires. At least two respondents (a project coordinator and a field staff) were interviewed for each of the twelve cases of innovation intermediaries. The 18 respondents involved in the case study (innovation broker), were key informants mainly leaders from the NGO (VECO), farmer groups, farmers group network and local program (VECO) coordinator in the District Agricultural Office.

1.7.3 Operationalization of the data collection

This study adopted a one-time or a cross-sectional study, but applied a sequential mixed methods design, which involved collecting quantitative data followed by qualitative data in order to explain or follow-up on the quantitative data in more depth (Creswell, 2007). In the first quantitative phase of the study, a survey questionnaire (Appendix 3 & 4) was used to examine perceptions of researchers from R&D institutions and also administered to researchers who were involved in development of technologies (multiplication and commercialization) (Table 7). The second qualitative phase involved interviews with key informants identified during the first phase (Table 7).

The design was considered appropriate for this study due to the stepwise nature of the innovation process. A mixture of quantitative and qualitative methods was used in data collection and analysis in a sequential manner and for the purpose of triangulation, and seeking complementarities and convergences (Creswell, 2007).

Table 7: Research phases and data collection methods

Phase	Data collection methods	Research question	Research questions
Phase one: Questionnaire survey			
Researchers survey	Structured questionnaire, Semi-structured interview	1	Categories of actors involved in innovation and their roles Indicators for successful innovation
Technology survey	Semi-closed questionnaire, Semi-structured interview	2	Influence of characteristics of technologies on actors of innovation process and their roles
Phase two: Case study			
Multiple case study of 12 innovation intermediary organizations	Semi-structured interview Unstructured interviews	3 5	Types of Innovation intermediary and their roles
A case study of an innovation broker on dried cassava VC in Mkuranga District	Semi-structured interview Unstructured interview	4	Roles of Innovation broker and their impacts on innovation system actors

1.7.4 Mixed data collection methods

The nature of this study necessitated the use of mixed methods of data collection from multiple sources of evidence to get deeper insights into the process and outcomes of agricultural innovation processes for different types of technologies and subsequently ensure the validity and reliability of the research findings. Mixed methods are data collection strategies that combine elements of qualitative methods such as in-depth interviews, and observation with element of quantitative methods such as structured or semi-structured interviews and surveys, either simultaneously or sequentially (Creswell, 2003). While quantitative methods are acknowledged for their strength in dealing with large populations where a sample can be used for generalization about the population, they are often criticized for their static view and inability to explore sensitive topics. Similarly for the qualitative methods, despite the capabilities of dealing with behaviors and explore sensitive topics, the methods have limited possibilities of statistical testing, are time consuming and use small samples which are problematic in making generations (Creswell, 2003; Scrimshaw, 1990). Hence, this study used a combination of methods to counterbalance their weaknesses (Creswell, 2003; Axinn and Pearce, 2006). Also a combination of qualitative and quantitative methods helps to understand the process being studied and the meaning behind the behavior under the study (Scrimshaw, 1990). The different data collection tools used in this study are discussed in the following section.

Structured questionnaire: Researchers and Technology Survey

The ability to collect data from large samples objectively using standardised questions is among the advantages of surveys (Creswell, 2003). In this study a questionnaire survey was conducted in 16 R&D institutions (Table 5) covering 100 researchers and 87 technologies. Grinnell (2001) proposed a sample size of at least 10% of the population (with minimum of 30 per category) as sufficient to provide reasonable control over sample error, a rule that was observed in this study. At each R&D institution, the Officer in-charge was consulted to identify researchers who had enough experience and have been involved in technology development, to fill the questionnaires. For the technology survey, five sources of data (data base) were used to identify commercializable technologies (Table 8).

Semi-structured and unstructured interviews

These two types of interviews were important data collection methods throughout this study. Scholars view semi-structured and unstructured interview as critical methods in qualitative research because of their flexibility, which allows interaction between the researcher and respondents (Creswell, 2003; Axinn and Pearce, 2006).

Table 8: Databases, accessibility and the status by April 2014

Data base	How to access	Status
1. Released crop varieties in Tanzania	Seed Unit at MAFSC	295 varieties (29 crops)
2. Protected varieties of plants	At PBR registrar office at the Seed Unit, MAFSC	43 varieties (and 78 applications)
3. Protected new technologies at SUA	At SUA TTO and TTO annual reports	Nine technologies (3 seed based technologies and 6 others)
4. Research catalogue at SUA	At SNAL and at respective departments	Latest issue was 2009
5. At ARIs: other technologies and in-situ conservation of basic seeds	Researchers, Field days, ZIELU (Brochures), National Agricultural shows and direct sale	Information mainly in form of brochures and reports (e.g. URT, 2010)

Having this flexibility, which was referred to a 'complete freedom in content and structure' by Kumar (2005), questions can be formulated in different ways, the researcher can use different wording to explain questions, and interviews can be arranged in any sequence. The respondent can sometimes change the course of conversation and bring up new issues that the researcher might not have thought of.

In this study, these methods were used in both phases, the first questionnaire survey phase and during case studies (Table 6). In the first questionnaire survey phase, semi- structured interviews with Officers in-charge of the R&D institutions were aimed at getting a general picture of the operations of the R&D institutions and service delivery arrangements. Both semi-structured and unstructured interviews were conducted in the second qualitative study phase; these methods formed the core of the explanatory and in-depth interviews with key informants. The researcher personally conducted all interviews and took field notes throughout the data collection processes.

Non-participant observation

Observation as defined by Kumar (2005) is a purposive, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place. Observation being relatively unstructured, can yield unique sources of insight and relations, and can allow the researcher to put him/herself in the position of the respondents (Axinn and Pearce, 2006). In this study, the researcher visited and observed field operations such as seed multiplication farms managed by farmers' groups and R&D institutions (as spinoff enterprises), processing units and collective market centers. This approach provided opportunities for the researcher to see the reality on the ground and therefore generate real life findings. The method was also used to verify information obtained through other methods.

Case study

This method of data collection aimed at verifying information collected from questionnaire surveys administered to researchers, particularly the 'why' questions and at comparing effectiveness between different innovation approaches identified in the surveys. Case study is an extensive data collection method using multiple sources of information. Yin (2003) recommended six types of information to be collected: direct observation, interviews, documents, archive records, participant-observation and physical artifacts. However, for this study participant-observation could not be applied due to shortage of time.

1.7.5 Data processing and analysis

Analysis of the collected data involved qualitative and quantitative methods. While qualitative approach help to facilitate deeper understanding of the research problem, quantitative approach uses mathematical and statistical techniques to quantify the collected data (Creswell, 2003; Grinnel, 2001).

Quantitative data analysis

The data collected through a structured questionnaire were summarised, coded and analysed by using Microsoft Excel 2007 and Statistical Product and Service Solutions (SPSS version 16) computer programmes. Summary of frequencies were run at the end of data entry exercise to check for completeness and accuracy of the data entered. Analysis of survey data was based on descriptive statistics, and chi-square test.

Descriptive statistical analysis was used in exploring the data for distribution of responses and central tendencies. Cross tabulation was also performed to ascertain responses and percentages. Cross tabulation is a powerful way of communicating information and the commonest data presentation mode (Creswell, 2003).

Qualitative data analysis

The technique for content analysis was used to analyse qualitative data collected through semi-structured and unstructured interviews and data from secondary sources. Content analysis helped to reduce the verbal information from key informant interviews into smallest meaningful units of information (Patton, 2002). Both conceptual analysis (establishing the occurrence and importance of concepts and phenomena in a text or communication) and relational analysis (examining the relations among concepts and situations) were applied in the content analysis. Furthermore, detailed analysis was done on documentary materials so as to get information that helped to explain the situation on the ground regarding R&D activities, relevant national and institutional policies and, regulatory bodies. The analysis and discussion of research findings particularly in Chapter 2 and 3 (Manuscript 1 and 2), therefore, combine quantitative and qualitative data, illustrating survey findings with concrete examples, and validating qualitative findings with survey data (Creswell, 2003; Jick, 1976). However, due to the exploratory nature of the study qualitative materials were considered to be of more value.

1.7.6 Validity and reliability testing

Literature report that data from multiple sources increased both internal and external validity (Yin, 2003). Reliability in this research was achieved by complementing survey data with qualitative material and also administering the questionnaire through interviews to ensure that respondents achieved uniform understanding of terms used in the questions before filling the questionnaire.

According to Yin (2003) internal validity is only concerned with explanatory case studies in which an investigator is trying to establish a casual relationship between two events with certainty that no any other third factor may have also contributed. The case studies presented in Chapter 4 and 5 (Paper manuscripts 3 and 4) are descriptive and explanatory. To strengthen the internal validity of the cases multiple sources of data were used.

External validity on the other hand is concerned with the establishment of the territories to which the findings from the study can be generalized. For some time this has been the major criticism of case studies research that the results are not widely applicable. However, scholars in responding to this challenge distinguish between analytical and statistical generalization. For example, using the 'previously developed theories as templates with which to compare the empirical results of the case study', Yin (2003), realized an analytical generalization. In this thesis, such comparison has been established when discussing the findings from all case studies (Paper manuscripts 3 and 4).

Reliability refers to the accuracy of the results (the same as this) obtained by any other investigator following the same procedures and conduct of the same case studies. In this thesis particularly in Chapter 4 (Paper manuscript 3), the variables such as innovation intermediation functions that are performed as one-time projects, were embedded in R&D institutions or NGOs. Thus, the same questions when repeated later may result in different answers. Hence, careful documentation is needed on data collection and analysis.

1.7.7 Limitations of the Study

Information about availability of commercializable agricultural technologies generated from R&D institutions is very limited. For example at SUA not all research projects conducted by SUA staff are reported in the research project catalogues. Until 2010 research projects that were not funded through the SUA financial machinery were not recorded, while for the reported research projects not much has been reported about the technology as an output. Project outputs are mainly abstracts from publications and theses (SUA, 2007, 2009) or lists of publications (SUA, 2000). None of the research projects for commercializable agricultural technologies reported technology as one of the deliverables. As a consequence, for the technologies whereby the innovator is no longer available either due to retirement or transfer, there was no other means of getting the information regarding that particular technology. Similarly in the Agricultural Research Institutes

(ARIs) there were no proper records or databases of technologies generated and recipients of technologies, except for the filed requests from clients and delivery books.

Another limitations include outdated technologies, this was common particularly for new crop varieties. Since the process of breeding and releasing new varieties of crops demanded between six to nine years, by the time new variety which is for example resistant to a certain pest or disease is released, one might find an outbreak of a new disease to which the variety is not resistant, hence the variety is not considered for promotion or commecialization. Establishment of new structural arrangements for commecilization and dissemination of new seed varieties also influenced availability of data. Establishment of Agricultural Seed Agency (ASA) in 2006 is a case example, whereby ASA was mandated to multiply basic seed and supply to private companies for further multiplication. However, this has not always been the case for some of the crops particularly legume and OPVs which have less market potential.

1.7.8 Delimitation of the study

The study focuses on technologies for which an attempt was made to commercialize through different approaches. Also all possible sources of technology were used to make sure that all new generated technologies relevant to the study are captured including ASA, R&D institutions, both government and private, SUA, and the seed unit in the MAFS. Also all relevant departments or sections within the institutions were contacted. For example at SUA apart from research catalogues, heads of relevant departments were also contacted to collect inventory of technologies generated from the departments. Similarly within Agricultural Research Institutions (ARIs) each department (based on the type of crops) were visited including Zonal Information and Extension Liason Unities (ZIELU).

1.8 Structure of the Thesis

This thesis is organized into six chapters. The first chapter is the general introduction, presenting the research background and methodological design of the study. However, since the empirical chapters (Chapter 2 to 5) of this thesis are based on published papers or papers in the process of being published in peer reviewed journals, each paper contains a brief methodological section. It starts by introducing the research context including the study sites, study designs used, reflection of the fieldwork processes and data collection methods. Fig. 1 shows how the chapters are connected to the three objectives of the study.

Chapter 2 (Paper manuscript 1) presents the results of a study of the researchers' perceptions on the features of AIS that have been incorporated in the NARS. Drawing from empirical data in the literature and the study findings, the paper seeks to answer the first research question regarding researchers' degree of awareness on the institutional features of AIS. The paper shows low awareness of researchers regarding the importance of multiple actors including private sector, in agricultural innovation, indicating that the mind-set of the majority are still oriented to the traditional linear model of innovation.

Chapter 3 (Paper manuscript 2) discusses the influence of characteristics of agricultural technologies generated from R&D on type and roles of actors of innovation. It investigated how the characteristics of technologies (physical and economic) hinder or promote the innovation process. The chapter reveals that the actors and their alignment in innovation seem not to be the same for technologies of different characteristics. The principle research question to which this study aims to contribute is research question 2 but research question 3 is also addressed.

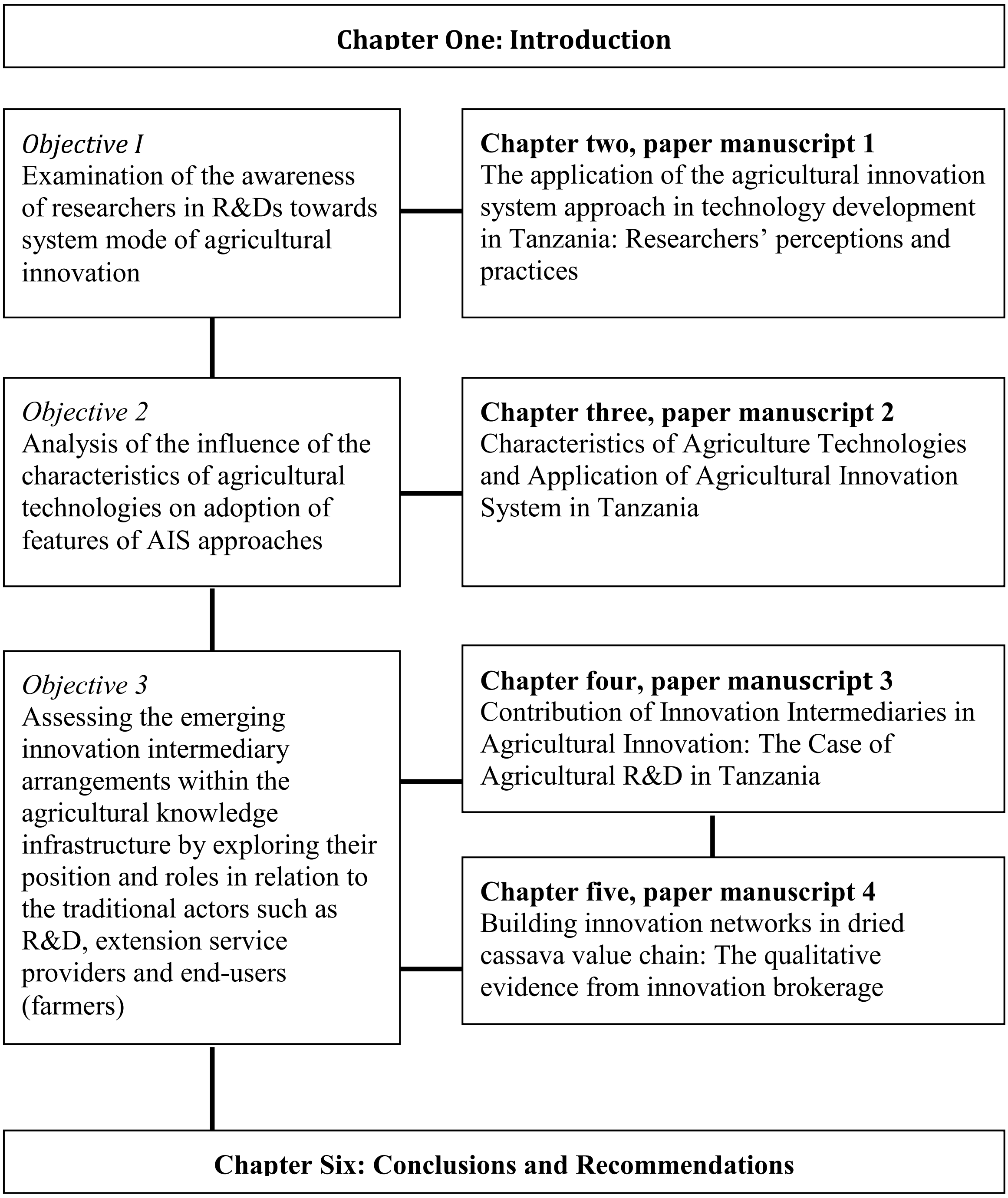

Figure 1: Outline of the thesis.

Chapter 4 (Paper manuscript 3) presents a multiple case study (of public organizations, NGOs and projects) that have taken up the role of innovation intermediation, acting as the bridge between several actors (R&D institutions, enterprises, farmers, extension providers, funding institutions) engaged in agricultural innovation. The chapter aims to provide guidance as to why emergence of these new roles, and to examine their setup and roles.

The principle research question to which this study aims to contribute is research question 3.

Chapter 5 (Paper manuscript 4) presents the case study of VECO, an NGO working to promote dried cassava value chain for smallholder farmers in Mkuranga District. This case study provides insights about innovation brokerage roles that are beyond the traditional (technology transfer) roles of agricultural extension. The study highlights the contribution of organizational and institutional innovations to the success of technological innovation. The principle research question to which this study aims to contribute is research question 3.

Chapter 6 presents the general synthesis, integrating the results from all four Paper manuscripts into a general discussion, the conclusions and recommendations emanating from the entire study.

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CHAPTER TWO

2.0 The Application of the Agricultural Innovation System Approach in Technology Development in Tanzania: Researchers' Perceptions and Practices

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This work was carried out in collaboration between the Authors. The first Author, Mgumia A. H designed the study, collected data, performed the data analysis and wrote the first draft of the manuscript. The second and third author Prof. Mattee, A. Z and Prof. Kundi B. A. T. gave comments; all authors read and approved the final manuscript.

Abstract

This paper examines the perceptions of researchers towards features of the ‘system’ mode of agricultural innovation in Tanzania. Contrary to the traditional ‘linear’ mode, the Agricultural Innovation System (AIS) approach allows multiple actors to participate in agricultural innovation and also accommodate the institutional and organizational dimensions of agricultural innovation. Quantitative data were collected through questionnaire survey from 100 purposively selected researchers from public and private agricultural R&D institutions. Data analysis indicates that about 50% of researchers are not aware of the importance and roles of entrepreneurs, regulatory bodies and intermediaries in agricultural innovation and about 88% of the researchers perceive the roles of these actors to be similar to the traditional roles of actors under NARS. On the other hand, indicators used in measuring the success of agricultural innovation were mainly associated with the pattern of adoption and productivity potential of technologies, suggesting that a transfer-of-technology mindset is still dominant in NARS. The major conclusions are that the mode of agricultural innovation under NARS in Tanzania is in transition from a linear to a system mode of innovation. The study suggested that, proper enhancement should be in place to include wider participation of stakeholders in agricultural innovation; the mandate and capacity of extension services should be expanded to include facilitation of interaction among the actors of innovation while indicators of monitoring and evaluation include technical and social changes.

Key words: Innovation, linear mode of innovation, Agricultural Innovation System, and R&D institutions

2.1. Introduction

In the last four decades, theoretical and practical approaches in promoting agricultural innovations have been evolving from a 'linear' mode of innovation, which entails production and exchange of knowledge (mostly technical) to a 'systems' mode of innovation (Sumberg, 2005: 22-23, Chema *et al.*, 2003: 38). A 'system' is perceived as a collection of related elements that function jointly to achieve the desired results (Lundvall, 1992; Hall *et al*., 2006: 7, 2005: 1). The major drivers to the change have been the economic liberalization of 1980s that promoted private economic initiatives (IMF, 1986: 6-7). The ultimate emergence of public–private relationship in agricultural innovation increases involvement of multiple actors and non-linear changes. Innovation requires interaction of many developers, possessors and users of knowledge (Skarstein, 2005: 341; Carney, 1998). In addition, the current national responsibilities in achieving the globally predetermined development targets such as the Millennium Development Goals demanded an increase in the scope of expectations from Research and Development (R&D) to include contribution to the broader developmental goals such as poverty alleviation, food and nutrition security, and environmental sustainability (Anandajayasekeram, 2011: 1-4).

The new roles of R&D institutions and extension services created the demand for broadening the scope of the actors of innovation to include actors previously not defined by research arrangements such as various combinations of researchers, enterprises, farmers, development workers and policy actors from the public and private sectors (Hall and Oyeyinka, 2005: l3, 2006: 17) and institutions (Lundvall, 2004). These changes have necessitated the evolution of organizational framework from National Agricultural Research System (NARS), which symbolized a linear approach, to Agricultural Innovation System (AIS) framework, which symbolizes a more inclusive approach (World Bank, 2006: 27; Hall and Oyeyinka, 2005: 3; Chema *et al*., 2003: 38). The agricultural

Innovation System approach recognizes the innovative performance of an economy as an outcome of interaction among multiple actors (private sector, research institutions, universities etc) and how they interplay with social institutions such as legal frameworks (Hall, *et al*., 2005: 5) rather than an efforts of isolated individual institutions.

Studies show that the countries of Sub Sahara Africa (SSA), have adopted features of AIS in the institutional arrangements for research and innovation such as public-private linkages in agricultural research (Sumberg, 2005: 24), innovation platforms (Hounkonnou, *et al*., 2012) and interactions among actors of innovations (Spielman, 2005; Ortiz, *et al*., 2013). In Tanzania and particularly in the agricultural sector, this can be related to the Client Oriented Research and Development Management Approach (CORDEMA) adopted in 2003, aiming at facilitating public and private providers of agricultural research to be able to provide more relevant and effective services. Also the Agricultural Sector Development Program (ASDP) launched in 2003 (URT, 2003), created a favourable environment for commercial activities, public and private roles in improving support services and strengthening marketing efficiency for agricultural inputs and outputs. However, despite the great potential of AIS approaches in enhancing the efficiency of agricultural research, in practice the success will depend on how well the new approaches are applied and adapted to the diverse local conditions. In Tanzania for example, despite the government efforts through CORDEMA and ASDP, the traditional reliance on achieving growth by supporting smallholder agriculture through the local government, the extension services are not sufficiently changed (Thornton, *et al*., 2011: 49).

Thus, under NARS where R&D institutions are a central component of innovation, researchers' knowledge of the actors of innovation system and their roles is important in enhancing partnerships and prompt alignment of R&D with other appropriate actors of innovation as need arises. This study therefore, intended to examine the perceptions of researchers in R&D institutions towards features of system mode of agricultural innovation. The specific questions addressed by this study are what are researchers' perceptions of the elements of AIS: the components (actors), the relationship and interactions within the actors, and the indicators for successful innovation.

2.2 The Agricultural Innovation System: A Conceptual Framework

Agricultural Innovation System approach introduced in agricultural sectors by Hall *et al*. (2006), originated from national system of innovation developed by Lundvall (1992). Agricultural Innovation System approach provides a framework that enables to analyze complex relationships among the agents, social and economic institutions from a diverse background. It signifies the view of innovation as a process that recognizes multiple sources of knowledge and interaction that are guided by social and economic institutions such as values, norms and legal frameworks (OECD, 1997).

Scholars have differentiated AIS from NARS using various institutional features including: the roles of actors/partners, the relationships involved the selection of partners, the work plan, policy focus, the knowledge produced and indictors of performance (Hall *et al*., 2005: 3). However, Anandajayasekeram and Berhamu, (2009) using Innovation System Perspective (ISP), grouped these features into three elements namely: (1) The components (actors) of the system; (2) The relationships and interactions between these components; and (3) The competences, functions and outcome of interaction among the components. To what extent researchers understand the importance of these elements, as contributing factors to agricultural innovation will be investigated in this article.

2.2.1 The components (actors) of the agricultural innovation system

The mainstream actors under NARS, who are responsible for the transfer of knowledge, include R&D institutions, extension, and the end-users. This arrangement is effective where there is only one source and one user of knowledge. The mechanism for innovation under NARS is technology transfer which is predominantly government driven. AIS, on the other hand, involves well-connected and coordinated actors mainly from five different domains (Box 1): research, entrepreneur, diffusion, market or demand and infrastructure (CABI/CTA/KIT/VRLIE/WUR, 2006). Apart from policies and market as triggers of innovation, AIS stressed on the importance of stakeholders and also importance for organizations and policies that are sensitive to demand and agenda from stakeholders (Hall and Oyeyinka, 2005). Therefore, researchers' understanding of the scope of the actors and their contribution in innovation is essential for the features of AIS to be effectively incorporated and applied in agricultural technology development.

Box 1: Possible actors of agricultural innovation system

Actors	**Roles**
Research	Generates knowledge, it can be either research institutes, universities, private research
Intermediary	Intermediary organizations/ knowledge transmitters, extension workers, farmers and traders organization, private consultants, NGOs and CBOs
Entrepreneur	Produces and sells products (mainly to intermediary users of knowledge) farmers, commodity traders, processing industries related to agriculture, transporters, input and service suppliers
Infrastructure	Policy making agencies, regulatory bodies, banking and financial system, transport and marketing infrastructure and education system
Market or demand	Consumers of different types: retailers, wholesalers, (Standards, Volume, price quality) and end-users.

Adapted from CABI/ CTA/KIT/ VRLIE/ WUR, (2006)

2.2.2 The relationships and interactions between components (actors)

The ISP element shows how the relationships of the actors in AIS are diverse, evolving and flexible, determined by the nature of the context or available resources (World Bank, 2006; Hall and Oyeyinka, 2005). These elements of ISP cannot be compared to NARS where the relationships of actors are narrow, hierarchical, and in most cases predetermined by the institutions' roles. In addition, the performance of innovation process in AIS is determined by institutional context rather than technical change as for the case of NARS (Hall and Oyeyinka, 2005). 'Institutions' under innovation system framework refer to common habits, routing, practices, rules or laws (Edquist, 1997). Hence, for effective agricultural innovation, the changes required, be the institutional, managerial or/and organizational, should be well institutionalized and internalized by researchers. Due to uncertainties (external factors) and rapid advancements in science, the successful innovation system is characterized by having organizations that are flexible and networked in such a way that can form new patterns of partnerships in responding to the emerging challenges.

2.2.3 The indicators for successful innovation

Indicators of performance of innovation process measure the competencies, functions, processes, and knowledge produced as a result of interactions among components. Under AIS, the indicators of performance include technical, scientific, and codified indicators, which are similar to those of NARS. But in addition, AIS also includes social change such as organizational and institutional development and change in behaviors (Hall *et al.*, 2005).

2.3 Methodology

2.3.1 Selection of respondents

This study involved researchers from public and private agricultural research institutions; 16 government Agricultural Research Institutes (ARIs), which are located in seven agro-ecological zones; two private R&D institutions which deal with two major cash crops: coffee and tobacco: Tanzania Coffee Research Institute (TaCRI) and Tobacco Research Institute of Tanzania (TORITA). Others include three Livestock Research Institutes (LRIs), which deal with pastures, livestock, and animal vaccines; and one university - Sokoine University of Agriculture (SUA). At SUA five Departments which are relevant to the scope of the study were covered by the study, and these are the Department of Crop Science and Production, the Department of Soil Science, the Department of Food Science and Technology, and the Department of Animal Science and Production, all in the Faculty of Agriculture; and the Department of Veterinary Medicine and Public Health which is in the Faculty of Veterinary Medicine.

According to Crawford *et al*. (2011), all the agricultural research institutes in the country had a total of 318 researchers, comprised of 223 (70%) males and 95 (30%) females, while the five selected departments (at SUA) had 175 researchers comprised of 161 (92%) males and 14 (8%) females. Therefore, the total population of researchers was 493. From this population, a sample of 100 researchers was purposively selected from all R&D institutions with the assistance of heads of department or research centres. The criteria for the selection included work experience of at least 5 years. The sampling intensity was theoretically acceptable based on Boyd *et al*. (1981) and Bailey (1994).

2.3.2 Data collection and sources

Three data collection methods were employed in this study: structured questionnaire survey which involved both closed and open-ended questions (Appendix 3); key informant interviews, document analysis from reports and published literature. The first and second method were used for collection of primary data, and the remaining two methods were used for the collection of secondary data. The main focus of the questions in the questionnaire survey was on the respondents' perceptions on the important key actors of AIS, their roles and indicators for successful innovation. The respondents' perceptions on reasons for R&D institutions to commercialize and sell research results directly to the end-users were measured by likert scale.

2.3.3 Data analysis

The qualitative data were analyzed through a meaning categorization (Kvale, 1996) whereby the information was broken down into meaningful units of information and grouped according to themes. For example, roles for each actor were categorized as related to the traditional or evolving roles. Furthermore, detailed analysis and synthesis was done on documentary materials so as to get information that could help to explain the situation on the ground regarding agriculture innovation system. This involved review and synthesis of research reports, annual reports, and programs such as ASDP and CORDEMA. Quantitative data were analyzed using Statistical Product and Service Solutions (SPSS) version 16. Quantitative data collected through structured questionnaire survey were analyzed through descriptive statistical analysis. Descriptive statistical analysis was used in exploring the data for distribution of response and central tendencies. Cross tabulation was also performed to ascertain responses and percentages. Cross tabulation is a powerful way of communicating information and the commonest data presentation mode (Pallant, 2005). For likert scale data, the average score was calculated as a sum of scores of each respondent divided by the number of the respondents. Since score ranged between 1 and 5, hence median scale 3 was selected as cutting point. Therefore, all values equal to or below 3 were collapsed and assigned ‘0’ and values above 3 were collapsed and assigned ‘1’; this allowed each response to be dichotomised into two categories: Disagreed and Agreed, respectively. A non parametric, one-sample Chi-square test was employed at 5% level of significance (Pallant, 2005) to examine whether any association existed between these categories (agree or disagree).

2.4 Results and Discussion

2.4.1 The perceived important actors in agricultural innovation

Among the five key components (actors) of AIS, a significantly larger percentage (81%) of respondents perceived end-user ($p = 0.0001$) as an important actor, and about half of the respondents, perceived entrepreneur (54%), extension (50%) and regulatory agents (51%) as important though not statistically significant (Table 1). The fact that 46% of the respondents did not recognize entrepreneurs as important actors in the innovation process (needed for multiplication and commercialization of technology) implies that a substantial number of respondents were ill informed about the importance of the entrepreneur domain in agricultural innovations. These results indicate that involvement of entrepreneurs in the existing mode of innovation is limited. However, R&D institutions were found to commercialize and sell some of the technology directly to the end-users. The same experience was reported by other studies done on industrial R&D institutions (Mwamila and Diyamett, 2009). In addition, a significant number (64%) ($p = 0.005$) of the respondents did not consider financial institutions as important actors (Table 1), which implies the dominance of government-driven (or projects funded by development partners) innovation mind-set by majority of respondents. Hence, most researchers perceived end-users as a more important actor than entrepreneurs or other actors, which illustrates the traditional thinking of linear mode of innovation.

Table 1: Researcher's perceptions on the important actors in AIS, Tanzania. (n = 100)

Components / Actors of AIS	% of respondents who considered the actors as:		χ^2	p
	Important	Not important		
Entrepreneurship firms/ companies	54	46	0.640	0.424
Regulatory agents	51	49	0.091	0.763
Technology transfer intermediary or extension service	50	50	0.000	1.000
End-users (farmers)	81	19	38.44	0.0001*
Financial institutions	36	64	7.840	0.005*

* Statistically significance at 5% level

2.4.2 The perceived roles of key actors in agricultural innovation

The respondents' perceptions on the roles of each actor were analysed and grouped into two sets of roles. The first set comprises the traditional roles of actors under NARS which were predetermined by the research system or defined by the institutions organizations, these were categorised as group A (Table 2), and the second set includes roles that are context based (or evolving) hence flexible (group B). Generally, with the exception of the end-users (whereby the reported roles fit the criteria for group A only), the perceived roles for the other actors fall under both groups A and B. However, the roles that were mentioned by the majority reflected the traditional roles of NARS (group A). Furthermore, a substantial number of respondents failed to mention the roles of some of the mentioned actors: end-users (45%), extension (48%) and entrepreneurs (22%) (Table 2) This observation implies that even researchers who could identify important actors of innovation were uncertain about the roles of the actors they (the respondents) identified. The following is the detailed discussion for each of the actors:

Table 2: Respondents' perceptions on the roles of key actors of agricultural innovation in Tanzania (n=100)

Actors	Group	Perceived roles for each of the actors	% of respondents
	A	Transform technology into products	46
		Dissemination of new technologies	10
Entrepreneurs	B	Determine the market potential of new technologies	11
		Source of research idea	11
	C	None	22
		Total	100
Financial	A	Support technology transfer activities	14
Institutions		Provide research funds	39
	B	Provide credit facilities to end-users	47
		Total	100
	A	Certification of the product	29
Regulatory		Regulate standard, monitor quality	59
Bodies	B	Market regulation (linkages and enabling environment for partnership)	6
	C	None	6
		Total	100
Intermediary	A	Provide extension services	28
(Extension)	B	Articulate demand and support of entrepreneurs	24
	C	None	48
		Total	100
Market / Demand (End-users)	A	Users of new technologies	37
		Source of new research ideas through feedback	11
		Assess practicability of the new technologies	7
	C	None	45
		Total	100

Group: A=Traditional roles B= Evolving roles C= The respondents who mentioned the actors but they could not specify the roles of such actors.

Entrepreneur: While nearly half (46) of the respondents did not consider entrepreneurs as important actors in innovation (Table 1), 22% of the respondents cited entrepreneurs as important actors in innovation, but they could not indicate any roles devoted to this actor (Table 2), this makes a total of 68% of the respondents who were not sure about the roles of entrepreneurs in innovation. Regarding the 54% of the respondents who recognized entrepreneurs as important (Table 1), about 56% of them reported roles under category A, while only 22% mentioned roles of entrepreneurs under group B (Table 2). Again this implies that only 22% of 54%, which is equivalent to 12% of all the respondents, had a systems perspective on agricultural innovation. The fact that these new and evolving roles (group B) were perceived by few researchers implies that there is need for such different actors as entrepreneurs (private sector) and R&D institutions (public) to interact and collaborate in innovation. According to the World Bank (2006), one of the functions of AIS is to enhance interactions and relationships between culturally and institutionally dissimilar actors in order to reduce cultural and/or social barriers between actors and foster agricultural innovation. Thus, a cross checking question was posed to examine whether the respondents perceived existence of any gaps (cultural or cognitive) between R&D institutions and entrepreneurs, and what is their suggestion as to who could effectively bridge the gaps, and through what functions.

The results showed that majority (92%) of the respondents perceived the existence of a gap (cultural or cognitive) between R&D and entrepreneurs. The distribution of the respondents on the proposed actors who could effectively bridge the said gap varied significantly (Chi-square (X^2) = 33.109, p=0.0001) where are these data presented, whereby half of the respondents (52%) suggested extension services providers (agricultural extension staff and ZIELU) could do better (Table 3). According to the national guidelines, extension services are mainly dealing with knowledge transfer in the form of information (URT, 2009a; URT, 2008). Except for the ‘specific unit within the R&D’ and ‘consultancy’, the rest of the mentioned roles (reported by 74% of the respondents) were referring to linking R&D and end-users and not entrepreneurs. This implies that the mind-set of majority of the respondents is still oriented to the traditional linear mode of innovation, with limited commercial perspective of innovation. The incorporated features of AIS through programmes, if any, are not yet internalized in the minds of many researchers, therefore extension services continue to be a major intermediating layer between the source and users of knowledge.

Table 3: Intermediaries suggested by the researchers and their roles (n=100)

Intermediary suggested	% of respondents	Roles
Agricultural Extension staff	38	Linking research and end user Enhance adoption of technologies through demonstration and exhibition
Specific unit within R&D	21	Facilitate common understanding of researchers and administrators about commercialization of technologies Develop commercialization strategies (protection, packaging, negotiate market and fundraising)
Independent unit outside R&D	22	Harmonize stakeholders Transfer information from research to end-users
ZIELU	14	Package information and prepare extension materials Serve as a bridge between research and other stakeholders Promote new technology through farmers day, training and seminar and successful stories 3
Consultancy	5	Get to know needs of users and search for the answers/solutions from research

Key: ZIELU: Zonal Information and Extension Liaison Unit

Infrastructure (financial institutions and regulatory bodies): Almost two-thirds (64%) of the respondents did not consider financial institutions as an important actor in innovation (Table 1). However, for regulatory bodies, out of 51 respondents who cited financial institution as an important actor, majority (88%) of these respondents assigned roles that are defined by institutional roles reflecting the traditional NARS (Table 2). In both cases, limited understanding among majority of the respondents on the importance of these actors and their roles in innovation might undermine the effectiveness of the features of AIS in agricultural development in Tanzania.

Intermediary (extension): It was interesting that with this actor, about half (48%) of the respondents who indicated extension as an important actor in innovation, could not associate this actor with any roles (Table 2). The remaining 28% indicated the role which is predetermined by the institutional role (group A), whereas only 24% cited facilitating roles (demand articulation and support of entrepreneurs) in the sense that they do not reflect the conventional transfer functions; instead they reflect more of the facilitation functions, which reflects the system nature of innovation (Hall *et al*., 2005). Half of the respondents did not consider extension as an important actor in innovation.

Demand sector (end-user): The majority (81%) of the respondents perceived end-users as an important actor (Table 1), whereas 37% of the respondents perceived end-users as recipients of technology (group A) (Table 2) implying that R&D institutions do not only generate new knowledge but they also multiply and disseminate such knowledge to end-users. However, with the exception of few highly sophisticated technologies (such as biotechnology-based technologies) multiplication and commercialization of research results are not within the capacity or mandate of R&D institutions (URT, 2010). These results are indications of a system (transition) failure, a situation whereby private firms (including entrepreneurs) are unable to adapt to new technological development (Smith, 2000: 95), hence R&D institutions perform multiple functions of generation, multiplication and dissemination of technologies.

Accordingly, an additional question was set to verify the motive of R&D institutions of engaging in the commercialization of research results. The researchers were asked why the public R&Ds are directly engaged in technology transfer and commercialization. The researchers' perceptions on this question were examined using five-point likert scale items (Table 4). The results indicate that a significant percentage (69%) of the respondents strongly agreed (with a mean score of 3.88) that lack of developed markets for the research findings as one of the major reasons for R&D institutions to commercialize and sell technologies directly to the end-users ($\chi^2 = 17.33$, $p = 0.0001$) (Table 4).

Furthermore, a substantial but statistically insignificant number of respondents cited other reasons including unclear institutional technology transfer guidelines, existence of sophisticated technologies, lack of entrepreneurship skills, and technologies that demanded skilled personnel as reasons for the R&D institutions to commercialize and sell research results directly to the end users (Table 4).

Table 4: Reasons for R&Ds to commercialize research results directly to end-users (%); χ^2 = chi square, n=97

Reasons for commercializing and selling research results directly to end-users	SD	D	N	A	SA	Mean score	χ^2	p
The technology demanded sophisticated facilities for multiplication	7	19	27	16	28	3.40	0.835	.361
The technology required high skilled personnel	7	17	22	28	21	3.91	0.167	.683
Lack of developed market for the technology, entrepreneurs would not take risk	4	7	17	37	32	3.88	17.33	.0001
Lack of clear institutional guidelines for technology transfer	1	7	34	24	31	3.79	1.742	.187
Lack of entrepreneurial skills	6	4	26	39	20	3.66	5.568	.018

These findings suggest that the private sector is either not willing or is unable to invest in the agricultural sector because of the inability of the sector to adopt new but sophisticated technologies, hence a transition failure (Smith, 2000: 95) or the economic features of the technologies generated by R&D institutions being a public good are rendered unattractive to entrepreneurs (Alston *et al*., 1999). Hence, these results indicate the existence of market and system failures within the agricultural knowledge infrastructure that compel actors such as the R&D institutions to perform market oriented or entrepreneurial roles. As a result, the roles of the entrepreneur have been shifted to R&D institutions (Table 4), consequently researchers perceive an entrepreneur as not being an important actor in innovation (Table 1). Due to the inherent differences in interest between researchers (scientific achievements) and entrepreneurs (making profit), another question was posed regarding the motive or source of research ideas. The responses show that 62% of researchers admitted the motive to be researchers' perceived problem (primarily on diseases, pest and yield). Others include feedback from uses (19%), national agenda (8%), donor's agenda (3%), political influence (1%) and directive from above (3%). This implies that the interests of end-users (mainly farmers) who are the target of entrepreneurs are less incorporated in the research outcomes.

2.4.3 Indicators in measuring a successful agricultural innovation process

Three levels of success were used to measure understanding of the respondents on the indicators of performance for innovation processes namely successful, partially successful and unsuccessful. For this study, successful innovations refer to the technologies that are made available commercially to potential clients by private sector. Studies illustrated that private sector appeared to be the most effective provider of goods and services because of its stronger links with clients (Carney, 1998). Thus the indicators that are commercial oriented and which capture social or behaviour changes assured not only availability and assimilation of the technology by the end-users but also they measured application of features of AIS. These indicators were considered as indicators for successful innovations. Partially successful innovations referred to technologies that were multiplied and disseminated through informal and unsustainable ways such as project-based interventions; this is particularly because project interventions always target a limited number of users and have short span of time. Unsuccessful innovation involved the technologies that were not moved or transferred from R&D institutions to the end-users.

Table 5 shows that the indicators which were reported by 67% of the respondents (for successful and partially successful innovations) were mainly associated with the pattern of adoption and productivity potentials of the technologies such as the number of adopters, an increase in productivity and technology disseminated. Only five (5%) respondents cited indicators of social change including introduction of commercial perspective to commodities that traditionally were regarded as public commodities (i.e. available in the shops). From these observations, majority of researchers are accustomed to quantitative oriented measurements or changes rather than qualitative measurements in assessing performance of innovation. This is supported by many reports and working documents (URT, 2009b), which indicate that the indicators used were mainly the number of adopters, productivity of the technology, the number of technologies disseminated and success stories of individual beneficiaries. The aspect of behaviour and social changes, which are equally important in measuring successful innovation, are less used.

However on the other hand, the 35% of respondents who ranked performance of R&D institutions in innovation as unsuccessful related failure in innovation to inadequacy in institutional and organizational arrangements of R&D institutions for innovation (Table 5). This observation implies that the respondents recognize the importance of policies (national and institutional) in providing an enabling environment and forming an integrated component of the successful innovation system, which is a typical feature of AIS. This is unlike for the traditional NARS, where the role of policy focuses mainly on resource allocation and priority setting (World Bank, 2006; Hall and Oyeyinka, 2005).

Table 5: Perceived indicators for measuring successful agricultural innovation

Level of success of innovation	Assigned indicators	% of Respondents
Successful		
	Available in shops	3*
	Large number of adopters	20
	Increase in productivity	4
	No reason	6
	Sub total	**33**
Partially successful	Less number of adopters and /or those who demanded the technology (at R&D)	13
	Technologies needed specialized knowledge and facilities for mass production hence not attractive to entrepreneurs/ they are only available (sold) at R&D	2*
	Technology disseminated through demonstration, trials, or is distributed to the end-users through project interventions.	10
	No reason	9
	Sub total	**34**
Unsuccessful		
	The commercial perspective on agricultural technologies is not well developed, farmers perceived agricultural technology as a public good, are not willing to pay for it	10
	Lack of appropriate policy, incentives, guidelines or model for technology transfer	7
	Lack of incentives and guidelines to involvement of entrepreneurs, extension service and end-users in technology development and dissemination	9
	Lack of funds and capacity for technology transfer and commercialization	9
	Poor coordination among R&D units and misunderstanding between researchers and administrators	2
	Subtotal	**33**
Grand total		**100**

* Indicator related to social changes (institutional / managerial/ organizational)

As for the indicators for success and partial success (such as technology dissemination through project interventions), and indicators for unsuccessful innovation (indicator of inadequacy in institutions policies and arrangements), it should be noted that the successful innovations were those which were implemented under project intervention levels and which addressed institutional and organizational inadequacy related to agricultural innovation operationally (such as incentives scheme, capacity building etc.). Hence, it is likely that researchers (respondents) who participated in these projects were the ones who were aware of the importance of actors of AIS and their roles.

2.5 Implications and Recommendations

Currently, Agricultural Innovation System (AIS) is viewed as a more practical approach to enhancing economic utilization of agricultural technologies than the traditional linear mode of innovation under National Agricultural Research System (NARS). However, effective adoption of the features of AIS requires researchers' understanding of the importance of the features of AIS and becoming actively involved. The findings from this study indicate that end users (farmers) were perceived as important actors of agricultural innovation by the majority (81%). Entrepreneurs, regulatory bodies and extension services were perceived important by half of respondents, while most (64%) of them considered financial institutions as not important. Therefore, policies should be redesigned to advocate and accommodate wider stakeholders' participation including private sector in technology development and dissemination, and thereby encouraging partnership between R&D institutions and the private sector.

The perceived roles of the actors of innovation systems by majority of the respondents appeared to be similar to the traditional roles under NARS with only few cited roles that can be associated with AIS. This suggests that, the researchers' transfer-of-technology mind-set is still predominant. Consequently, most respondents believe that extension services (workers) could do better in bridging the claimed gap between R&D institutions and entrepreneurs as actors in innovation. This confirms the misconception of the researchers about the roles of the key actors in the innovation system. The perceived facilitation roles by extension indicate the potential for extension services in adapting to the emerging and indispensable roles in innovation. Therefore, the mandate and capacities of agricultural extension services should be expanded to include facilitation of innovation through exploring both technical and institutional innovation, and organizational and managerial innovations, at least for the time being while the research system is in transition from a linear to a system mode of innovation.

Furthermore, majority of the researchers measured success in innovation by using indicators associated with the pattern of adoption only regardless of the sustainability of the dissemination approach used, whereas very few researchers used social and behavioural change as an indicator of measuring success in innovation. Hence, the Government should re-design the indicators of performance used in Monitoring and Evaluation (M&E) of public R&D institution’s activities, and extension services to become more inclusive in capturing both technical and social changes.

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CHAPTER THREE

3.0 Characteristics of Agriculture Technologies and Application of Agricultural Innovation System in Tanzania

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This work was carried out in collaboration between the Authors. The first Author, Mgumia A. H designed the study, collected data, performed the data analysis and wrote the first draft of the manuscript. The second and third author Prof. Mattee, A. Z and Prof. Kundi B. A. T gave comments, all authors read and approved the final manuscript.

Abstract

The globalisation of the world economy and advancement in science including use of biotechnology for agricultural production, has subjected agricultural technologies to market forces for their generation and dissemination. It is evident, however, that while some technologies are more amenable to commercialisation, there are other technologies that may still need strong participation of public institutions for their generation and dissemination. This study analysed a total of 87 agricultural technologies in crop, food, and soil thematic areas with respect to the extent of incorporation of innovation systems in the process of technology development, multiplication and commercialization. Each of the technologies was assessed in terms of its characteristics, actors involved and their roles at each stage of innovation. The study found that the economic features and multiple dimensional characteristics of agricultural technologies determine actors involved in the development and dissemination of the technologies through commercialisation. While 40% of the technologies were commercialized by business enterprises, 60% needed intermediation interventions, implemented in project-setups by R&D institutions or NGOs, which is an indication that the coverage and sustainability is questionable. Thus, government interventions in promoting agricultural innovations should focus on both operations and policy issues for effective incorporation of innovation system.

Key words: Innovations, System of Innovation, characteristic of technologies, Tanzania.

3.1 Introduction

For decades, the agricultural sector has witnessed a number of changes in the context of promoting technological changes in responding to the emerging challenges. Farmers have been progressively unable to engage profitably in agriculture due a number of reasons including limited access to technology, advances in technology (e.g. biotechnology), climate change, growing need of inter-sectoral linkages, changing expectations of science, technology and innovation and environmental concerns (Anandajayasekeram, 2011: 2-3; World Bank, 2008). In responding to these challenges, the mechanism of agricultural innovation has gradually been shifting from a linear technology transfer mode to building of Agricultural Innovation Systems (AIS) (Chema *et al*., 2003: 38; Hall *et al*., 2005; Sumberg, 2005: 22-23).

Despite the fact that these paradigm shifts have a great potential in enhancing the effectiveness of agricultural research, the extent to which they are effective will depend on how well the new approaches are applied and adapted to the diverse local conditions (Chema *et al*., 2003). For example, while in developed countries where the agricultural research and service provision is privatized, the agricultural technologies are behaving in the same way as industrial technologies. In developing countries, particularly in sub-Saharan Africa (SSA) on the other hand, since liberalization reforms of 1980s, the actors of agricultural innovation have expanded. The National Agricultural Research System (NARS) which were established in many SSA countries (Taylor, 1991), are now made up of conglomeration of private and public sectors, NGOs, government agencies and civil society organizations, and also the technologies are characterised not only by their physical features (physical product and knowledge of application) but also economic features (excludability, rivalry/subtractability and appropriability) and level of sophistication. In this case the innovation approach may require different actors and relationships for different types of technologies.

Consequently, various system-based innovation frameworks/approaches have been developed and used to analyse essential characteristics for specific innovation systems such as: structural elements (Lundvall, 1992; Malerba and Mani, 2009; Carlson *et al*.,

2002) and functions (Hekkert *et al.*, 2007). Other scholars of system studies, have analysed innovation systems in terms of systemic problems (Smith, 2000; Klein-Woolthuis *et al.*, 2005). Nevertheless, the systemic problems were limited within the description of systems (Carlsson *et al.*, 2002), which includes the components, relationships, and attributes of components, and also attributes of relationships as argued by Wieczorek and Hekkert, (2012). However, in developing countries, particular the SSA countries, where the NARS is characterised by public–private relationships and agricultural technologies have both public and private properties, the analysis of agricultural innovation systems in the perspective of technology characteristic is also crucial to highlight the essential features of an agricultural innovation system suitable for specific country, in this case Tanzania, and emphasizing the need for institutional change for agricultural research organizations to contribute more effectively to innovation.

This paper contributes to this analysis by exploring the kinds of actors and their roles that have been engaged in the innovation process for agricultural technologies with different characteristic (physical and economical) in Tanzania. Specifically, the study aimed at answering the following research questions: What are the characteristics of technologies generated from R&D institutions in Tanzania? Who are the actors and what have been their roles in the development of those technologies and their uses? What is the relationship between characteristics of agricultural technologies, actors involved and their roles?

3.2 Theoretical framework

The literature differentiates a ‘systemic’ agricultural innovation framework (AIS) from the conventionally ‘linear’ research driven system framework, through various institutional features that have influence on interaction and the creation of enabling environment for actors to innovate (World Bank, 2006: 27; Hall *et al*., 2005: 3). However, in developing countries and Tanzania in particular, due to inadequate entrepreneurial investments and enforcement of Intellectual Property Rights (IPR) protection on agricultural technologies (Ngwediagi, 2009: 10), the appropriability nature (the ability to capture all the benefits accrued from innovation) determined by the characteristics of agricultural technology, might be among the factors influencing the innovation process mostly by determining the type of participating actors and their roles. Therefore two sets of literature were used in this study: The institutional features determining the type of innovation systems and the physical and economic features of agricultural technologies.

3.2.1 Agriculture innovation systems: Evolution of the concept

The term innovation is conceptualized differently as a product, a process or a new way of applying knowledge. While other scholars tend to adopt a narrow definition, focusing mainly on technological innovations, others include non-technological innovation particularly institutional components (Lundvall, 1992) or social dimension (Leeuwis, 2004: 12-13). Thus, in the context of this study, innovation is conceptualized as 'anything new introduced into an economic or social process' (OECD, 1997: 12). A system on the other hand (including innovation system) constitutes of components (actors) of innovation, relationships and their attributes (Carlsson *et al*., 2002: 234, Lundvall, 1992: 2; Hall *et al*., 2006: vi-vii). Carlsson *et al*. (2002) define components as "operation part of the system", relationships as "the link between components" and attributes as "the properties of the components and relationships between them" (Carlsson *et al*., 2002: 234).

The system thinking in agricultural (organizational and institutional analysis) R&D began, in SSA in the 1980s when National Agricultural Research Institutes (NARIs) evolved to National Agricultural Research Systems (NARS) and became focused on the research supply to enhance the linear model of innovation (Taylor, 1991). Since then, there have been a number of attempts to use concepts from system of innovation theory in agriculture research and innovation process. Hence, progressively shifting from the linear model towards a multiple, interactive and learning based systems of innovation. The major focus in the NARS reform agenda includes: governance, decentralization, stakeholder participation, emerging funding mechanisms and strengthening of system linkages (Chema *et al*., 2003: 11-16; Clark, 2002) as well as knowledge and information system (World Bank, 2006) which led to the emergence of the multiple-actors and flexible AIS. The AIS approach was pioneered in the agriculture domain from the National Innovation System (NIS) by Andy Hall and his colleagues (Hall *et al*., 2005). AIS is defined as "a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organizations into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge" (Hall *et al*., 2006: vi-vii). Having a broader set of relationships between actors and contexts, AIS, contrary to NARS, offers a framework which accommodates flexible, multiple and evolving roles of actors that are determined by the nature of their tasks, skills and resources available, including high degree of market integration.

Scholars in agricultural innovation highlighted different approaches that have been developed to analyse agricultural innovation systems (Klerkx and Gildemacher, 2012: 457-465). This study, however, focused on structural and functional approaches of innovation systems. Following the established argument that functions of the system are useful to signal the presence of a systemic problem (problem with system structure) which requires specific systemic instruments to be solved (Wieczorek and Hekkert, 2012: 78), this suggests that, functional and structural analysis complement each other, leading to the identification of the systemic problems and proposing systemic policy instruments.

The structural analysis views the AIS as an innovation support infrastructure (Vellema, 2008, cited by Klerkx, and Gildemacher, 2012), which offers possible linkages and relationships among the diverse actors in AIS (Fig. 1) but the composition of actors may differ depending on the location and institutional context (Freeman, 1988; Nelson, 1993). The major concern is to what extent the type of actors involved in any innovation and their attributes may support or hinder agricultural innovation. Functional analysis on the other hand tries to identify the missing components or components that are not interacting amicably (Hekkert *et al*., 2007). Based on the generic functions of innovation system (Lundvall, 1992: 2), the analysis involves knowledge/technology development, entrepreneurship activities (in this case multiplication and dissemination) and economic utilization.

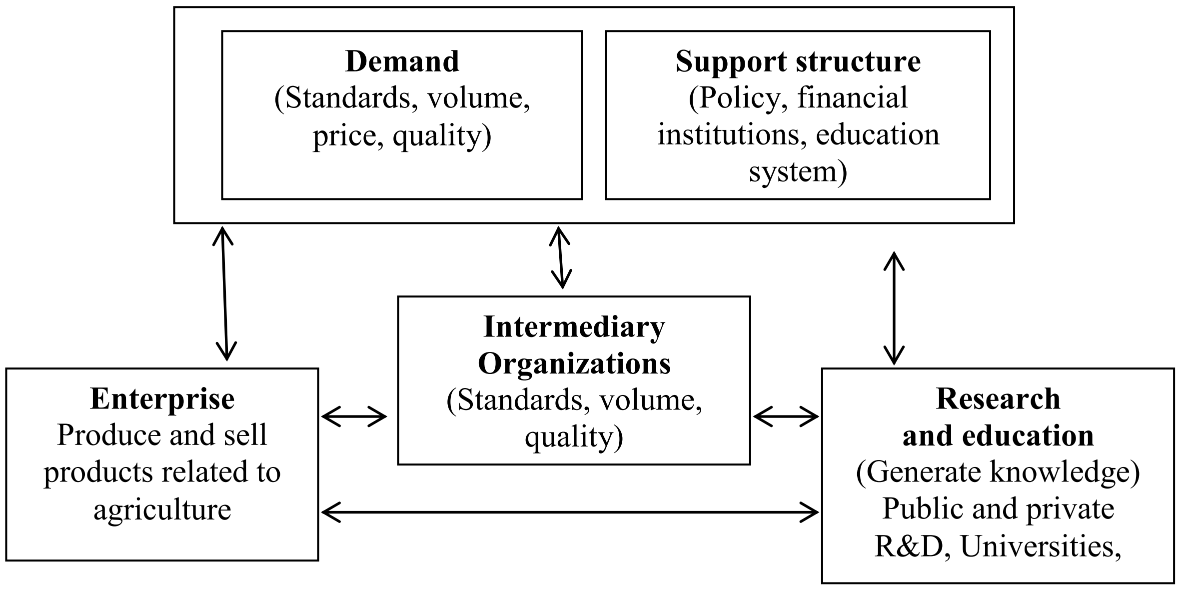

Figure 1: Possible actors in the agricultural innovation system. Adapted from CABI/CTA/KIT/VRLIE/WUR (2006); Rajalahti *et al.* (2008: 4); Arnold and Bell (2001: 279).

3.2.2 Features of agricultural technologies: Excludability, rivalry and appropriability

Liberalization of private economic initiative in Tanzania which included privatization of agricultural technologies from public research institutions such as seed and fertilizer (Skarstein, 2005: 341) led to the emergence of public/private sector relationships in agriculture. Though the technologies embodied in the agricultural practices (such as recommended seed rate, soil and water conservation) have little market value, and are considered as ‘public goods’, which anyone could use without diminishing the value (Van den Berg and Margree, 2001), in many SSA countries, there are exceptions regarding the appropriabiliy of new generated technologies. Varieties of seed is a good example, while hybrid seeds are considered as ‘private goods’, seeds of Open Pollinated Varieties (OPVs) for which farmers can use seed from previous harvests, are considered as “public” by business firms. Thus, other categories of economic features of agricultural technologies such as impure public (mixed) goods are now recognized in addition to the two classic groups, public and private goods (Muraguri, 2006: 2).

Therefore, although private sector appeared to be the most effective provider of goods and services because of its stronger links with clients (Carney, 1998: 13-26), the concept of rivalry and excludability can be used as a framework to predict whether the expected research results (goods and services) will be provided by the private sector or market failure will necessitate the public sector to provide, regulate or subsidize research results to end users (Hall *et al.*, 2001: 5; Pineiro, 2007). The term rivalry is used for the goods and services that one person’s use or consumption reduces its availability, while excludability refers to the capture of property right to the knowledge (Van den Berg and Margree, 2001:6). Thus, the extent of rivalry and excludability influences the appropriability nature and consequently determines whether a private actor takes up a certain activity (Hall *et al.*, 2001: 5; Van den Berg and Margree, 2001:7).

3.3 The Tanzania Case

In Tanzania, the trend of shifting towards a system mode of innovation is illustrated by the policies and regulations guiding research and development. In recent years, Tanzania has been shifting from Science and Technology (S&T) policies, which were dominant in 1970s and 1980s towards Science, Technology and Innovation (STI) (URT, 2010). Under this new thinking, the emphasis is for the scientific and technological knowledge generated by research institutions to be responsive to the socio-economic development of the country. On the other hand, the National Research and Development Policy (NRDP) of 2010, emphasizes the commercialization and dissemination of research results. Under the current NARS, agricultural research is mainly conducted in government and private R&D institutions and universities. Agricultural research has largely been a public undertaking over the past three decades (Rutatora and Mattee, 2001), but following the provision for public-private sectors relationship, the current NARS is now a loose collection of multiple public, NGOs and private institutions (Sempeho, 2004).

The Agricultural Sector Development Strategy (ASDS), which was adopted in 2001, formed the basis for public-private partnership in support of agricultural growth and rural poverty reduction. The Agricultural Sector Development Programme (ASDP) which was launched 2003 puts ASDS into effect at subsector level including research, and created the Zonal Agriculture Research and Development Fund (ZARDEF) aimed at making the research agenda demand-driven and also to support technology transfer interventions (Sibuga, 2008).

Through ASDP, the Zonal Information and Extension Liaison Units (ZIELUs) were formed to enhance communication between research and Local Government Authorities (LGAs), farmer groups/networks, the Agricultural Sector Lead Ministries (ASLMs), national level organizations and institutions. Parallel to ASDP, NARS adopted the Client-Oriented-Research and Development Management Approach (CORDEMA) in 2003 in order to enhance agricultural innovation for poverty reduction. Therefore, ASDP through CORDEMA facilitated public and private providers of agricultural research to provide more relevant and effective services. However, with the exception of few studies on multi-sectorial system of innovation (Malerba and Mani, 2009), the focus of majority of studies on innovation system is inclined towards industrial technologies mainly on effective knowledge sharing (Szogs and Lugano, 2006; Szogs, 2010); role of mediator organizations (Szogs, 2008; Szogs *et al*., 2011) and cluster initiatives (Diyamett, 2009).

3.4 Methodology

Tanzania has 14 government agricultural research centres located in seven ecological zones under the mandate of the Ministry of Agriculture, Food Security and Cooperatives. The centres are involved in crops, food and soils researches in relation to their respective ecological zones. Initially, the study intended to survey all research centres, however, 15 out of the 16 government research institutions /centres were visited, one centre could not be reached because of logistical difficulties. In addition, the study included two private Agricultural Research Institutes (ARIs) dealing with two major cash crops (coffee and tobacco), and Sokoine University of Agriculture (SUA). This made a total of 20 research institutions / centres surveyed by the study.

3.4.1 Data collection and sources

The research was conducted between July 2012 and March 2013, and data were collected in two phases. Phase One involved identifying all commercializable technologies generated in the 16 research institutions involved, followed by identifying the responsible researchers for the development and dissemination or commercialization of each of the technologies, this was done with assistance from officers in-charge of research stations. Commercializable technologies in this case included technologies in the form of physical products, designs or formulations that required either manufacturing or multiplication before dissemination. For example, planting materials such as seed or seedlings and agro-chemicals. Commercializable technologies also included practices or protocols that require special facilities or equipment in order to be effectively utilized. Therefore, a list of all commercializable technologies generated by each research institution between 1995 and 2010 and their associated developers/disseminators was established. Phase Two involved administering questionnaires (Appendix 4) to each of the researchers associated with each of the identified technology. In this case, all generated technologies were surveyed. Reliability and validity of data were achieved by administering the questionnaire through personal interviews to ensure that respondents achieved a uniform understanding of terms used in the questions, and also for clarifications as it was deemed necessary. In addition, documentary review especially on reports was used for validating data from questionnaires.

3.4.2 Data analysis

Analysis of the data involved quantitative and qualitative methods. Quantitative data on characteristics of technologies (objective one) and on actors and their roles (objectives two and three) were analysed using the Statistical Products for Service Solution (SPSS) version 16 in exploring frequencies and percentages. A cross-tabulation with Chi-square (χ^2) test was employed at 5% level of significance (Pallant, 2005), to see if any association existed between physical and economic characteristics of agriculture technologies. Other data were more qualitative in nature, and some had multiple answers, hence inferential statistical analysis was not illuminative. Therefore, large numbers of qualitative responses were reduced through a meaning categorization (Kvale, 1996). Results were cross-tabulated whereby answers from different questions were summarized in tables and correlated. Materials from the survey were related to the analytical framework of this research (as described in section 2).

3.5 Results and Discussion

3.5.1 Characteristics of technologies generated from R&D institutions

A total of 134 technologies were identified from 17 research institutions including 16 ARIs (government and private) and SUA. However, only 87 technologies were surveyed (Table 1). The information for the remaining 47 technologies could not be easily accessed. Seventy eight (90%) technologies were crop based and were mainly on improved varieties and seedling propagation. Of the remaining technologies, 5 (6%) were on food science and 4 (5%) were on soil science.

Table 1 shows the number of surveyed technologies according to their physical and economic characteristics and their distribution, which differed significantly (χ^2 = 87.000, p= 0.0001). Majority (94%) of the technologies were physical products and the remaining were sets of procedures or protocols governing development of certain products. Furthermore, the results indicated that 60 technologies (69%) had characteristics of mixed goods. Mixed goods are essentially public goods in the sense that they are non-excludable and non-rivalrous, but since they need further investments (for multiplication/manufacturing) for them to be available, their access can be denied to those who cannot pay for the product hence they become private (Umali and Schwartz, 1994). Similar results were reported by Muraguri (2006), that only few agricultural technologies fall neatly under either public or private good while the majority were mixed goods (Appendix 5).

Table 1: Surveyed agriculture technologies grouped in terms of their physical and economic characteristics (n= 87)

Physical feature	Economic features			
	Public good (%)	Private good (%)	Mixed good (%)	Total (%)
Physical product	0	22 (25)	60 (69)	82 (94)
Protocol	5 (6)	0	0	5 (6)
Total	5 (6)	22 (25)	60 (69)	87 (100)

Thus, although all the surveyed technologies needed further investments for multiplication or manufacturing, the fact that they were potentially public goods made entrepreneurs, such as commercial seed companies or agencies, less interested to invest on them. This situation makes the developed technologies unavailable for use by the general public due to what may be termed as market failure. Van den Berg and Margree, (2001) relates market failure with a situation whereby the private sector is either not existing or not willing to invest because the goods are non-rivalrous and non-excludable.

On the other hand, five (6%) technologies were in the form of protocols. Despite being public goods, protocols also needed either sophisticated and/or expensive equipment or special skills for mass multiplication, which were not within the capacity of agricultural entrepreneurs, hence, resulting into unavailability of the technologies to the majority of farmers, for example in vitro propagated banana seedlings. This is synonymous with the systemic failure, a situation whereby firms and/or sectors failed in adapting to new technological developments due to low levels of knowledge and the ability to learn (Smith, 2000: 95).

3.5.2 Roles of different actors involved in agriculture innovation

To examine the contribution of each actor in the agricultural innovation, this study split the process into three phases: (1) technology development; (2) technology multiplication or manufacturing, and (3) technology dissemination and commercialization.

Stage one: Technology development

At this stage, six key actors were identified, and all actors, except for the business enterprises, their roles were predetermined by their institutional roles and/or defined by the research arrangement (Table 2a) such as: Researchers – sources of research ideas for all 87 (100%) technologies; Donor or financing institutions – financing researches; Local Government Authorities (Extension services) – community mobilization and training; Farmers – provide feedback; and Regulatory bodies – regulate the quality of the technologies for quality assurance. Business enterprises were involved in developing the five (6%) technologies (Table 2a) in which the R&D were obliged to identify engineers from contracting or consulting business firms to design or provide machinery with specific specifications which were needed as components of new technologies. Hence, business enterprises were also regarded as a source of research idea. This is different from the early mechanism of agricultural innovation (technology transfer) under NARS whereby public sector was the main actor, oriented to diffuse knowledge to farmers to enable them to unlock the knowledge embedded in the products (chemicals, seeds, equipment) through extension services so as to increase productivity.

The policy reforms of 1990s and privatization of some of public services shifted the government-driven research system to a multi-actor system in which private actors (such as input companies/industries) came to play a larger role (Chema *et al*., 2003: 38). Thus, business enterprises appeared not only as new actors within agricultural knowledge infrastructure but also established new roles for the R&D institutions.

Table 2a: The actors involved at technology development stage and their roles

Actors	Roles	Percentage of technologies*
R&D institutions: Researcher	Source of research idea and technology development Verification of technology performance	100
	Identify and involve business enterprises to design and produce specific materials and/or equipment needed in processing or application of new technologies.	6
Local Government Authorities: Extension service	Extension staff mobilize the community to participate and provide field supervision on trials and demonstrations Farmers contribute in kind (land and labour) and evaluate the performance and acceptability of new technology	84
Regulatory bodies	Quality assurance	69

*Percentage of technologies that benefited from roles performed by the actor

The outcome of interaction of actors in technology development stage made some of the resulting technologies to be constituted of multidimensional components available from multiple sources and not from a single supplier (the R&D), hence, transfer of such technology packages needed concurrent interaction of more than one supplier of different products and services (Case 1). This challenge requires a new institutional and organizational orientation for R&D to interact with business enterprises and also for business enterprises (multipliers) to access the complete package. This will require policy instruments to guide interaction between R&D and industry on issues related to intellectual property disclosure agreements, ownership of innovation and incentive schemes. Intermediate organizations are reported as one of the options in dealing with this problem whereby they facilitate innovation by providing the bridging and brokering role needed (Klerkx and Leeuwis, 2008; Hall *et al*., 2005).

Case 1: The multidimensional nature of the cassava flour processing technology

Researchers from Sokoine University Agriculture developed a protocol for the production of quality flour and animal feed from fresh cassava; an engineer (machine designer) from a private firm designed the cassava chopper according to the requirement prescribed by the researchers. The researcher, engineer, livestock keepers and feed millers tested the technology and developed the technology package (the machine and processes). The development partner, Farm Africa provided funds for dissemination of the technology package and Tanzania Gatsby Trust an experienced Non Governmental Organization, managed the funds for dissemination through a revolving fund arrangement so as to add the commercial perspective in acquiring the technology. The technology was disseminated to farmer's groups in Kibaha, Kibiti and Mlandizi in Coast Region.

Stage two: Multiplication of Developed Technologies

Despite the fact that surveyed technologies required business enterprises to do the multiplication before dissemination or commercialization, the findings (Table 2b) indicate that business enterprises were involved in multiplication of only 35 (40%) of the technologies. The remaining 52 (60%) of the technologies were multiplied by five different actors namely R&D, Farmer groups, NGOs, Local Government Authorities (LGAs) and private processing companies (Table 2b). However, the role of technology multiplication was not a core function of most of these actors, except where necessary as an imbedded activity and/or a complement to their principal goals, subject to the availability of resources. For example, the reported engagement of R&D in technology multiplication and particularly for the sophisticated or complex technologies (Table 2b) happened because there were no business enterprises that could afford to perform the job. Hence, the idea was to establish a spin-off business where the expertise and facilities from the owner (R&Ds) of the technology could be easily accessed. As for the involvement of the LGAs, the Local Government Reform Program (URT, 1998) and the Agricultural Sector Development Programme (ASDP) (URT, 2003) governed this, whereby government funds were provided to the District Councils for this purpose. At the same time, the NGOs were interested in improving the income levels of the people and hence rural livelihoods (Case 2).

Table 2b: The actors involved in technology multiplication stage and their roles

Actors	Roles	Percentage of Technologies*
Business enterprises	Mass production of technology for sell	40
R&D Institutions	Propose and implement donor funded project to: Establish demonstration plots, Facilitate establishment of commercial farmer's managed multiplication farms Facilitate establishment of spin-off business enterprises particular for sophisticated technologies Contracted by NGOs and companies to multiply	45
Local Government	Contract R&D to multiply and distribute technologies to groups free, particularly to vulnerable households Facilitate establishment of secondary multiplication nurseries	9
Farmers	Establish commercial multiplication units (farmers owned) through the support from NGOs and R&D, whereby farmers provide land and labour and some NGOs guarantee market of the innovated technologies from entrepreneurs.	36
Regulatory bodies	Quality control of the products	24
Company (processes)	Guarantee purchase of the outcome of innovation at least initially Support farmer group in the establishment of commercial seed multiplication farms.	2.2

*Percentage of technologies that benefited from roles performed (or facilitated) by the actor

- Note that some of technologies were handled by more than one actor.

Case 2: Development NGO as a facilitator for agricultural innovation
The Mwanza Rural Housing Program (MRHP) started in 1990 with the main aim of supporting the rural population in Mwanza Region and improving the standard of their habitat. An evaluation which was conducted in 1998, revealed that despite MRHP's efforts in disseminating knowledge and skills on the building of low-cost houses, farmers did not have the financial resources needed to invest in improving their habitats. The only source of income for the farmers was agriculture (mainly green gram and cowpeas), which production had been declining due to unavailability of quality seeds. Thus MRHP partnered with Catholic Relief Services (CRS) to implement Misungwi Grain Legume Pilot Project (MGLPP) aimed at improving grain legume production. MGLPP used a collection of complementary interventions including new seed variety, seed multiplication, integrated pest management and improved agricultural marketing techniques. MGLPP facilitated formation of farmer's groups to manage both seed multiplication and marketing on commercial bases. To strengthen the farmer organization, MGLPP also facilitated formation of Saving and Internal Lending Communities (SILC). Later on, under the support of CSR, SILCs were merged to form SILC Group Association (SIGA) as marketing cooperative that negotiated with buyers of crops produced by SILC members.

This is in line with observation by Klerkx and Leeuwis (2008: 270) who urged that in developing countries, some NGOs and projects have taken up intermediation roles either as a core or embedded activity to support business enterprises with agricultural innovations.

Table 2b further reveals that other actors such as R&D institutions, LGAs and farmer groups who were involved in the multiplication of the remaining 52 (60%) of the surveyed technologies, performed this role as an extra function either as a project targeting specific location for a specific time, or as a one-time intervention. This raised the issue of sustainability and scalability. However, in the course of implementing these agricultural innovation projects, new facilitation roles emerged which were neither a source nor a carrier of technology such as: establishing commercial multiplication enterprises, demand articulation, managing interfaces, linking actors from different cognitive and cultural backgrounds and financing. The current literature on innovation terms these types of organizations that are involved indirectly in enabling stakeholders in the innovation process as innovation intermediaries (Hall *et al*., 2005; Klerkx and Leeuwis, 2008) or innovation brokers (Klerkx and Leeuwis, 2009; Klerkx and Gildemacher, 2012). However, the question is whether or not the existing R&D institutional framework can accommodate these emerging roles.

Stage three: Technology dissemination and commercialization

A total of eight actors (except donors) were involved in the dissemination of all 87 identified technologies (Table 2c). From the analysis of the roles of the actors presented in Table 2c and in relation to the results in Table 3, four different categories of actors can be differentiated at this stage: the first category was actors involved in the dissemination of the 82 (94%) technologies in the form of physical products (Table 1 and 2c) through direct sale or free distribution, examples include R&D, LGAs, farmer groups, NGOs and business enterprises; the second category included actors who specialized in handling technology in the form of information. These actors were Zonal Information and Extension Units (ZIELUs), LGAs (extension service) and Ministry of Agriculture Food Security and Cooperatives (MAFSC) through Agricultural Technology Transfer Centres (ATTCs). Different actors in this category handled all 87 technologies (Table 2c). This implies that, 82 (94%) technologies in the form of physical products were handled by both the first and second categories of actors. This suggests that most of the technologies constitute two components i.e. physical and information components, which require different specialized actors, media and strategies for their effective dissemination. This was also illustrated by the study of Kavia *et al*. (2007: 1877) on factors affecting adoption of cassava in the Lake Zone Regions of Tanzania which showed that households which received information (technological package) concerning improved varieties were more likely to adopt improved varieties compared to households which had no such information.

The third category of actors supported the dissemination/commercialization of 33 (38%) technologies indirectly by either developing the market for the technology or articulating the demand through subsidies, credit schemes, spin-off business enterprises or supporting value addition (Table 2c). The fourth category consists of actors meant to create favourable conditions/incentives for business enterprises to operate, for example the Plant Breeders' Rights (PBR) office and the Business Registration and Licensing Agency (BRELA) (Table 2c). However, there was no evidence that this last category of actors does create conducive environment for dissemination or commercialization of any technology, at least during the time of the survey. Here, legal instruments were considered only in the narrow sense of protecting intellectual property (IP) rights and not as facilitating the innovation process.

Table 2c: The actors involved in technology dissemination and commercialization stage and their roles

Actors	Roles	Number of technologies Per role	Total
R&D Institutions	Develop project or request special funds to support multiplication and dissemination of technology through:		
	Direct selling or distribution through training and demonstrations	36	82
	Establishment of spin-off business enterprises	3	
	On farm demonstration trials	19	
	Training of business enterprises (processing)	5	
	Develop and distribution of educational materials: brochures, exhibitions (ZIELU)	82	
Local Government	Selling from multiplication units	6	82
	Training field days and exhibition (Extension service)	82	
Farmers groups	Selling from commercial multiplication units	35	35
NGOs	Distribute technologies to end-users (farmers) freely	12	
	Establish credit /revolving fund	6	
	Subsidizing products from business enterprises (multipliers)	5	28
	Support value addition (processing) of the outcome of innovation	5	
Business enterprises	Selling to end-users	16	
	Produce components of technology according to the order from multipliers (entrepreneurs or R&D or individuals)	1	17
Government (MAFSC)	Provide competitive funds (ZARDEF) to support Quality Declared Seeds (QDS) or subsidies to specific crops of priority	14	31
	Establish ATTC to show case new technologies from R&D and to liaise between stakeholders	17	
PBR, BRELA*	Intellectual Property Right protection	24	24
SUA Technology Transfer Office*	Facilitate patenting	4	4

* No evidence for these actors influencing dissemination

3.5.3 The relationship between characteristics of agriculture technologies, actors and their roles in innovation

Linking the characteristics of the surveyed technologies (Table 1) and actors involved in agriculture innovation and their roles (Table 2 a, b & c) shows that actors and their alignments in the innovation process (development, multiplication and commercialization) seem not to be uniform across the technologies. For example, all technologies characterised as physical products 82 (94%) were disseminated with their accompanied knowledge (of application). However, the physical part was further developed through the enterprise domain while the knowledge part, being a public good, was diffused through the intermediary's domain (one–to–one) such as extension services (Table 3). Further analysis shows that private goods 22 (25%) were handled by actors under the enterprise domain and sometimes motivated by subsidies (Table 3). Mixed goods 60 (69%) on the other hand, were managed through the intermediary domain that facilitated establishment of enterprises (Table 3). The three (3%) technologies that needed sophisticated techniques were commercialised through specific businesses (spin-off enterprises) established at R&D institutions. This implies that characteristics of technology influence both the type of actor and their roles, and interaction within the agriculture innovation system (Appendix 6). Hence, the dimension of characteristics of technologies when coupled with structural elements of the innovation system frameworks may enhance the performance the framework in terms of signalling the potential systemic problems (Appendix 7).

The notable findings in Table 3 were that, some actors were flexible, taking multiple roles needed for innovation. For example, LGAs and R&D institutions appeared in different domains (i.e. undertake different roles) for different types of technologies. This observation signifies a systemic nature of an innovation system, such an innovation is a result of interaction of different actors and their roles. However, since most of these interventions were donor-funded through projects or programmes, the issue of sustainability emerges. The challenge is whether the existing R&D institutions and LGAs institutional framework can facilitate the link and coordination of these different domains (entrepreneurs and intermediary).

Table 3: Characteristics of agriculture technology, actors and their roles in agriculture innovation (n=87)

Characteristics of technologies		%	System actors / components involved	Examples of technologies
Physical product	Private good	25%	Enterprise domain: Private firms, R&D and LGAs Support structures: Subsides from Government, private and NGOs	Hybrid varieties of crops, fertilizer types
	Mixed good	69%	Intermediary domain: (Facilitators): NGOs, LGA, and R&D that facilitated establishment of commercial multiplication units and demand articulation	OPV*, and vegetative planting materials
	The knowledge of use or application of technologies (public)	94%	Intermediary domain (diffusion) sectors (LGAs through Extension services and R&D through ZIELU) and ATTC including brochures, training, exhibitions and demonstrations	Agronomic practices
	Sophisticated (public)	3%	Intermediary domain: through Business established at R&D (spin-off enterprises).	Banana tissue culture seedlings
Protocol	Public	6%	Intermediary domain: (facilitators): supported designing or accessing associated technologies	Cassava flour processing

* Open Pollinated Varieties of crops

3.6 Conclusion and Recommendations / Policy Implications

The objective of the study was to identify characteristics of agricultural technologies generated by R&D institutions in Tanzania, and to examine their influence on actors involved and their roles in agriculture technology innovation system. The main characteristics of technologies identified include: physical and economic characteristics and level of sophistication.

Most of technologies (69%) were in the category of physical products and mixed goods. Few of the surveyed technologies (28%) including hard simple and sophisticated technologies were private, and only 9% were in the form of protocols and pure public. Being pure public or mixed goods it implies less market potential, hence the technologies were less attractive to entrepreneurs. Therefore, basing on the economic and physical features of the agricultural technologies, the actors and their alignment in innovation, seem not to be uniform, while 35 (40%) technologies were taken up by business enterprises, 52 (60%) technologies needed intermediaries (such as LGAs, NGOs and R&D institutions) to overcome market and systemic failures. Hence, in the Tanzanian context (and other similar countries in SSA), the 'physical and economic' features of agricultural technologies can be considered as essential features of an agricultural innovation system in addition to the previously highlighted features by Hall *et al*. (2005: 3) which constitute mainly the 'institutional' based features. Hence, for the agricultural technologies to be available to the end-users, policies and institutional framework should facilitate SMEs with skills, funds and expertise to enable them to invest in dissemination of agriculture technologies.

Furthermore, the roles of actors are evolving as the economic characteristics of technologies are changing along the innovation processes (development, multiplication and dissemination), for example R&D institutions are navigating from being a source of knowledge, intermediary organization to business enterprises. Thus the roles for the actors of innovation (both public and private) are evolving beyond what is predetermined by their institutional roles and mandates. This signifies the practices of complex and systemic approaches of innovation. However, these changes are not yet adequately institutionalized and the emerging innovation intermediation roles are not yet officially recognized as crucial for agricultural innovation. These findings highlight the essential features of agricultural innovation needed for technologies of different characteristics, hence, emphasising the need for institutional change for all key actors of agricultural innovation if research results are to be effectively utilised.

The observed initiatives of adopting the systemic approach of innovation are mainly under project intervention, which raises the issue of sustainability and scalability. The study suggests that for research capacity to innovate in systemic context it requires capacity development, institutional change, and flexibility to respond to multiple recipients' priorities. Also we concur with Smith (2000: 96) for a rational public support to innovation intermediaries.

In addition, even though different national policies advocate private sector involvement in technology development and commercialization, local context may in various ways limit their roles; hence deliberate partnerships between public and civil society organizations may be a better option. Further studies are needed to investigate the roles and attributes of innovation intermediation.

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CHAPTER FOUR

4.0 Contribution of Innovation Intermediaries in Agricultural Innovation: The Case of Agricultural R&D in Tanzania

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This work was carried out in collaboration between the Authors. The first Author, Mgumia A.H designed the study, collected data, performed the data analysis and wrote the first darft of the manuscript. The second and third author Prof. Mattee, A. Z. and Prof. Kundi B. A. T gave comments; all authors read and approved the final manuscript

Abstract

With the current global economic reforms and advances in science, the move has been towards privatization of the agricultural knowledge infrastructure. However, inadequate capacity of agricultural entrepreneurs and the diversity in the characteristics of the agricultural technologies have created market and system failures resulting in imbalances of the supply and demand of technologies hampering private agricultural business development. Experience from countries with mature innovation systems, indicates the emergence of innovation intermediaries that facilitate agricultural entrepreneurs to innovate. Using a case-study approach, the present study identified and mapped the recipients of technologies from agricultural research institutions in Tanzania and analyzed the extent to which 'innovation intermediation roles' have been applied by recipients in relation to demand articulation, network brokerage and innovation process management. Through an in-depth analysis of twelve cases, the study revealed the role of innovation intermediation performed by NGOs and R&D institutions as project interventions not as their specialized activities. The study demonstrates the potential contributions of innovation intermediaries in agricultural innovation processes and recommends official recognition and government support in the establishment and implementation of innovation intermediation activities outside the project set-ups.

Key words: innovation, innovation intermediaries, National Agricultural Research System, marketable technologies, innovation networks and Tanzania

4. 1 Introduction

The requirements for successful application of new agricultural knowledge in the current market-based global economy are changing (Sumberg, 2005: 22-23; Hall *et al.*, 2005: 1; Hall *at al.,* 2006:7). In the 1980s, the sub-Saharan African countries created the National Agricultural Research Systems (NARS) purposely to conduct applied research so as to adapt the imported technologies to relevant ecological and production conditions (Rajalahti, 2009:3). But, much of the knowledge and many of the technologies created through such activities which were mainly appropriate agronomic practices (i.e. seed rate) had little market value and relied on public research institutions and universities (Pineiro, 2007). This system worked well especially with the diffusion (non-commercial) model of technology dissemination, whereby public agricultural extension services linked researchers and farmers (Rogers, 2003; Simpson, 2006: 10).

Nevertheless, the model is no longer feasible as public funding for agricultural research and extension services has diminished, and science has grown more complex (Chema *et al.*, 2003: 38; Sumberg, 2005: 22-23). Thus, the technologies produced by research are requiring private entrepreneurs to develop them further (multiplication/ manufacturing/ purification) before dissemination, depending on the nature of technologies. However, economic characteristics of agricultural technologies (either public or private good) influence participation of private sector in technology development and dissemination. For example seeds of open pollinated crop varieties and legumes are regarded as public goods (farmers can collect seeds from previous harvests), hence not attractive to private entrepreneurs. In additional, inadequate technical knowhow and the lack of capital are preventing agricultural entrepreneurs from investing in sophisticated and /or expensive technologies such as tissue culture to enhance mass multiplication (Mtui, 2011: 194).

Apart from the characteristics of technologies, on-going government reforms are also influencing the actors needed for putting agricultural technologies into economic use. As a case example, privatization of public knowledge from Research and Development institutions (R&D) (Skarstein, 2005: 341) resulted into increased number and categories of stakeholders in the NARS, and their interactions have become more complex (World Bank, 2006; Anandajayasekeram, 2011: 2-3), hence innovation processes are less linear.

Recent literature on agricultural innovation from developed countries highlights the role of emerging specialized actors characterized as 'systemic intermediaries' or 'systemic facilitators', whose function is to connect multiple actors (Howells, 2006: 717-718). They also facilitate small and medium scale agricultural entrepreneurs to participate in the commercialization of agricultural innovations (Klerkx and Leeuwis, 2008a: 260). Howells (2006: 718) identified these organizations as innovation intermediaries. In other countries including developing ones, a conglomeration of actors such as research organizations, NGOs and projects have taken up this intermediation role either as a core or a side activity (Klerkx and Leeuwis, 2008a: 265-266). The working definition of innovation intermediary for this study as adopted from Howells (2006: 720) is:

> '…..an organization or body that acts as an agent or a broker between two or more parties in any aspect of the innovation process. Such intermediary activities include helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator, or go-between bodies or organizations that are already collaborating; and helping to find advice, funding and support for the innovation outcomes of such collaborations.'

In Tanzania, like in many sub-Saharan African countries, despite the fact that NARS have allowed new actors (i.e. NGOs, private sector, farmer organizations, Local Government

Authorities) to participate in agricultural innovation (Sempeho, 2004: 1; Rutatora and Mattee, 2001: 157), the existence and contribution of the innovation intermediaries in the agricultural knowledge infrastructure (R&D institutions, agricultural extension) is not yet clearly recognized. This poses the question as to how these actors that are involved in the innovation process, operating under different institutional frameworks (public, private), with different knowledge backgrounds (scientific and business) and different socio-economic backgrounds can create and maintain effective networks needed for agricultural innovation in Tanzania.

This study sought to highlight the importance of innovation intermediaries in agricultural innovation and emphasizes the need for setting-up of a more enabling environment for these actors to facilitate linkages and relationships between stakeholders, which operate under different institutional and knowledge backgrounds, but have the potential contribution to innovate when coupled with existing opportunities.

It is against this background that this study was carried out with the aim of analyzing organizations that facilitate the economic use of new knowledge and technologies generated from Agricultural Research Institutes (ARIs) and how they are positioned as 'innovation intermediaries' within innovation networks. Specifically, the study attempted to answer the following questions: What are the categories of organizations that perform innovation intermediation functions? What are their roles in supporting agricultural innovation? And what are the outcomes of the innovation process? We begin by providing a conceptual background on recent thinking on 'systems' mode of agricultural innovation and the innovation intermediation roles followed by a presentation of case studies in which innovation intermediation roles were applied in agricultural innovation in different organizational settings in Tanzania.

4.2 Conceptual framework

4. 2.1 Systems of agricultural innovation

Over the past four decades, a range of agricultural innovation (AI) approaches have emerged and resulted in the widening of theoretical perspectives of the AI approaches (Klerkx *et al.*, 2012: 459; Leeuwis, 2004). Innovation is understood to be neither research nor science and technology, but rather 'the application of knowledge (of all types) in the production of goods and services to achieve desired social or economic outcomes' (World Bank, 2006: 16).

The innovation system concept in agriculture evolved, though not consecutively, from the National Agricultural Research System (NARS) that dominated in 1980s through Agricultural Knowledge and Information System (AKIS), which emerged in the 1990s (Assefa *et al.*, 2009), to the current Agricultural Innovation System (AIS). Despite the fact that the NARS has been effective in creating agricultural science capacities, it did not explicitly link research to technology users and other actors in the sector. Similarly, the AKIS framework was mainly focused on the rural environment while the role of the market, private sector and enabling policy environment were not given adequate consideration (World Bank, 2006: 27).

Agricultural Innovation Systems (AIS) were developed from the research perspective reflecting the thinking of National Innovation System (NIS) approach developed by Lundvall (2004). The AIS concept, in addition to capacities and processes emphasized in NARS and AKIS frameworks, recognizes the broader range of actors and particularly the private sector involved in innovation (Hall *et al.*, 2006a: 17). AIS regard other factors such as policy, legislation, infrastructure, funding and market development equally important in innovation processes, as mechanisms for generation and dissemination of new knowledge

(World Bank, 2006: 27). This makes the features of AIS approaches distinct from NARS and AKIS, in that they are complex with multi-actors performing evolving roles (Klerkx *et al.*, 2012: 462-463).

4. 2.2 Roles of innovation intermediary organizations

Experiences of innovation intermediary organizations, particularly in the industrial sector with regards to supporting SMEs, are adequately documented in the current literature (Howells, 2006; Szogs and Lugano, 2006; Szogs, 2008; Szogs *et al.*, 2011). In the agricultural sector, however, the focus of these organizations is on overcoming uncertainties arising from commercialization of research results that hinder effective cooperation for innovation. The uncertainties on the supply side (R&D and extension services) include: funding instability in terms of availability and timely disbursements and lack of space for actors to interact and achieve a demand–driven model of working. Uncertainties on the demand side (SMEs, farmers and consumers) include information and managerial gaps (Klerkx and Leeuwis, 2008b).

Using case examples from the United Kingdom, Howells (2006: 720-725) shows a range of functions that an innovation intermediary should normally perform such as foresight and diagnostics, scanning and information processing, knowledge and processing, testing and validation, accreditation, gatekeeping and brokering, validation and regulation, protecting the results and commercialization. In the context of economic utilization of agricultural knowledge, the innovation intermediaries are positioned as facilitators of linkages and interactions that govern the flow of knowledge needed by innovation networks (the providers of R&D institutions on the supply side and uses of knowledge on the demand side) (Klerkx and Leeuwis, 2008a: 263). At that position, scholars summarized the different innovation intermediation functions into three main functional frameworks: 'demand articulation', 'network composition' and 'innovation process management', aiming at overcoming market and system failures (Klerkx and Leeuwis, 2008a: 262-263; Perez *et al*., 2010).

Demand articulation is a terminology used in the field of innovation to explain a learning process about the needs not only for new technologies but also for technologies in their early phase of development, or emerging technology whereby the needs of users are not yet specified (Smits, 2002). Demand articulation is an iterative, inherently creative process in which stakeholders try to address what they perceive as important characteristics of new technology, and attempt to express preferences for an emerging innovation (Boon and Moors, 2008: 4). Demand, as a major driver of client oriented systems, entails demand articulation as a key role of innovation intermediaries (Smith and Kuhlmann, 2004: 12; Izushi, 2003; Boon and Moors, 2008:4). This role can be achieved through establishing dialogues between users and providers of knowledge, problem diagnosis and foresight exercise.

Network composition involves developing links between a variety of producers and users of information and their effective working relationship where there is a wide gap between them (Izushi, 2003: 786). Thus, network brokerage includes channeling of knowledge between different actors (Bessant and Rush, 1995), organizing space for dialogue between players of innovation (innovation platforms) (Anandajayasekeram, 2011: 10-14), and sourcing of funds for innovating activities such as subsidies (Kolodny *et al*., 2001: 216).

Innovation process management involves alignment and facilitating interaction of relevant actors with different institutional frameworks (norms, values, incentive and rewarding systems). Due to the differences in backgrounds of actors, to achieve the intended functioning stakeholder coalitions it requires continuous interface management (Smith and Kuhlman, 2004); interpretations amongst the different actors' domains, described as 'boundary work' (Kristjanson *et al.*, 2009); facilitation roles to attain productive and sustainable interactions among actors; the building of trust; managing conflict and managing intellectual property (Klerkx and Gildemacher, 2012).

Thus, innovation intermediaries facilitate linkage and interactions not only at the innovation network (supply and demand sides) level but also between innovation network and the national agricultural innovation system (e.g. policies, infrastructure) (Klerkx and Leeuwis, 2008a: 263). Hence, the success in facilitating such a diverse set of actors can be achieved when innovation intermediaries operate as neutral and as unbiased as possible (Hanna and Walsh, 2002: 205-206). Also the outcomes of process-oriented innovation intermediation roles are both technical and social (institutional, managerial and organizational) innovations. This is illustrating the complex nature of packages for agricultural innovations. Therefore, it is because of the complexity of agricultural innovation that the role to be played by innovation intermediaries is envisioned as activating the non-linear innovation process, connecting different actors of the system, filling the gap between knowledge and practice and facilitating platforms for innovation.

4.3 A need for innovation intermediation in Tanzania

Agricultural technology dissemination, which was principally provided by extension services, has largely been a public undertaking in Tanzania. Following the Local Government Reform Programme (LGRP) and decentralization reforms (URT, 1998), most of the public services including agricultural extension were decentralized and moved from Ministry of Agriculture to Local Government Authorities (LGAs) which are two different ministries, resulting into weak linkages between research institutions and extension services (Sibuga, 2008: 25). This institutional framework has hindered the flow of information regarding new knowledge not only from researchers to farmers but also from researchers to the private sector. Technologies generated from research are also diverse in nature, that is, from simple agronomic practices such as fertilizer rates disseminated through extension services, to physical products (e.g planting materials) and sophisticated bio-technological technologies requiring entrepreneurs for multiplication and commercialization (URT, 2013; URT, 2010).

Since the 2000s, organizational reforms as well as national strategies, particularly in the agricultural sector, were geared towards making the private sector more active in the transfer and commercialization of intellectual property emerging from public research institutions. For example, Zonal Information and Extension Liaison Units (ZIELUs) were established to enhance the linkage between R&D institutions and other stakeholders. Additionally, through the Agricultural Sector Development Programme (ASDP), various technical committees were established to oversee the entire process of technology development which consisted of sector-wide representation, including the private sector. Examples are the Zonal Research Technical Committees (ZRTCs), the Zonal Agricultural Research and Extension Development Funds (ZARDEFs) and the District Facilitation Teams (DFTs) as platforms of key players at Zonal and district level (URT, 2003; Sibuga, 2008: 17). However, with all the efforts made by the ASDP in encouraging the private sector to participate in the innovation process, they did not bring changes as expected (Thornton *et al*., 2011: 47-51). The incentive scheme incorporated in ZARDEFs encouraged the researchers to publish other than to innovate and DFTs were hardly utilized (URT, 2011). This situation indicated that the key actors of innovation including researchers, private sector, farmers, extension service providers, NGOs etc. operate in isolation due to lack of a mechanism that allows adequate linkage and interactions of the actors to innovate.

4.4 Study Methodology

Description of Study sites

This study was conducted from July 2012 to March 2013, involving 13 out of 14 government agricultural research centers located in seven ecological zones in Tanzania. The study involved technologies related to crop, food and soil science research under the mandate of the Ministry of Agriculture Food Security and Cooperatives (MAFSC). The remaining one research center could not be reached due to logistical difficulties. The study also included two private Agricultural Research Institutions (ARIs) involved with two major cash crops: coffee and tobacco; and at Sokoine University of Agriculture (SUA), the only agricultural university in the country, were five relevant Departments were involved: four in the Faculty of Agriculture including Crop Science and Production, Soil Science, Food Science and Technology and Animal Science Production and the Department of Veterinary Medicine and Public Health in the Faculty of Veterinary Medicine.

4.4.1 Data collection and data sources

Data were collected in two phases employing two different methods and tools. The first phase involved a questionnaire while the second phase employed personal interviews. In the first phase, all marketable or commercializable technologies were identified from research centers. The sources included the officers –in-charge, commodity delivery books at each center, and research catalogues (specifically for SUA). After identification of technologies, each technology was subjected to questionnaire survey whereby, at least one researcher who was involved in the development of the technology responded to a questionnaire (Appendix 4). Marketable technologies for this study were described as technologies in the form of a physical product (which needed further investment such as multiplication or manufacturing before dissemination) and processing technologies (e.g. food formulations) that needed associated technologies such as processing machinery or equipment. One of the outcomes of the first phase of data collection included identification of intermediary organizations involved in engaging businesses in dissemination of the technologies to end-users.

The second phase involved interviews with the head of the intermediary organizations identified in the first phase. The data collection tools included detailed structured interviews focusing on their functions, roles, and challenges (Appendix 8).

4.4.2 Data analysis

The analysis of the data involved quantitative and qualitative methods. The quantitative data of the identified technologies and their associated intermediary organizations were subjected to descriptive statistical analysis using Statistical Product and Service Solutions (SPSS) version 16. The qualitative findings from interviews (case studies) were fully transcribed and analyzed using content analysis method whereby both conceptual and relational analyses were employed.

4.5 Results and Discussion

4.5.1 Technologies identified and their recipient organizations

A total of 134 technologies were identified covering three agricultural sub-sectors: Crop 125 (93%), food 5 (4%) and soils 4 (3%) (Table 1).

Table 1: Identified technologies from R&Ds and the recipient organizations

Types and number of technologies surveyed			Number of technologies received by the recipient organizations		
			Business enterprises	**Intermediary organization (IO)**	**Both business enterprises and IO**
	Vegetative	17	0	17 (14)	
	OPV	102	28	45 (18)	29
Crop	Hybrid	5	5		
	Protocol	1	-	1 (1)	
Food	Protocols	5	-	5 (4)	
Soils	Fertilizers	4	1	1 (3)	2
Total		**134**	**34**	**69 (44)**	**31**
			25.4	51.5	23.1

Key note:
(*) In brackets are numbers of intermediary organizations dealing with that particular type of technology
OPV: Open (self pollinated) Pollinated Variety

Two types of actors received the technologies from R&D institutions: business enterprises, and intermediary organizations for the purposes of dissemination. About forty-four (44) different intermediary organizations were identified while business enterprises were mainly Agricultural Seed Agency (ASA). ASA is a semi autonomous government seed agent that was mandated to handle pre-basic and basic seed from government R&D institutions. Under that arrangement, other private seed companies purchased certified seed from ASA for further multiplication and dissemination. A total of 34 (25.4%) technologies were taken by business enterprises; 69 (51.5%) were taken by intermediary organizations and 31 (23.1%) technologies were handled by both business enterprises and intermediary organizations (Table 1). This implies that intermediary organizations are playing the role of dissemination and utilization of majority of agricultural innovations, particularly vegetatively propagated and OPV seed varieties.

4. 5.2 Innovation intermediation projects: what are they?

According to Howells's definition of innovation intermediary, out of the 44 intermediary organizations (Table 1), only 12 organizations (Table 2) were engaged in activities such as bridging between supply and demand sides, not by carrying technologies but facilitating other actors to innovate, hence qualifying as Innovation Intermediary Project Interventions (IIPIs) (Table 2). Furthermore, out of the 12 identified organizations that perform innovation intermediation functions, nine were project interventions of which eight of them were coordinated at R&D institutions as a side activities, the remaining three organizations were projects implemented by NGOs though not as specialized innovation intermediaries (Table 3). The IIPIs were funded by external donors except the Soya bean project and ATTC, which were funded by the government.

The remaining 32 organizations either procured technologies directly from R&D institutions or commissioned government R&D institutions to multiply the technologies for them then distributed free the technologies to the end-users (farmers). This happened mainly during food crises or natural disasters such as floods and drought that necessitated emergency supply of planting materials to the affected communities. These observations further confirm that the capacity of the traditional agricultural extension service providers and private companies are inadequate to handle these types of technologies.

Table 2: Names of the identified intermediary innovation organizations and the technologies involved

Name of Innovation Intermediation Project Interventions (IIPIs)	Acronym	Technology involved
Belgium Development Agency – Tanzania *	BTC Tanzania	Five Improved banana varieties
Dissemination of New Agricultural Technologies in Africa – for Quality Protein Maize*	DONATA-QPM	Maize (QPM)
Dissemination of New Agricultural Technologies in Africa – Orange Fleshed Sweet Potato*	DONATA-OFSP	Sweet potato (orange flavored)
Soya bean for the Southern Highlands of Tanzania Project*	Soya bean project	Soya bean (Bossuer)
Tanzania Food Security Project: Integrated Soil Fertility Management In Southern Highlands Zone *	TFSP	Minjingu phosphate fertilizer / Minjingu mazao
Food security and increases income to farmers: implemented by Vredeseilanden Tanzania	VECO-TZ	Cassava (Kiroba)
Common Fund for Commodity, International Institute for Tropical Agriculture (IITA) – in collaboration with TFNC	IITA	Cassava (Kiroba)
Project for Improvement of banana multiplication and cultural practices in Eastern and Southern Zones of Tanzania*	TC- Banana	Improved Banana varieties (in vitro micro propagation)
Agricultural Technology Transfer Centre**	ATTC	Many varieties
Uluguru Mountains Agricultural Development Project	UMADEP	Sunflower (Record)
Mwanza Rural Housing Project Agricultural Project*	MHRP	Green gram and pigeon peas
Cassava Processing Technology Project*	CPTP	Cassava flour and feed processing

(Source: own data)

Key note:

(*) Phased out IIPIs (not necessarily the implementing organizations)

(**) The center has a collection of all technologies generated from two ARIs in the northern zone of Tanzania (Selian and Tengeru)

4.5.3 Innovation intermediary projects: Categories, functions and outcomes

Categories of innovation intermediary projects

The analysis of the identified IIPIs can lead to further categorization based on the main targets and type of implementing organizations. Based on the category of targeted audiences, IIPIs can be grouped into three categories:

Category 1: Projects that facilitated setting-up of innovation-specific business enterprises, targeting farmer groups and individual, purposely for mass production and commercialization of a specific technology.

Category 2: Projects that support establishment of business enterprise at R&D institutions (as a spin-off) for multiplication and commercialization of specific technology.

Category 3: Brokering organizations that demonstrate the actual and latent potential of the new technologies generated from R&D institutions to the public.

The setup of IIPIs categories 1, 2 and 3 illustrated the 'facilitation' role, which contrasts with the traditional roles of R&D institutions (source) and agricultural extension services (technology transfer). Haga (2009) describes innovation intermediation functions as indirect innovation processes contrary to extension, which is a direct carrier (technology transfer) of technologies. Nine out of twelve IIPIs (75%) belong to Category 1 (Table 3), which implies that either appropriate business enterprises do not exist or for some reasons are not willing to commercialize these types of technologies. According to Kaul *et al.* (1999: 459), whenever goods face supply problems, a market failure occurs. On the other hand, for the three technologies handled by Category 2 organizations (Table 3) indicate the inability of entrepreneurs to adapt new technological development, due to the lack of competence, capacity, or resources. Literature on innovation refer this to failure as capabilities' failure (Klein-Woolthuis, 2005: 614) or transition failure (Smith, 2000: 95).

The analysis of IIPIs according to the types of implementing organizations (either R&D institutions of NGOs), showed that the majority (nine organizations) of them are based at government R&D institutions and only three (IITA, MHRP and VECO tz) are independent NGOs (Table 3). Thus, the effectiveness of innovation intermediation functions being embedded and not specialized to the implementing organization, may be influenced by lack of capacity, lack of favorable policy environment and a linear, transfer-of–technology mindset of the implementers (Klerkx *et al*, 2012: 462-463).

Table 3: Innovation intermediary organizations, core functions, innovations produced, categories and implementing organization.

Innovation Intermediary Projects	Core functions	Category	Innovations produced* T	I	M	O	Implementing organizations
BTC Tanzania	Improve banana cropping system	1,2	√		√	√	ARI Maruku
DONATA-QPM	Innovation platform for technology adoption	1	√	√	√	√	ARI
DONATA-OFSP		1	√	√	√	√	SARI
Soya Bean Project	Awareness, seed multiplication, utilization and varietal development	2	√	√			Uyole AC
TFSP	Fertilizer promotion	1,3	√	√			Uyole AC
VECO-TZ	Food security and increase income to farmers	1	√	√	√	√	NGO
IITA	Develop Small-scale cassava processing	1	√	√		√	NGO
TC- Banana	In-vitro mass production of clean planting materials of banana	2	√		√		SUA
ATTC	Technology Transfer (agronomic practices)	3	√		√		MAFSC
UMADEP	Support rural livelihood security	1	√	√		√	SUA
MHRP	Improve rural habitat	1	√	√	√	√	NGO
CPTP	Develop cassava processing technology	1	√	√	√	√	SUA

*Innovation produced: T-technological, I-institutional, M- marketing, O-organizational

Functions and outcomes of innovation intermediation interventions

The IIPIs were neither the core functions of the projects (Table 3), nor areas of specialization for the implementing organizations. However, the outcome (knowledge produced) included both technical and social (institutional, managerial and organizational) innovations (Table 3). These findings illustrate the complex nature of packages for these types of technologies to be handled by traditional extension service providers using the traditional technology transfer approaches. The following section presents the innovation intermediation functions and outcomes.

4.5.4 Unpacking contributions of the innovation intermediation

The following are contributions from the identified IIPIs gathered from the survey, which were aimed at either articulation of the demand of new technology, forming innovation networks (network brokerage) or managing innovation processes. The descriptions of the contributions are complemented with examples of the innovation intermediation roles and their outcomes as presented in Table 4.

Creating awareness of new technology to potential partners and collaborators:

The IIPIs raises awareness about new technologies by facilitating a dialogue between the source (R&D institutions), the end-users (farmers) and potential partners or collaborators to clarify demand and supply of the technology. This was achieved through verification trials, demonstrations, subsidies, facilitating creative processes to arrive at a 'real need,' and piloting creative models of various technologies to validate and demonstrate their efficacy and other comparative advantages.

This role may resemble traditional agricultural extension services, but the focus for the IIPIs went beyond the connection with farmers (through dialogue, incentives etc.) to the interface with strategic partners, including decision makers at district level, especially the councilors who are responsible for allocating funds for promoting agricultural technologies through District Agricultural Development Plans (DADPs).

Capacity building to potential partners and collaborators (network brokerage):

The establishment of business enterprises at R&D institutions served not only as an important link for the innovation networks (especially for sophisticated technologies) but also activated the needs of the technologies and demonstrated the potential market.

This is in line with the concept of 'spin-off' whereby an employee or a group of employees takes the existing products from the parent organization (R&D institutions) to form an independent start-up firm where expertise and facilities from the owner of the technology can easily be accessed (Cook, 2007). However, the success of this arrangement needs institutional policies that can respond favorably to market forces and provide incentives to both supply and demand side, or else the scalability and sustainability of supply will be questionable regardless of the existence of demand for the technologies.

Establishing and managing innovation networks:

Some of the IIPIs supported establishment of innovation platforms or meeting places for various actors. This is another approach for demand articulation (Boon and Moors, 2008). The forums were made more dialogical and neutral spaces where stakeholders of all levels (farmers, professionals, decision makers and NGOs) met for the purpose of sharing resources, coupling of the existing technical possibilities with opportunities and identifying potential collaborators to innovate. Two approaches were recorded during the survey: Innovation Platforms for Technology Adoption (IPATs) supported by DONATA (QPM & OFSP), stakeholders' platforms by VECO TZ and farmers group networks by UMADEP.

Enhance communication between actors with different institutional frameworks:

This function involved engagement of local facilitators as an interface to overcome cognitive and cultural barriers between sources and users of the knowledge (network brokerage). Different forms of local facilitators were reported including village-animators engaged by MRHP and para-professionals established by UMADEP, VECO Tz. The other IIPIs implemented by VECO Tz, UMADEP, BTC Tz and DONATAs collaborated with government departments through hired staff from different government departments. This arrangement served not only as a conduit of knowledge from government (technical and policy guidelines) to the targeted audiences, but also served as a source of expertise for the projects. In this way, the projects overcame one of the controversies of innovation intermediaries posed by Koutsouris (2012: 68) that IIPIs as 'facilitators', are unlikely to have both the facilitation and technical background for different technologies.

The ATTC on the other hand played liaison roles to connect various stakeholders needed for agricultural innovation networks. This connection function of ATTC allowed flow of knowledge, hence actors with different institutional backgrounds effectively interact to innovate. As commented by the Officer in-charge of ATTC:

> '…it is easier for the farmers or small entrepreneurs to access new knowledge when visiting the center than seeking information from R&D institutions'

Facilitating social innovation (non-market factors) to overcome unfavorable economic behavior of some agricultural technologies:

For the commercialization of process-oriented technologies, the IIPIs facilitated a creative process to establish organizational and institutional innovations (Table 3) and to coordinate them to influence the economic behavior of the agricultural technologies. In this way technologies that entrepreneurs were not willing to adopt due to high capital investment or lack of highly skilled labor and/or sophisticated facilities could be commercialized.

Table 4: The contribution from innovation intermediation project interventions and the outcome of innovations

	Unpacked Roles	Outcomes
Creating awareness of new technology to potential partners and collaborators		
TFSP	Validation (on farm) of Minjingu fertilizers in Mbinga District	Minjingu fertilizers were included in subsidy scheme starting from 2009.
VECO Tz	On farm demonstration of clean cassava planting materials	Establishment of farmer's managed commercial cassava seed farms
Capacity building to potential partners and collaborators for network brokerage:		
BCT Tz	Establish commercial banana seedlings macro-propagation unit at ARI-Maruku	ARI- Maruku were consulted by Bukoba District Council and individuals to build the units for commercial purposes.
TC banana	Facilitate application of in vitro micro-propagation technique at SUA for commercial banana seedling production	The SUA-Horticulture unit took over the enterprise when the project was phased out, though at a very reduced production level.
Soya bean Project	Seed multiplication at Uyole Agricultural Research	Activated demand of soya bean in Mbeya region
Establishing and managing innovation networks		
DONATA	IPTAs involving stakeholders at district levels to; identify and align actors needed for specific innovations (QPM & OFSP)	QPM and OFSP are produced and distributed commercially through 'innovative' collaborations between farmer groups, entrepreneur.
VECO Tz	Regular stakeholders platform meetings for cassava stakeholders in Mkuranga District	Motivated partners to share resources, negotiate solutions and later took over intermediation activities when VECO Tz phased out in 2013
Enhance communication between actors with different institutional frameworks		
MRHP	Setting up of network of village – animators which was crucial for the organization of Savings and Internal Lending Communities (SILCs) in Mwanza region	Dissemination of chickpea, pigeon peas, groundnuts and sweet potato in Mwanza Tanzania through collective market, seed multiplication, input loan and insurance for the members of SILC
UMADEP/ VECO	Train and motivated paraprofessionals	Reduced cognitive and cultural gaps between farmers and other actors (researchers and extension workers)
ATTC	Display agricultural technologies from R&D Member of technical committees of R&D Liaise the MAFSC and its institutions* with stakeholders.	Facilitate channeling of the new knowledge from R&D to intermediate users (SMEs), end-users (Farmers) and decision makers (councilors**). Many users were linked to reliable sources of technologies
Facilitating social innovation (non-market factors) in order to respond/ overcome economic behaviour of technology		
CPTP	Identified and assigned entrepreneurs to design and manufacture appropriate machines Mobilised a sizeable group of users for optimum use of the machine. Motivated credible organizations to manage the revolving funds for the groups to purchase the machines	Introduces the commercial perspective on cassava processing technology (protocol) by coupling it with the processing technology (machine).

*) Includes Agricultural Seed Agency (ASA), Tanzania Official Seed Certification Institute (TOSCI), National Food Reserve Agency (NFRA).

**) Responsible for allocating funds for promotion of new technologies through subsidies and other infrastructure

These cases demonstrate valuable contribution of organizational and institutional innovations (Table 3) as an outcome of the IIPIs' capacity building, which is as important as technical innovations for realization of the intended innovations (Hall, *et al*., 2005).

4.6 Conclusion and Recommendations

The study revealed innovation intermediation performed by R&D institutions and NGOs as project interventions though not as their specialized functions but rather as side activities. The innovation intermediation roles are aimed at establishing commercial perspectives of new agricultural technologies through activities such as demand articulation, network brokering and innovation process management.

However, building innovation intermediation capacities into existing organizations such as R&D institutions and agricultural extension service providers requires more favorable institutional features. These features include flexibility in plans of actions, less restricted source of funds, reliable sources of knowledge and information and timely response to the challenges encountered by innovation-based enterprises which might be difficult to achieve in government institutions, private companies or consultancy.

The connection functions were essential in overcoming the challenges of fragmentation of actors along agricultural knowledge infrastructure, which were caused mainly by differences in incentive structures for the actors (public or private institutions). Thus, the 'unbiased' nature of innovation intermediaries particularly between the source (public R&D institutions) and the user (SMEs) require public funding.

However, apart from the demonstrated importance of innovation intermediary organizations in harmonizing the supply and demand of technologies, the innovation intermediation roles are not clearly recognized within the NARS, thus, threatening sustainability of organizations or intermediation activities. This furthermore, being process-oriented, contributions (such as organizational and institutional innovations) of innovation intermediaries in the innovation process, though appearing to be essential, are not easily captured and managed by the system. Therefore, changes in institutional features in R&D institutions and extension service providers are necessary, such as the core functions and policy focus to accommodate innovation intermediation. Also the system should develop evaluation tools with indictors sensitive to capture rather intangible activities and outcomes of innovation intermediation.

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CHAPTER FIVE

5.0 Building Innovation Networks in Dried Cassava Value Chain: Qualitative Evidence from Innovation Brokerage

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Authors' contributions

This work was carried out in collaboration between the Authors. The first Author, Mgumia, A. H. designed the study, collected data, performed the data analysis and wrote the first draft of the manuscript. The second and third author Prof. Mattee, A. Z. and Prof. Kundi B. A. T. gave comments; all authors read and approved the final manuscript.

Abstract

Agricultural development in developing countries is challenged by weak innovation systems and lack of innovation capacities among key actors. Integration of agricultural innovation perspectives and value chain approach for development have made the interaction between a wide range of actors of innovation to become more complex demanding different sets of knowledge, environment and incentives. The traditional homogeneous intermediary layer of agricultural extension appeared to be ineffective to this situation. As a result the majority of smallholder farmers are facing exclusion from participating in supplying the long value chains. In countries characterized by mature innovation systems, a specialized innovation-brokering role emerged as an alternative to deal with innovation challenges in agricultural sectors (market and system failures). This study, using a case study approach, intended to offer empirical evidence of the roles of innovation brokerage implemented on cassava value chain by NGOs in the setting of developed countries and where the innovation brokerage is not recognized by the agricultural knowledge infrastructure (R&D institutions and extension services). Important outcome of this analysis was that innovation brokerage roles were crucial in agricultural innovation as it is beyond the capacity of R&D extension service. Hence, the Ministry of Agriculture Food Security and Cooperative and other relevant stakeholders should recognize the innovation brokerage roles and establish an institutional framework for its functioning within the agricultural knowledge infrastructure.

Key words: Innovation broker, cassava, innovation network, value chain, Tanzania

5.1 Introduction

The number and diversity of stakeholders in agricultural innovations have been increasing in recent decades, making their interaction more complex and non-linear than they used to be (Chema *et al*., 2003; Sumberg, 2005; World Bank, 2006). In addition and more importantly, with the ongoing promotion of Value Chain (VC) approach in agriculture (Anandajayasekeram and Gebremedhin, 2009: 22), farmers need to supply the long value chains which involve stringent quality and safety standards and regulations (Dolan and Humphrey, 2000: 158; Trienekens, 2011: 52). Smallholder farmers, in addition, need to establish new forms of collaboration so as to increase their capacities and bargaining position in the value chain (Rondot and Collion, 2001: 5). Thus, participation in agricultural innovation, particularly for the smallholder farmers, needs effective linkages and relationships that govern not only the flow of commodities along the VC (vertical integration) but also the flow of resources and knowledge needed to innovate at each node of the VC (horizontal integration) (Trienekens, 2011: 59-62; World Bank, 2006). However, the observed limited interactions of such important actors of innovation (farmers, agribusiness and government institutions) is often a result of inadequate capacity and lack of structure and incentives, rather than unwillingness of the actors to interact effectively. This role of facilitating horizontal integration is likely beyond the transfer-of-technology role of traditional agricultural extension services and also the roles and mandate of research institutions.

Recently, scholars in developed countries recognized the emergence of a specialized or systemic innovation intermediaries with an expanded role of public agricultural extension services (Klerkx and Leeuwis, 2009: Klerkx and Gildemacher, 2012; Klerkx *et al*., 2009), which proved to be relevant in developing countries as well (Perez *et al*., 2010). These evolving specialized intermediaries are distinguished from the innovation intermediaries described by Howells (2006) by brokering innovation as its core function. Klerkx and Leeuwis (2009) called these new emerging actors as innovation brokers or systemic intermediaries. Innovation brokers mainly analyze the context, articulate demand, establish innovation networks and facilitate interactions (Klerkx and Gildemacher, 2012).

Currently, the agricultural policy of Tanzania emphasizes value addition to agricultural produce (VC approach) and provision of enabling environment to attract private sector investment (URT, 2013). This role is in alignment with the Agricultural Sector Development Programme (ASDP) (URT, 2003). However, so far, the contribution of innovation brokerage in agricultural innovation, particularly in terms of forging linkages among value chain actors has yet to be fully appreciated due to a lack of empirical evidence on its functionality. This paper contributes to this knowledge gap by exploring the kind of innovation brokering roles that have been played in project interventions that seek to foster value chain innovations.

Taking project interventions of Vredeseilanden Country Office Tanzania (hereafter referred to VECO Tz), an NGO working on dried cassava value chain as a critical case study, this paper aimed at describing the contribution of innovation brokerage on dried cassava value chain in Mkuranga District, Tanzania. The main research questions guiding this study were: what innovation brokerage roles were performed by VECO Tz on dried cassava VC in Mkuranga, and how have the roles contributed to cassava innovation. Although the findings presented in this paper relate to cassava production and processing, they present an example of innovation system in root and tuber crops which are faced with the challenges around improvement of their seed system, as they mainly use vegetative propagation planting materials (stem cuttings), hence, perishable and bulky, thus not attractive for commercial multiplication and dissemination.

5.2 Conceptual framework

5.2.1 Concept of innovation as an expansion of technology transfer

Contrary to the conventional technology transfer in agriculture, which is essentially a linear movement of knowledge (mostly knowledge on how to apply the technology) from research to extension services to farmers, innovation is a complex and dynamic process, taking place in interconnected networks of actors (both in supply and demand sides) to generate and use new knowledge and other resources to innovate (World Bank, 2006). Looking at it in a different perspective, an innovation constitutes of: technology (product or process), knowledge (how to use the technology) and a social component representing a third embodiment which includes organizational arrangements, compliance with quality standards, appropriate policies, incentives, which are needed to convert invention into innovation (Vermeulen *et al*., 2008; Vellema and Boselia, 2003). Smits (2002) defined the three embodiments of innovation as: Hardware, software and orgware. The first two embodiments of technology (hardware and software) are easy to disseminate through technology transfer (Bozeman, 2000; Li-Hua, 2006; Gopalakrishman and Santoro, 2004). However, with the current type of technology and multiple actors of innovation with diverse interests, the third embodiment (orgware) of technology becomes crucial. This indicates how challenging it is for an individual actor such as a research institution or agricultural extension to innovate or participate in innovation.

Likewise, technical knowledge alone is not sufficient to achieve successful innovation; a process of social learning is also becoming an important part of innovation. Social learning, according to scholars in innovation systems, includes imparting new skills to participating actors, flexibility in organizational roles, ability to navigate positions along the value chain, and negotiating and sharing benefits among actors (Leeuwis, 2004). In order to achieve these outcomes of social learning, proper facilitation of the social organization of innovation by the way of providing space for interactions between different actors to innovate (Smith and Raven, 2012: 1027) is required. Hence, systemic intermediaries or innovation brokers are better positioned to facilitate establishment of functional orgware part of innovation and social learning than the traditional extension services.

5.2.2 The concept of innovation brokers as specialized innovation intermediaries

Winch and Courtney (2007) defined an innovation broker as 'an organization acting as a member of an innovation network of actors that is focused neither on the generation nor the implementation of innovations, but on capacitating other organisations to innovate'. Innovation capacity, on the other hand, refers to the capacity of the innovation system to adapt and involve reworking ideas, resources, relations and links (Ruben *et al.*, 2006). In VC, for example, innovation brokers, thus, focus their attention on linkages and relationships governing the knowledge flow, which is contrary to the linkages and relationships governing the movement of commodities, although, in some cases the actors involved may be the same (World Bank, 2006).

Innovation brokers target multiple actor relationships (systemic focus) rather than individuals. Klerlx and Leeuwis (2009: 851) figured the relationship of innovation broker as many–to-one–to-one, one–to-one-to-many or many-to-one-to-many, as compared to that of innovation intermediary which, as argued by Howells (2006), operates in a simple triadic of one-to-one-to-one. Hence, it requires a different role to enhance continuous 'interface management' (Smits and Kuhlmann, 2004), which involves:

(i) Context analysis, articulation of demand for technology, knowledge, funding, favourable policies through problem diagnosis and foresight exercises (Klerkx and Gildemacher, 2012; Klerkx and Leeuwis, 2009);

(ii) Facilitation of linkages between relevant actors aiming for innovation network building (Howells, 2006) and providing platforms for decision-making (Klerkx and Leeuwis, 2009).

(iii) Facilitation of interaction between various heterogeneous actors whereby innovation brokers traverse a range of roles: managing conflicts, building trust among the partners, fostering learning, managing intellectual property (Leeuwis, 2004) and testing new ways of doing things.

In developing countries (particularly SSA) however, the national innovation systems and Intellectual Property Rights (IPR) regime are still immature, and most of agricultural technologies are generated from public institutions. Thus, in these (developing) countries, the innovation brokers are expected to be not-for-profit organizations such that they can perform functions more impartially to ensure the balance between supply and demand of technology including supporting emergence of capable business enterprises to deal with agricultural technologies. Also brokers need to provide enabling environment for actors from both private and public sectors to participate effectively in innovation (World Bank, 2006).

5.3 Description of the case: Dried cassava in Mkuranga District, Tanzania

Traditionally cassava VC mainly includes production and processing either as traditional cassava flour or frying / boiling fresh cassava. A successful introduction of cassava processing technologies in the rural communities since 2003 (Abass *et al*., 2013) increased demand for fresh cassava and, therefore, enhanced farmers' willingness to adopt improved production technologies particularly new varieties, in order to increase cassava productivity and expand production (Abass *et al*., 2010). However, the biological features (vegetatively propagated) and economical features (public good) of these cassava technologies hinder or exclude majority of smallholder farmers in rural areas from producing cassava commercially. For example, the multiplication rate of the vegetative planting materials (cuttings) is very low, bulky and highly perishable. These characteristics have made commercial multiplication of cassava-planting materials unattractive to entrepreneurs. On the other hand, majority of smallholder farmers are yet to participate and benefit fairly in dried cassava value chain due to higher cost of the cassava processing machinery, stringent food safety standard requirements and the large quantities of the intermediary shelf-stable cassava products demanded by the market (Ruben *et al*., 2006, Vermeulen *et al*., 2008).

5.4 Methodology

5.4.1 Study area

Mkuranga is one of the six districts of the Pwani Region. Cassava is a major food cum cash crop traditionally traded through a fresh cassava value chain. VECO Tz works in partnership with other actors according to their complementary attributes (resources, institutional roles, expertise) in fostering innovation networks in dried cassava value chain; thus, it was identified to be a critical case for this study. VECO Tz was active in Mkuranga District from 2008 – 2013 and aimed at enabling smallholder farmers to increase productivity and income through commercial farming of cassava. The project covered a total of 16 villages, which constitute the study area.

5.4 2 Data collection and analysis

Due to the qualitative nature of the research questions, the research adopted a case study design. This approach is appropriate in answering ‘how’ and ‘why’ questions (Yin, 1994) and for studies whose objective is to offer description, exploration or to generate and test theory (Creswell, 2007). As the study aimed at describing the planned and evolved processes for cassava innovation, the case study was found to be an appropriate research design. Data were collected between November 2013 and March 2014. A total of 11 interviews (Appendix 8, 9 and 10) were conducted involving 18 key informants: three VECO staff; one extension officer, the local coordinator; 10 farmers from different villages and farmers' groups; chairman of *Mtandao wa Vikundi vya Wakulima Tanzania* (MVIWATA); Manager-cum-sells officer of bulk marketing center and two staff from small and medium enterprises support programme, in kiswahili commonly known in Kiswahili as *Muunganisho wa Ujasiriamali Vijijini* (MUVI).

The data were supplemented with observation during site visits and activity reports including minutes of stakeholders' meetings. Various data collection methods and multiple sources were used to understand clearly the processes but also to ensure reliability and validity respectively (Yin, 2002) including: primary source materials (detailed interview), literature (activity reports) and observation on cassava value chain in Mkuranga District. Qualitative materials were analyzed using qualitative content analysis, which involved reading through the field notes and transcribing them to identify key themes and patterns relevant to the research questions and concepts (Patton, 2002), and presenting empirical evidence of facilitated innovative processes by innovation brokers.

5.5 Case study: VECO Tz as an innovation broker in dried cassava value chain in Mkuranga District

5.5.1 Establishment of farmers managed Cassava Seed Multiplication Farm (CSMF)

VECO Tz conducted cassava value chain analysis to identify potential actors in dried cassava value chain in Mkuranga District. The actors identified were trained and assigned specific tasks relevant to their capacity, experience and institutional roles. The agreements were formalized with a Memoranda of Understanding (MoUs). The actors included:

Agricultural Field Officers (AFO) from District Agricultural Irrigation and Cooperative Office; *Mtandao wa Vikundi vya Wakulima Tanzania* (MVIWATA) and researchers from agricultural research institutions.

MVIWATA triggered the process by mobilizing farmers from 16 villages that constitute the project area to form groups; 40 groups were formed. The AFO provided training on agronomic practices and oriented the group members towards commercial cassava production. In partnership with farmer groups, 40 on-farm demonstration plots and 16 Farmer Field Schools (FFSs) (one in each village) were established to promote new agronomic practices aimed at increasing cassava production. Due to limited number of AFOs; VECO Tz, in collaboration with the District Agricultural Office and researchers, trained two farmer representatives from each farmer group to become paraprofessionals.

In addition to promotion of agronomic practices, evidence from demonstration plots and FFS, articulated the demand for the clean cassava planting materials (cuttings). Responding to this demand, VECO adapted a model of commercial 'Farmer Managed Cassava Seed Multiplication Farm' (CMSF) which was developed by the Food and Agricultural Organization (FAO), and implemented in nearby villages. To implement the model, VECO supported establishment of multiplication plots in each of 16 villages (this activity was not in VECO's original plan). These farms were owned and managed by the farmers' groups. VECO provided initial seed (cuttings) to the CSMF from agricultural research institutions (research center specialized in root crops and sugar cane research), and supported field inspection, which was done by researchers in collaboration with paraprofessionals who were trained by VECO for the purpose. As a consequence, the outstanding massive demands of clean planting materials at the District Agricultural Officer (from within and outside the District) were directed to CSMFs. Throughout the process, VECO remained as the lead operator and facilitator and also responsible for the financing of the activities and capacity building to orient all collaborating partners towards a common vision.

5.5.2 Establishment of cassava processing centers

To advocate for dried cassava VC against traditional fresh cassava VC; DAICO, as part of its responsibilities in the MoU, organized practical training on processing cassava intermediary products (chips and flour). Forty farmer groups from the 16 villages were trained on processing technologies, and at least one-machine operator was also trained from each group (A portable machine was used for the training). However, the number of group members (15-25) was insufficient to own and efficiently use the machines. Hence, VECO proposed joining at least three groups to create bigger but manageable groups, and called them Community Family Farmers' Organizations (CFFOs); a total of six organizations were formed.

Then, VECO ordered six sets of cassava processing machines from a local manufacturer; each set consisted of a chipper, grater and milling machine. The machines were made available to CFFOs under hire-purchase arrangements. It was up to the group to decide on which type of machine they needed basing on the knowledge provided and the market situation (Box 1). To ensure the quality of the product, VECO supported a seminar on quality control conducted to group members by the Tanzania Food and Drugs Authority (TFDA).

Box 1: The products demanded by consumers determined the kind of the machine needed by CFFO.

Taking an example of one CFFO known as *Kizapata* agriculture and marketing primary cooperative group, it started with a chipper and used common milling machines to produce cassava flour from cassava chips. Unfortunately, the cassava flour appeared to be blended with unfavourable smell because the same machines were used for different cereals. So the group was forced to acquire a milling machine through the same hire-purchase arrangements. Again some of the consumers did not prefer cassava flour made from cassava chips as it had too much starch, which implied the need of using grater and not chipper in processing, hence the group had to acquire a grater as well.

Another challenge for the CFFO operations was the availability of adequate water. VECO, on behalf of CFFOs, wrote a proposal to raise funds for drilling deep water wells, which was submitted to BTC Tanzania, a Belgium NGO. The proposal for one center *Kizapata* was successful; VECO supported the drilling of deep-water wells for the other centers.

5.5.3 Establishment of District Marketing Bulking Centre (DMBC)

When CFFOs started to process cassava flour, it was realized that "quality of the product" was not the only requirement for accessing a reliable market but also the "quantity". Hence, VECO consulted experts from Moshi Cooperative College of Business Studies (MUCCOBS) to conduct a feasibility study for the establishment of the DMBC, and subsequently prepared the first three years' business plans for the same. The aim was to collect products from CFFOs, pack properly and sell them to consumers and bigger suppliers. The marketing center was established as an apex body for the CFFOs. Hence, named as Mkuranga Cassava Processing Cooperative Joint Enterprises (MKUCAPCOJE), and consisted of a governing board, marketing committee, manager and sales officer. The center was designed to generate funds from selling intermediary shelf-stable cassava products. VECO supported initial establishment costs including salary of the manager and initial capital. Marketing committee members were trained on quality control and marketing.

Giving the center a status of District level offered an opportunity for other players (NGOs) working on dried cassava VC but in different villages to partner with VECO in supporting establishment of the market center. Therefore, VECO in partnership with other NGOs particularly the Rural Micro, Small and Medium Enterprise Support Programme (MUVI) facilitated other basic requirements such as: office furniture, preparation for the registration of the center as a cooperative (the process is still going on, currently it operates under the business name registration); and testing samples of the product by the Tanzania Bureau of Standards (TBS) clearance of which the product passed the test. When VECO phased out in December 2013, MUVI and the Local Government Authority (LGA) took over most of the activities of VECO. However, the DMBC is constrained by insufficient operating capital.

5.5.4 Enhancing interaction through District stakeholders platform

Since the first year of implementation, VECO facilitated an annual stakeholders platform to create awareness of the project, lobby, and advocate for political support from district officials and other key stakeholders. The stakeholders' platform created a neutral arena where different actors of the cassava value chain met face-to-face and had the opportunity to communicate their problems and share their experiences, challenge and opportunities. The stakeholders included: smallholder cassava producers-cum-processors, traders, researchers, government and private service providers, NGOs and decision makers such as District Commissioner (DC), District Executive Director (DED) and councilors.

Among the agenda discussed in the platform meetings were activity reports from VECO and other stakeholders. To make sure that the deliberations from the meetings were implemented, in the first meeting, the platform formed a special committee to follow-up on issues raised and to get commitment from district authorities. This committee also involved farmer representatives, councilors, agricultural officers and MVIWATA members (MVIWATA, 2010). The main target for the committee was the District Executive Director (DED) who has authority and resources. Among the achievements of the committee was the commitment of the head of department (in District Council) to attend the subsequent stakeholder meetings. Also, the LGA formalized a position for a farmers' representative in the Ward Development Committees (WDCs) and the District Business Council. One of the functions of WDCs is to prioritize activities to be supported under the District Agricultural Development Programme (DADPs). Initially, VECO financed and organized the meetings, but later on other NGOs working on cassava in the District contributed.

5.6 Analysis and Discussion

The findings from this study were analyzed in the light of the concept of innovation brokerage in a system mode of agricultural innovation. The analysis intended to unpack the innovation brokerage roles to ascertain whether the contribution of innovation brokers' activities were linked to the developed cassava innovation networks, that put the improved cassava variety (Kiroba) in economic use.

5.6.1 Matching the interest of multiple actors of innovation to enhance innovation network formation

On mapping the actors involved in dried cassava VC and their relationships, two cassava innovation networks can be observed: the network for multiplication and commercialization of cassava-planting materials (clean cuttings) and network for producing intermediary shelf-stable cassava products (Figure 1). The findings show that the formation of innovation networks was the outcome of different types of innovation brokerage roles fused in the facilitation activities done by VECO. Thus, the subsequent organizations and institutional arrangements (such as CSMFs, CFFOs, DMBC and stakeholders platform) and their contributions to the cassava innovation (which neither extension nor R&D institutions could achieve alone) form a critical part of the cassava innovation (Orgware) (Figure 1). This confirms that innovation brokers facilitate both tangible and intangible resources that are crucial for innovation to be realized (Klerkx and Leewis, 2009). Furthermore, the findings revealed how the innovation brokers combined technical potential of cassava technologies and existing opportunities (for example the experience of farmer managed seed multiplication and cassava processing technologies) to foster organizational and institutional innovations which, according to Hounkonnou *et al*. (2012), is one of the main limitations facing smallholders in SSA.

Analyzing the findings in the system perspective of agricultural innovation, the strength of VECO as an innovation broker was in line with mediation of multiple relationships governing the flow of knowledge among the actors of different backgrounds (Horizontal integration) (Fig. 1). Hence, innovation brokerage ensured involvement of the actors from key domains such as research, enterprise, extension, regulatory and demand sector. For example, flexibility in plan of action to accommodate the evolving roles enabled the establishment of farmers' group enterprises (CSMFs) and paraprofessionals, which were instrumental in seed multiplication and reducing the cognitive and cultural gap among the actors respectively. Also the neutral position of VECO in capacity building (training, budget allocation to actors, provision of incentive and initial capital) of the key actors, enhanced linkages, institutionalization of the project activities and articulation of demand for technical innovations. Hence the innovation broker contributed considerably to formation of networks, facilitating interactive learning (Klerkx and Gildemacher, 2012) and also indicated willingness to withdraw when its presence was no longer required.

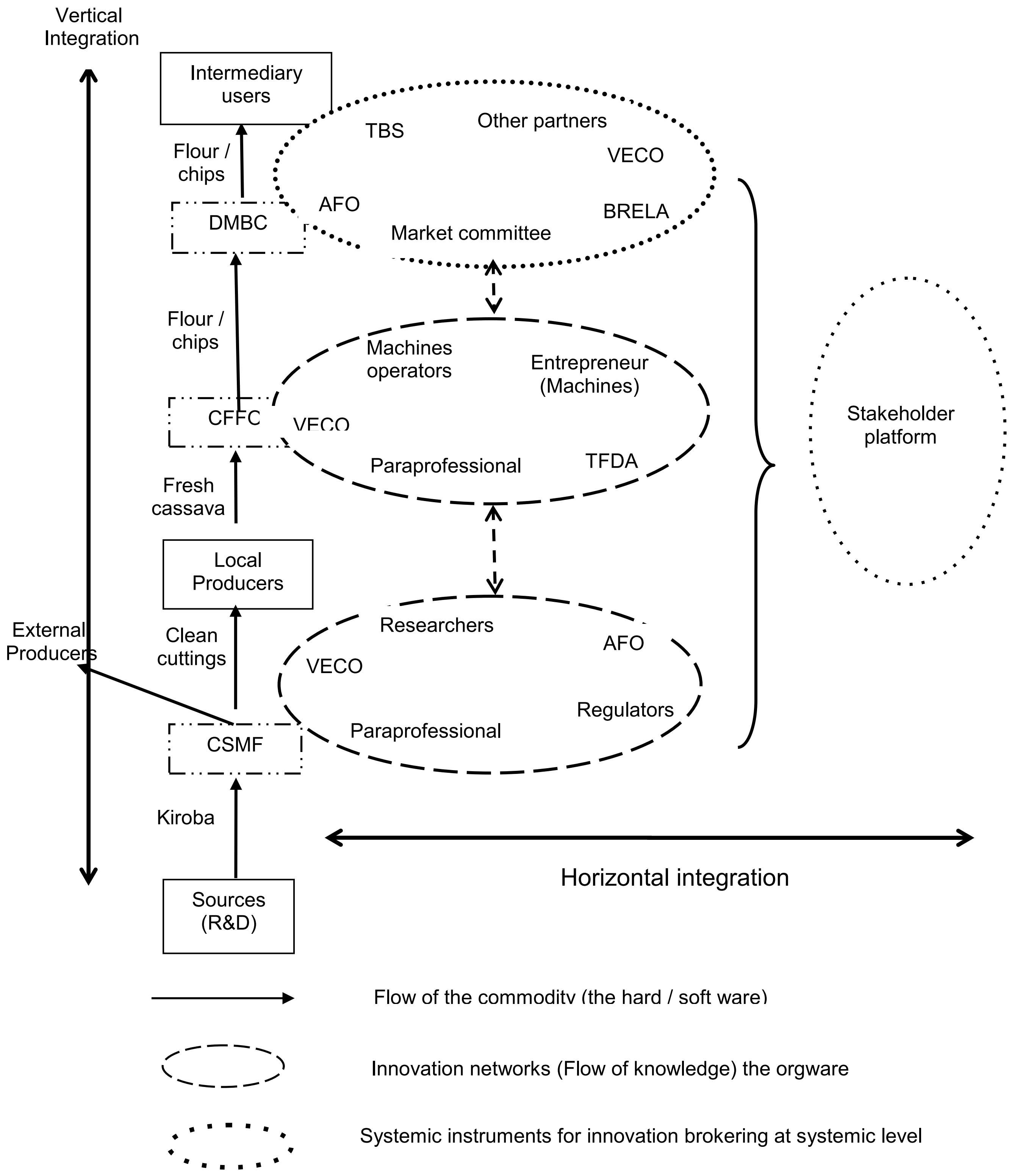

Fig. 1: The integration of the three parts of cassava innovation (Hardware, software and orgware).

The absence of reliable source (private sector) of cassava cutting and cassava processing enterprise extended the role of VECO beyond the bridging and brokerage to facilitate establishment of farmers' group enterprise to take up the roles. This was also possible due to the flexibility of the plan of action and neutral position of the VECO that enabled to balance the interest of multiple actors including: maximizing profit (as for case of CSMF, DMBC and CFFO); ensuring the good quality of products (regulatory bodies); scientific achievements (researchers) and adoption rate (extension service providers). In addition, through facilitation of tangible and intangible resources, farmers and other community members managed to build trust and culture of collective action as a leader of one group confessed: "…Through FFS we learned that working together is possible, since customarily we did not trust each other very much, and collective responsibility is also new in our culture…"

The findings concur with the previous observation on the context specific nature of the innovation brokerage roles (Klerkx and Gildemacher, 2012).

5.6.2 Optimizing system interaction: Linking cassava innovation networks with broader innovation

The findings show that DMBC and stakeholders' platform, established and maintained through bridging and brokerage roles facilitated by VECO, contributed much in stimulating and influencing the innovation process. The flexibility in the plan of action and through DMBC and Stakeholders' platform made it possible for VECO to navigate different positions (production, processing and marketing) along the dried cassava VC as well as mediation of several parties from different domains (research, business, regulatory, financial, LGA and farmers groups) (Figure 1). Thus, at each node, VECO facilitated innovative processes to ensure that supply and demand were balanced, potentials and opportunities of the market and service providers were made known. This can only be possible under independent working positions (Hanna and Walsh, 2002). The functions of VECO, in this dried cassava VC demonstrated the more complex relationships intermediated by innovation broker (VECO) integrating both chain activities (vertical integration) and chain governance (horizontal integration) (Fig. 1).

Furthermore, the strength of VECO as an innovation broker was made possible through being transparent to other stakeholders, in terms of what it does and why. This practice stimulated knowledge sharing and commitment of other stakeholders in supporting what VECO was doing and avoiding misinterpretations. For example, other NGOs were ready to share the cost for organizing stakeholders' platforms, and when VECO phased out in December 2013, it was easier for the LGA and other NGOs working on dried cassava VC to take over VECO's activities and continue working with the same actors. These findings confirm that innovation brokerage through stakeholder platform contributes to institutional change and in turn has an effect on quality of interactions among the actors (Klerkx and Gildemacher, 2012). Another factor that can be attributed to the success of VECO as an innovation broker is readiness of VECO to forego some of the credit from their investments to go to other stakeholders to avoid diminishing ownership of the latter, as this is among the key features of the innovation brokers (Klerkx and Gildemacher, 2012). This was demonstrated when VECO handed over the bulk market to be a farmer-owned intervention. This may be difficult for other actors depending on their institutional policy or the policy of their financing institutions. The factors that enabled VECO to perform innovation brokerage successfully are summaries in Table 1.

Table 1. Factors for VECO to be successful in brokerage functions and outcomes

Successful factors	Outcomes
Context analysis and demand articulation	Took advantage of existing experience as well as linkages and relationships among the actors to enhance interactions.
Independent position and unbiased support (private, pubic and civil societies)	Established revolving fund in the form of hire-purchase of the processing machines
Flexible in plan of action	Establishment of farmer 'group enterprise to take up the roles of entrepreneurs such as CSMFs and CFFOs.
Transparent in what and why they do	Achieved common vision and understanding and avoiding misinterpretations
Shared the credit with other stakeholder particularly farmers	Enhanced ownership of the innovation processes to farmers
	Encouraged stakeholders participation and supporting the VECO activities including taking over brokerage activities when VECO phased out

5.7 Impact of the Innovation Brokerage to the Dried Cassava VC in Mkuranga

This section presents the impact of the interventions on dried cassava value chain by VECO, on the activities of the various chain actors in Mkuranga. Generally the approach in terms of what and how VECO performed its activities has impacted the key actors involved in several ways (economically, socially). As a result the cassava sub sector in Mkuranga is changing from semi subsistence to commercial, the quality of the cassava product is also given high consideration by both regulators (government) and consumers and most of its activities have been taken over after phasing out of VECO. The study revealed evidence from several actors along the dried cassava value chain as follows:

Broadly, VECO improved communication (contacts) from the reduced cultural and cognitive gaps and working coalitions formed between stakeholders as a result of innovation brokering, hence, dictated a more demand – driven advisory and extension service. Because of their neutral position and overview of the system that they can provide, VECO forged contacts between parts that would normally not cooperate.

Looking at the level of specific actors, farmers outside the project site (the 16 villages) started to prioritize cassava seed multiplication farm and cassava processing centers as a programme to be included in DADPs for government funding. Traditionally projects proposed in DADPs are mainly on infrastructure such as irrigation schemes and animal dips. In the financial year 2013/14 Mkuranga District, through DADPs supported four multiplication farms and four cassava processing centers.

The project activities along the value chain have reduced if not removed gender restricted roles. For example women are involved in farm activities, processing and marketing of cassava products. Men on the other hand participate fully in preparing (cooking) products such as cake, spaghetti, pasta. from cassava flour, traditionally this was not possible. These changes inculcated commercial perspective into cassava farming and broadened opportunities for self-employment for both men and women in the society. Another social impact realized is social capital built in the form of CFFOs that allows individual smallholder farmers to participate and benefit from a fairly cumbersome and costly cassava processing practice, and collective marketing of intermediary shelf-stable cassava products.

Mkuranga District, through DAICO also approved the funds and started construction of the District quality control center to cater not only for cassava products but also other crops. The idea of establishing the center emerged from the challenges experienced by the DMBC. Furthermore, the district launched a campaign for establishing clean cassava multiplication farms at each village.

5.8 Conclusion and Recommendations

The findings from this study have demonstrated the innovation brokerage functions performed by development NGOs that were important for the establishment of innovation networks and therefore enhanced interaction in an innovation system. As this study indicated, innovation brokerage roles are crucial in the agricultural innovation as they operated beyond the capacity of the traditional technology transfer performed by the homogeneous intermediary layer of agricultural extension and R&D institutions. Innovation brokerage roles facilitate connectivity of different networks of actors at different levels crossing with interfaces of technologies, knowledge, civil societies and market domains; building the capacity of actors to innovate, resulting not only into tangible gains but also intangible ones. It is not, therefore, the technical potentials only that determine the extent of putting knowledge and technology into use; instead, it is a combination of the technology, organizational, institutional and governance innovations (organizations, routines and rules) that matters.

For innovation brokering to be effective, considerable freedom and flexibility is needed to explore different options and linkages, which might not be possible with organizations such as government agencies, consultancies or even private companies. In addition, as emphasized earlier that innovation brokerage roles are context specific (Klerkx and Gildemacher, 2012). Thus, the MAFSC and other stakeholders such as LGAs and NGOs need to recognize the innovation brokerage roles, and build their innovation-brokering capacities by changing their institutional conditions including developing indicators for measuring innovation that capture both tangible and intangible activities of an innovation broker for the majority to realize the potentials of innovation brokerage roles, and hence justify investment in their existence. On the other hand, other innovation champions including LGAs and private firms should also integrate the cost of innovation brokering when designing agricultural innovation projects.

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CHAPTER SIX

6.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 Synthesis of the Major Findings

The study has explored the extent of incorporation of features of the Agricultural Innovation System (AIS) in the Tanzanian National Agricultural Research System and how the characteristics of agricultural technology have influenced the type of actors and their roles in agricultural innovation. This section synthesizes the results and findings presented in Chapters 2 to 5 (paper manuscripts 1 - 4) according to the objectives of the study and the ongoing debates in the field of agricultural sectoral systems of innovation. The objectives of the study were:

(i) To determine the degree of awareness of researchers in R&D institutions on the features of the system mode of agricultural innovation;

(ii) To determine the influence of characteristics of agricultural technologies on the adopted features of the agricultural innovation system approaches; and

(iii) To assess the emerging innovation intermediary arrangements within the agricultural knowledge infrastructure by exploring their position and roles in relation to the traditional actors such as R&D, extension service providers and end-users (farmers).

The main question in this study was: why the adapted features of the system mode of innovation by the National Agricultural Research System (NARS) over time, have not sufficiently enhanced the impact of technological innovation in Tanzanian agriculture, particularly on the majority of smallholder resource-poor farmers that are weakly linked to the market. The conclusions and recommendations of the study were derived from studies of agricultural innovations through different perspectives of AIS: Structural, functional and technology characteristics.

6.1.1 Researchers' understanding of features of AIS: enhancing effective application of the features

Research question: How are the features of system mode of agricultural innovation, particularly key actors and their roles which have been incorporated in NARS, perceived by the researchers in the R&D institutions?

Agricultural Innovation System (AIS) as an innovation support system can be viewed as a set of factors that determine networking for innovation. Among the reported forms of AIS include multi-stakeholder platforms (Perez, *et al.,* 2010), innovation configuration (Engel 1995); pub lic-private–partnerships (PPP) (Spielman *et al.,* 2007); and innovation networks (Klerkx, *et al.,* 2012). To enhance such 'networking for innovation', the AIS literature emphasizes the need to arrive at: shared vision, well established linkages, adequate markets, legislative and policy environment and well developed human capital (Hall, *et al.,* 2001; Spielman *et al.,* 2008). In addition, apart from markets as triggers of innovation, AIS stresses on the importance of stakeholders and policies that are sensitive to demand and agenda from stakeholders (Hall *et al.*, 2005; World Bank, 2006). Thus, in Tanzania where R&D institutions are considered as the main source of agricultural technologies, while their institutional policy and regulations do not adequately favor agricultural innovation, researchers' awareness of the features of innovation systems is essential for stimulating an effective performance of innovation systems.

This study question is addressed in Chapter 2 (paper manuscript 1). The study found out that, only about half of the researchers recognized the importance of the key actors for agricultural innovation, with the exception of end-users. Other domains of important actors of AIS are entrepreneurs, market or demand, intermediary and infrastructure (Rajalahti *et al.,* 2008). Regarding the roles of these actors, less than half of the researchers were certain about the roles devoted to the actors in the innovation process. Thus, majority of researchers were either not aware of the important actors or not sure what should be the roles of these actors in agricultural innovation. With respect to the indicators of performance, few (about 5%) researchers, mainly implementers of donor supported agricultural projects, are considering social change (institutional, managerial and organizational) as important indicators for successful innovation.

However, the analysis of agricultural technologies generated from R&D institutions in the perspective of characteristics (physical and economic) of technology (Chapter 3, paper 2), revealed dominance of technologies that are potentially public goods (mainly OPVs, legumes and vegetatively propagated crops). Theoretically, the inappropriable nature of public goods discourages participation of private sector in innovation for these particular technologies. Consequently, the innovation intermediation roles that are illustrated through the case studies in the Chapter 4 (paper manuscript 3) indicated the presence of inadequate space for direct interaction between entrepreneurial activities (business enterprises) and R&D institutions (researchers) in agricultural innovation. In addition, some of the entrepreneurial activities are embedded in the traditional actors such as farmers' owned commercial seed multiplication farms and spin-off business enterprises (at R&D institutions) thus their entrepreneurial contributions are sometimes confused with the institutional roles of the host organizations. This may contribute to the majority of researchers not recognizing the importance and contributions of actors from other domains essential for agricultural innovation particularly entrepreneurial, market and infrastructure.

The indicators for successful innovation perceived by the researchers are mainly based on patterns of adoption (mainly quantitative and technical changes) as indicated in Chapter 2, while from to the analysis of the characteristics of technologies (Chapter 3) and the transfer arrangements (Chapter 4 and 5), it shows that the packages for the successful agricultural innovation generated from R&D institutions consisted of three elements: hardware, software and orgware. Hence, the indicators that measure only one or two elements are misleading.

6.1.2 Mapping the characteristic dimensions of agricultural technologies to stimulate and enhance technological innovation.

Research question: What are the influences of the characteristics of agricultural technologies on the innovation process? Focus points related to this question are the types of actors and their roles for technologies of different characteristics

The relevance of this question stems from methodological and theoretical arguments. The AIS literature reported four different approaches of analysing and evaluating the performance of systemic innovation including: structural (Nelson, 1993), functional (Hekkert, *et al.,* 2007), systemic problems (Smith, 2000; Klein-Woolthuis *et al.*, 2005) and systemic instruments (Smiths and Kuhlmann, 2004; Wieczorek, and Hekkert, 2012). However, in developing countries, and Tanzania in particular, where privatization reforms have necessitated public–private relationships, characteristics of technologies have influence on the relationships and functions of the actors of innovation (Chapter 3, paper 2).

Chapter 3 (paper 2), introduced the element of characteristics of technologies in the analysis of agricultural (technological) innovation system. The study theorized that characteristics of technologies are of greater influence on the technological innovation process particularly in Tanzanian agriculture. The major concern being fulfilling the interests of different stakeholders (public and private) needed to participate in innovation process for technologies of different characteristics.

The results in Chapters 2 to 5 show that, despite the reforms on policies and programs towards private sector participation on commercialization of research results (URT, 2010a; URT, 2010b; URT, 2003), participation of private sector in agriculture and particularly in the seed sector is insufficient. Private companies are more interested with appropriable technologies such as hybrid varieties. This trend indicated that appropriability (the ability to capture all the benefits accruing to the innovation) nature of the agricultural technologies is among the factors that contribute to the fragmentation of actors along the agricultural knowledge infrastructure following the privatization reform. Hence, private sector tends to focus on more appropriable (marketable) technologies mainly hybrid varieties while public institutions such as extension services, R&D and NGOs are dealing with public goods (OPVs, legumes, vegetatively propagated varieties and knowledge of use).

Level of sophistication is another characteristic which demanded special actors and roles. The case studies (Chapter 4, paper manuscript 3) unpacked innovation intermediation roles such as facilitating establishment of spin-off business enterprise at R&D institutions where researchers will be accessible to provide technical support at all stages of production-to-consumption chain (e.g. TC banana). Also protocol needed facilitation to combine two or more technologies for optimum performance, for example protocols for food processing and processing machine Cassava Processing Technology Project (CPTP).

With this observation, the study highlighted that the impact of technological innovation (particularly improved seed varieties) in the agriculture sector depends not only on technological potential and institutional context in which technological change occurs (Agwu, *et al.,* 2008) but also on application of innovation system appropriate for that particular characteristic of technology. For example Chapter 3 (paper 2) indicates how the characteristics of technologies determine the system actors (private enterprises, intermediaries, Non-Governmental Organizations, Government), and infrastructures (financial, physical) that are appropriate for agricultural technologies with different physical and economic characteristics (Appendix 6). Chapters 4 and 5 (paper manuscript 3 and 4) on the other hand illustrate the importance of the dimension of characteristics of technologies in determining key actors of innovations and also contribution of innovation intermediary/broker in the process of putting into use the inappropriable technologies (public goods) particularly vegetatively propagated crops and OPVs (Appendix 11). Thus, when the dimension of characteristics of agricultural technologies is coupled with the developed structural and functional dimensions of technological innovation systems they can form a more effective framework for analysing the performance and sustainability of technological innovation systems.

6.1.3 Innovation intermediation and brokerage as a new role to enhancing interactions of actors within NARS in Tanzania

Research question: What are the types and contributions of the new types of organizational arrangements that have emerged in the process of putting new agricultural knowledge into economic use?

Table 1: Dimensions of characteristics of agricultural technology in an innovation system perspective

Characteristics	Subcategories	Structural dimension	Functional dimension
Physical	Soft part Hard part Sophistication Associated technologies	Actor Interactions Institutional Infrastructure	Entrepreneurial activities Knowledge development Knowledge dissemination Guidance of research Market information Resources mobilization Creation of legitimacy
Economic	Private Public Mixed	Actor Interactions Institutional Infrastructure	Entrepreneurial activities Knowledge development Knowledge dissemination Guidance of research Market information Resources mobilization Creation of legitimacy

The agricultural innovation capacity in Tanzania and many other countries in SSA have roots from the National Agricultural Research System (NARS), which evolved from National Agricultural Research Institutions (NARI). Initially NARS was a highly integrated system comprising mainly of three key actors, researchers-extension-farmers with the aim of generation and provision of agricultural knowledge, information, experiences and technologies needed to increase and sustain productivity (Taylor, 1991; NRI, 2011). Prior to decentralization, this was possible due to the excessive government dominance in the management of agricultural technologies. With the decentralization, privatization and liberalization reforms, the linear supply-driven mode of innovation proved inadequate (Chema *et al.,* 2003; Sumberg, 2006). These major reforms intended to limit the role of government to the core functions of governance, rationalize the roles and functions of Ministries and pass on commercial activities to the private sector (URT, 1998; Skarstein, 2005: 341). The Local Government Reform (URT, 1998), partly form the basis of the reforms, which were intensified by subsequent programs especially

Agricultural Sector Development Strategy (ASDP) (URT, 2003).

After the decentralization of the public services to Local Government Authorities (LGAs), following the Local Government Act No. 6 of 1999, the extension services, provided by Ministry of Agricultural Food Security and Cooperatives (MAFC), were reduced to providing technical support to the local authorities and an enabling environment for extension services to function at the farm level (Rutatora and Mattee, 2001). This also led to the public sector withdrawal from direct production and provision of goods and services as well as reliance on centralized control and state ownership of the major means of production. These changes are evidenced by the increased private sector and Non-Governmental Organizations (NGOs) participation in the production, processing and marketing of agricultural inputs and produce.

Liberalization has also encouraged involvement of different actors in the delivery of extension services (pluralistic extension) such as the public agencies, private service providers, producer organizations and NGOs. However, despite the fact that the empirical studies revealed that many of the modalities in pluralistic extension entail partnerships between the public sector, farmers' organizations or communities and private sector providers, the private sector involvement in extension is not only a solution but also a challenge (Feder *et al.,* 2001). Practically, involvement of private sector excludes smallholders and less commercial farmers (excludability), while theoretically, substitutability will occur such that less marketable commodities will be substituted with highly marketable commodities regardless of their importance or priority to the public. The recent trends towards value chain (VC) approaches of agricultural innovation is further excluding the less resourceful farmers due to high demands in terms of quality and quantity of produce needed by the market and also the cost of value-adding facilities.

The reaction to this challenge has been the emergence of new forms of organizational arrangements aiming at facilitating the system integration. The reported organizational arrangements include innovation intermediaries and innovation brokers. This study, has attempted to explore the existence of the two major reported actors, innovation intermediaries and innovation brokers. Using multiple case studies, Chapter 4 (paper manuscript 3) unpacked the innovation intermediation functions and described the type of the organizations involved, their position and contributions in the agricultural innovation. Chapter 5 (paper manuscript 4) illustrated innovation brokerage interventions in dried cassava Value Chain.

The results presented in the Chapter 4 revealed several kinds of organizations (including R&D institutions, NGOs, LGAs and projects) arranged in such a manner that they connect actors from research and enterprises domains. This is happening in the process of putting new technologies into use, particularly technologies that are of less market value (non appropriable) such as OPVs, legumes and seeds of vegetatively propagated crop). Further analysis of the results in Chapter 4, categorized the organizations into extension service providers and innovation facilitators. The innovation facilitators (or innovation intermediaries) are neither sources nor implementers of the innovation (Howells, 2006).
Despite the fact that several different types of organizations are involved in innovation intermediation functions, they are all having common features in terms of organizational set-ups and roles performed. Objectively, the study revealed that innovation intermediation functions were mainly project interventions performed by R&D institutions and NGOs as side activities and not as a core or specialized functions. With regard to their roles, the innovation intermediation activities reported in Chapter 4 fit well in the three aggregated intermediary functions of demand articulation, network brokerage and innovation process management (Klerkx and Leeuwis, 2008a). Nevertheless, being

operated under project set-ups with short life spans of two to three years, the projects could not sustain the outcome of the innovation intermediation interventions to bring impact on sustainability of innovations.

Chapter 5 (paper manuscript 4) on the other hand illustrated the contribution of innovation brokerage in analyzing the context, articulating the demand, composing the innovation networks, facilitating interaction and sustaining brokerage roles. This was possible because of its independent position and flexibility in the plan of action, which was not easy for innovation intermediaries presented in the Chapter 4 due to embededness of the intermediation roles (Perez, *et al.,* 2010). Furthermore, the independent position allowed the innovation broker to optimize interactions both at innovation and systemic levels. Chapter 5 unpacked innovation brokerage functions that led to the establishment of systemic instruments mainly innovation networks and stakeholder platform. These two systemic instruments were important in achieving some of the essential features of the innovation system such as shared vision, market, linkages and human capacity, findings which concur with those of Hall *et al.* (2001) and Spielman *et al.* (2008). Independent position also allowed the innovation broker to share some of the credit for the investments purposely to institute ownership of results of brokerage roles to the stakeholders and thus encouraging their contribution to support brokering activities and even taking over some of the brokerage activities when the broker phased out.

The facilitation and connection roles make the innovation intermediaries and brokers important actors governing the vertical and horizontal flow of knowledge which is crucial for integrating smallholder farmers in activities of the VC. This can be achieved at the level of innovation networks or stakeholders platforms, hence demonstrated the importance of the three elements of agricultural innovations (the hardware, software and the orgware). However, in Tanzania innovation intermediation is not recognized by the agricultural knowledge infrastructure.

Thus, the findings from Chapter 4 and 5 are in line with earlier understanding that demand, as a major driver of client oriented (demand-driven) systems, entails demand articulation, which can be achieved through innovation intermediaries (Smith and Kuhlmann, 2004: 12; Izushi, 2003; Boom and Moors, 2008).

6.2 Conclusions

This study addresses three main issues regarding agricultural innovations in Tanzania: incorporation of features of AIS in NARS, characteristics of technology as a new dimension of AIS analysis and emergence of new organizational arrangements in NARS to facilitate innovation.

6.2.1 Incorporation of features of AIS in NARS

With regard to the incorporation of features of AIS in NARS, a number of conclusions can be drawn. The first conclusion is that the understanding by the majority of researchers, of the important actors of agricultural innovation and their roles is inadequate. Only a minority, who worked with relevant projects, appeared to be aware of other actors in the other domains such as entrepreneurs, markets and infrastructure and their roles.

Secondly, looking at the structural and functional perspective of AIS framework it can be concluded that, some of the institutional feature of AIS have been incorporated in NARS such as: multiple and evolving actors/partners; evolving and flexible role of actors and partners determined by resources available, a national agenda and available opportunities; knowledge produced (technical, institutional, organizational and managerial innovation) and indicators of performance (both quantitative and qualitative). Nevertheless, due to in-appropriability nature of many agricultural technologies, the research domain is linked to entrepreneurs and market domain through intermediary domain. In addition, the intermediary domain, which comprises innovation intermediaries, operates mainly in the project set-up, embedded within R&D institutions or development NGOs. Hence, key actors of innovation such as entrepreneurs and their contributions are not clearly recognised by researchers. Consequently this makes research more of demand-oriented (research problems are determined by researchers but considering the users) rather than demand-driven (…determined by users' demands).

6.2.2 Characteristics of technology as a new dimension of AIS analysis

With regard to incorporating the characteristics of technologies in the structural and functional analysis of agricultural innovation system, the first conclusion is that characteristics of technologies have a potential in prescribing the appropriate actors needed to form innovation networks for technologies of different characteristics. For example, characteristics of technologies highlight the sources of knowledge and major elements or parts (hardware, software and orgware) of technologies that form a complete package of innovation. Also the characteristics of technology can determine the institutional environment that is favourable to both the supply and demand sides. Thus the dimension of characteristics of technology calls for answering various demands that need to be satisfied in order to successfully bring about innovation. In other words, analysis of characteristics of technologies can predict the occurrence of system problems (market or systemic problems) in case the actors are missing.

Therefore, the dimension of characteristics of technologies will enhance effectiveness of the structural and functional frameworks for analysing the performance of technological innovation system and designing effective systemic instruments that will ensure demand-driven and sustainable innovation networks. This also shows that indicators of successful innovation should capture both technical (technical change) and social (organizational, managerial and institutional changes) changes.

6.2.3 Emergence of new organizational arrangements in NARS

With regard to the use of agricultural technologies, particularly technologies that are not attractive to private sectors (inappropriable technologies), the first conclusion is that the innovation intermediation and brokerage roles are important on both the supply (R&D institutions and extension services) and demand sides (SMEs and farmers) of innovations. On the demand side, since there are no sufficient numbers of SMEs that are willing and/or capable of developing further the inappropriable technologies, innovation intermediaries and brokers performed extra function of supporting establishment of business enterprises to fill the gap. But due to the limited time (working under project–setups) and embeddedness (being side activities) of its activities, innovation intermediaries and brokers rely on start-ups of farmers' owned business enterprises such as commercial seed multiplication (Chapters 4 and 5) and informal spin-off business enterprises at R&D institutions (Chapter 4).

The second conclusion is that, innovation intermediaries being side activities of existing organizations, limit their scope to linking individual organizations (one-to-one-to-one) at innovation system levels, while existence in a project set-up jeopardizes the sustainability of its outcome (Chapter 4, paper manuscript 3). On the other hand, independent position is a key to the success of innovation brokers in making a systemic contribution such as fulfilling liaison functions between different innovation systems (Chapter 5, paper manuscript 4).

Thus, the third conclusion with regard value chain approaches, (VC is another form of agricultural innovation system), is that innovation brokerage appears to be needed to stimulate, to bridge the missing linkages, to connect innovation networks, to build and to manage social learning processes among the key actors at both the level of individual actors (innovation network) and at a higher systems aggregation level (i.e. stakeholders platforms) (Chapter 5, paper manuscript 4). The paper has further shown that, innovation brokers can integrate smallholder farmers in vertical and more importantly, in horizontal activities of the chain. In this way innovation brokers add value in terms of the products but at the same time add value to social processes. Consequently, as indicated by the impact of brokerage roles in dried cassava value chain (Chapter 5, paper 4), most of the actors participating in the brokerage interventions (especially smallholder farmers and Local Government Authorities) enhance their capacity to respond to new challenges of value chains.

The fourth conclusion regarding innovation brokerage role concerns the impact of multiple-actors approaches and flexibility. The interventions such as farmer field schools, farm demonstrations and stakeholder platforms were made neutral and dialogical spaces involving multiple stakeholders' interactions. These spaces provide opportunities for combining informal and formal knowledge, articulating demands for new technologies and stimulated formation of innovation networks (Chapter 5). This new approach of agricultural innovation can be viewed as a transition from a linear and technical oriented to a more holistic (including technical and social innovation) and demand–driven approach of agricultural innovation. It also implies that, innovation brokerage results not only in quantitative improvements (yield per hectare) but also qualitative (social and institutional) changes.

Regarding flexibility, as it was presented in Chapter 5, innovation brokers implemented activities beyond a pre-determined action plan. Therefore, innovation is context-specific and innovation broker roles also go beyond implementation of pre-determined plans of action. As reported by Klerks *et al.* (2009), some impacts of innovation brokerage such as social learning, enhancement of trust and commitments are difficult to measure. In addition, in Tanzania, the roles, outcome and impacts of innovation brokers are not formerly recognized, and hence justification for the support from government and development partners is also difficult.

6.3 Recommendations

A number of institutional features of AIS have been incorporated in the current NARS in Tanzania. However, this has policy implications for research delivery. The study therefore recommends the following:

i. Government and policy makers should promote, support and sponsor research using the 'system' analytical framework at all levels (sector, sub-sector or commodity of priority). This will create an opportunity for on-site learning process for researchers and other stakeholders involved, to understanding the strengths, weaknesses and determine the alternative direction for policies and programmes.

ii. The dimension of characteristics of technologies should be incorporated in the analytical frameworks for the technological (agricultural) innovation systems. This is to ensure that all actors and functions needed in innovation process of that particular technology are considered. See the recommended tool (Appendix 12) that can be used to develop checklist questions for specific technologies.

iii. The stakeholders including the Ministry of Agriculture Food Security and Cooperatives should support and recognize the organizations (innovation intermediaries and brokerage) that contribute in strengthening the innovation system.

iv. From the AIS perspective, the innovative performance of the system is determined by presence of linkages and quality interactions among the key actors such as research, extension, entrepreneurs, education and farmers, as equal partners. For this to happen, it demands policy re-orientation regarding modes of operation, management style, and the legal framework. It means that policies that are responsible for creating the enabling environment for wider stakeholder participation in research and extension should be adopted. The flexible institutional management style, backed up not only with national, sector and institutional policies, but also institutional guidelines for the linkage and interactions, should be adopted to encourage and facilitate public - private sector interactions for example is guidelines for government agricultural extension services should be oriented towards facilitating the comprehensive packages (hardware, software and orgware) of technologies.

v. The indicators used in conducting annual Monitoring and Evaluation (M&E) for R&D institutions should capture not only technical potential of innovations, but also social processes such as demand articulation, formation of innovation networks and network management which lead to institutional, organizational and managerial innovations. Presently, the indicators used are focusing more on patterns of adoption, which rely mainly on quantitative measures including number of adopters and increase in productivity. Little or no attention is devoted to measure these other categories of innovations, which need more of qualitative measures to capture social (behaviors, habits, practice, links) changes. Consequently, useful interventions such as innovation intermediation and brokerage are not documented, shared and appreciated.

vi. The guidelines of assessing good performers in the agricultural sectors which are usually conducted during annual farmers' shows (*Nane Nane*) should expand the scope to include contributions from innovation intermediaries and brokers. This goes in line with documenting success stories of other participating actors in agricultural innovation apart from beneficiaries (farmers) only.

vii. Finally, it appears that only a limited number of researchers (the ones involved in the innovation–oriented agricultural project) are aware of features of AIS and their importance in innovation. However, the reported reasons for evolving roles such as R&D involvement in agricultural innovation through either direct commercialization of research results (Chapter 2, paper 1), establishment of spin-off enterprise (Chapter 3, paper 2) and embedding innovation intermediation roles to the R&D and NGOs (Chapter 4, paper 3) proved that, institutional and organizational context in which the technologies are developed enhances the impact of technological innovation in agriculture in addition to the technological potential. Thus policy makers should enact policies and processes to guide analysis of institutional context of innovation (including characteristics of technologies) being promoted, starting from the development stages at R&D and also include this information in the packages transferred to innovation intermediaries and end-users (farmers).

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APPENDICES

Appendix 1: Seed of major food crops demanded vs availability for year 2007/08 - 2011/12 (Tons)

Crop	Demand	Availability				
		2007/8	2008/9	2009/10	2010/11	2011/12
Maize	28 160	9 932.8	13 323.5	17 780.9	25 007.9	26 270.2 (93)
Paddy	13 860	149.5	784.9	951	950	821.7 (6)
Beans	10 840	62.2	111.8	219.9	110.6	223.8 (2)
Sorghum	3 360	319.7	1 346.1	1 507.4	2 374.4	1,083.8 (33)
Others	3 760	591.9	577.9	528.4	327.3	1 787.4 (47)
Toal	60 000	11 056.1	16 144.2	20 987.6	28.770.2	30 186.9

Note: In the bracket are percentages of increase in the availability of seeds in tons from 2007/8 to 2011/12.

Source: Ministry of Agriculture Food Security and Cooperatives, 2013

Appendix 2: The proportion of crops and varieties developed and those that were distributed by companies in Tanzania in 2013

Type of crop	Crop	No o Varieties* developed and used	No of Varieties** distributed by companies Hybrid	OPV/ Vegetative	None (%)
Cereals	Maize	98	40 (23)	10 (22)	48
	Rice	17		9 (8)	47
	Wheat	23		6 (1)	74
	Barley	8	2 (1)	2 (1)	50
	Sorghum	10		3 (9)	70
	Peal millet	2			100
Legumes	Beans	30	5 (5)	11 (6)	46
	Cowpeas	6		1 (1)	83
	Pegion peas	3		1 (1)	70
	Green gram	2			100
	Chick peas	4		1 (1)	75
	Njugumawe	4			100
Oil	Groundnuts	10			100
	Sesame	4		2 (3)	50
	Soya bean	4			100
	Sunflower	4		2 (8)	50
Root	Sweet potato	11			100
	Cassava	24			100
	Round potato	13		4 (1)	70
Others	Pyrethrum	4			100
	Banana				100
	Grape vine	2			100
Total		283	47	52	

* Crop varieties developed at ARIs according to update variety list (2013), seed production and importation (2013), report from ARI (URT, 2010) and list from SUA TTO office (cash and vegetable crops are not included)

** Include imported varieties

In the brackets are numbers of companies involved

Source: Seed Unit, MAFSC

Appendix 3: Survey questionnaire for general perceptions of researchers on technology transfer

Information about individual transfer object (technology)

A: General Information
In order to have a common understanding of the terms used in this questionnaire brief definitions (according to this work) are provided. Pleases take few minutes to go through them so that we have a common understanding.

Technology Transfer
Technology transfer is the process by which Intellectual Property (IP) is transferred from the research to a commercial entity to be applied for society use and benefits.

Intellectual Property (IP)
Is the innovative and novel output of intellectual and creativity, effort and thought.

Intellectual Property Right (IPR)
Defines the legally protected rights that enable owners of items of IP to exert monopoly control over the exploitation of these rights, usually with commercial gain in mind.

Public Goods
Public goods are that are not under competition (non-rivalrous) and non-excludable hence are available and accessible to everyone, usually not attractive to private entrepreneurs.

Private Goods
Private goods are competitive (rivalrous) and excludable therefore attractive to private entrepreneurs.

Spin-out/off
The common definition of spin-out is when a division of a company or organization becomes an independent business. The "spin-out" company takes assets, intellectual property, technology, and/or existing products from the parent organization. Shareholders of the parent company receive equivalent shares in the new company in order to compensate for the loss of equity in the original stocks. Another scenario of a spin-out is a firm formed when an employee or group of employees leaves an existing entity to form an independent start-up firm. The parent entity can be a firm, a university, or another organization.

Commercializable or marketable technologies
Technologies that are embedded in physical products or processes, in most cases this type of technologies need entrepreneur for manufacturing and / or multiplication. Example: seed varieties, design of farm machineries etc.

B: Personal Particulars

Name ……………………………….Mobile No……………………….(Optional)
Institution/Organization…………………………………………………………………

Gender: □ Male □ Female
Age group: □ 25 – 45 □ 46 -65 □ 66 – and above
Education: □ BSc □ MSc □ PhD □ Post Doctoral □ Diploma
Specialization:……………………………………………………………………………
Work experience: …………………………………………years

C: Specific Questions

Part I: Information about Research Results (new Technology/knowledge).

1.1 To what extent do you agree with the following statements (Please circle your rank (1 to 5 – from strongly disagree to strongly agree): 1 =strongly disagree; 2 = tend to disagree; 3 = neither agree nor disagree; 4 = tend to agree; 5 = strongly agree).

Features of Research Results (Technology)	Ranking by Agreement				
1. Entrepreneurs are needed to transform commercializable technologies generated from R&D institutions into sellable products before reaching end users	1	2	3	4	5
2. Technologies that are developed to a prototype level (Proven technologies) have clearer market application and more robust legal protection hence more chance of being taken by entrepreneurs	1	2	3	4	5
3. Researchers are motivated to disclose their inventions when they are legally protected.	1	2	3	4	5
4. Legally protected technologies are attractive to entrepreneurs because protection ensures monopoly of the market	1	2	3	4	5
5. Research results that are considered as “public goods” are not attractive to entrepreneurs than “private goods” hence are unlikely to be transferred to the end users.	1	2	3	4	5

1.2 To what extent are the sources of research ideas (motivation to develop a new technology) can enhance the transfer of the technology to end-users: (Please circle your rank 1 to 5 – from lesser extent to strong extent).

Type of motivation for conducting a research to develop new technology		Ranking by importance				
1.	A request from entrepreneurs who are interested to commercialize the technology	1	2	3	4	5
2.	Researcher's perception on the existing problems	1	2	3	4	5
3.	Demand from the end users	1	2	3	4	5
4.	Need for the improvement of existing technology (feedback from end users)	1	2	3	4	5
5.	National priority area or agenda	1	2	3	4	5
6.	Priority area of development partners (donors)	1	2	3	4	5
7.	Researchers' Intuition	1	2	3	4	5
8.	Others (specify)	1	2	3	4	5

1.3 Researchers have many expectations from their research work. Please RANK the list below of expectations according to their importance (from 1 as the most important to 5 less important)

☐ Technical achievement ☐ Professional growth
☐ Promotion ☐ Financial gain
☐ Satisfaction of curiosity ☐ Others
(specify)………………………………………………

Part II: Information About Technology Development and Transfer Regarding Organizational and Management Practices:

2.1 Of the following stakeholders which ones need to be involved in technology development stage (from idea to prototype or proven technology) for it to be successfully transferred and commercialized: (Mark with "√" against your choices of preference).

☐ Entrepreneurial firms / companies
☐ Regulatory agents (for quality and standards)
☐ Technology Transfer intermediaries
☐ End users
☐ Financial institutions
☐ Others (specify) ………………………………………………

2.2 Do you agree that an adequate knowledge about market potential of the research result (technology) is the prerequisite for the successful transfer and commercialization? ☐ Yes ☐ No

2.3 If your answer to Q 2.2 above is yes, do you agree that to assess the market potential of the research result (new technology), a multidisciplinary team of stakeholder is required? ☐ Yes ☐ No

2.4 If your answer to Q 2.3 above is yes, which among of the following stakeholder are important and what should be their role?

Type of Stakeholder	Their Roles
☐ Potential entrepreneurial firm	………………………………………………………
☐ Financial institutions	……………………………………………………
☐ Regulatory authorities	……………………………………………………
☐ Technology Transfer intermediary	………………………………………………
☐ End users	……………………………………………………………
☐ Others (specify)	……………………………………………………………

2.5 Do you agree that R&D institutions with special program to support entrepreneurial firms /or spinoff activities have large influence on technology development, transfer and commercialization? ☐ Yes ☐ No

2.6 If your answer to Q 2.5 above is yes, what approach or mechanism of support do you believe is appropriate for the current situation in Tanzania? Please RANK the list of support mechanism to entrepreneurial firms below according to their importance (from 1 as the most appropriate to 5 less appropriate).

☐ Lease arrangement to access expensive equipment or facilities

☐ In kind product development assistance

☐ Conducting applied research at agricultural experimental stations or government laboratories to downstream complicated technologies to the level of understanding and capacity of the entrepreneurs.

☐ Other (specify)……………………………………………………………………

Give reason for the option you ranked first ……………………………………………

2.7 Do you consider that the transfer and commercialization of commercializable agricultural technologies from R&D Institutions as successful?

☐ Yes, its successful ☐ Yes, its partially successful ☐ No, its unsuccessful

2.8 If the answer for Q 2.7 above is No what could be the reason? (Outline)

………………………………………………………………………………………

………………………………………………………………………………

If the answer for Q 2.7 above is yes what are the indicators?

…………………………………………………………………………………

2.9 Transfer of Commercializable technologies from R&D Institutions is a time demanding and knowledge specific interventions. For your opinion who should be responsible for the technology transfer processes within R&D Institution?

☐ Researcher

☐ Department within R&D institution

☐ Independent unit specialized for TT (eg Technology Transfer Office)

- Extension Officers
- ZIELU
- Others (specify)………………………………………………

Give reason for your choice ……………………………………………………………

Part III: Information about transfer mechanism:

3 To what extent do you agree with the following statement with regard to transfer mechanism: (Please circle your rank (1 to 5 – from strongly disagree to strongly agree): 1 =strong disagree; 2 = tend to disagree; 3 = neither agree nor disagree; 4 = tend to agree; 5 = strongly agree).

Influence of Transfer Mechanisms on technology Transfer process	Ranking by importance				
1. Transfer mechanism is an important factor for successful Technology Transfer from the source (research) to entrepreneur.	1	2	3	4	5
2. Technologies with different characteristic need different type of transfer mechanisms to be transferred successively.	1	2	3	4	5
3. Commercializable technology can be effectively transferred commercially.	1	2	3	4	5
4. Effective technology transfer mechanism must encourage private sector to actively participate in the technology transfer and commercialization process.	1	2	3	4	5
5. Highly sophisticated technologies generated from research institutions can be effectively transferred to where expertise and/or facilities from owner of technology can be easily access.	1	2	3	4	5

Part IV: Information about Technology Transfer Intermediaries:

4.1 Do you agree that there are cultural misunderstandings or gap between research institution and private sector that hinder technology transfer process? ☐ Yes ☐ No

4.2 If your answer to Q 4.1 above is yes:

(a) Indicate where it is most evident in situation or experience?

- Cultural gap between research and private sector
- Misunderstanding between researcher and administrators (within research institution)
- Both of the above ☐ weak contact between them
- Others (specify)…………………………………………………………

(b) Who among the following can effectively bridge the gap?

- Extension workers
- Specific department/unit within the R&D institution (eg technology transfer office)
- Independent unit outside R&D

- Zonal liaison officer
- Consultancy services
- Other (specify)……………………………………………………………..

4.3 What should be the role of the actor you chose above (question 4.3 (b) in reducing the gap and enhance technology transfer process particularly for marketable technologies? (outline)
……………………………………………………………………………
What are the necessary skills needed for successful performance of the actors you chose in Q 4.3b above
………………………………………………………………………………………
…………………………………………………..……………………………
…

Part V: Information about private sector

5.1 To what extent do you agree with the following statement in a view of private sector (agricultural enterprises) capabilities (Please circle your rank (1 to 5 – from strongly disagree to strongly agree): 1 =strong disagree; 2 = tend to disagree; 3 = neither agree nor disagree; 4 = tend to agree; 5 = strongly agree).

Transfer Recipient Capabilities	**Ranking by Agreement**				
1. Private sector is essential for successful technology transfer especially for commercializable or marketable technologies	1	2	3	4	5
2. Adequate knowledge of new technology / knowledge is a prerequisite for private sector to succeed in the technology transfer process.	1	2	3	4	5
3. Adequate marketing capabilities and well-developed business plans is needed for successful transfer of technologies generated from research	1	2	3	4	5
4. Adequate funds (or contact with funding institutions) are required for private sector to successes in transfer process.	1	2	3	4	5

5.2 Tanzania government recognizes the importance of private sector in the process of transferring marketable technologies form research to the end users. To what extent do you agree that the Tanzanian government should perform the following new roles to ensure effective involvement of private sector in technology transfer process. (Please circle your rank (1 to 5 – from strongly disagree to strongly agree): 1 =strongly disagree; 2 = tend to disagree; 3 = neither agree nor disagree; 4 = tend to agree; 5 = strongly agree).

New roles of Government	Ranking by Agreement				
1. Knowledge Management	1	2	3	4	5
2. Promoting private investment	1	2	3	4	5
3. Regulating safety, quality and effectiveness of private company's activities and their products	1	2	3	4	5
4. Technical and environmental impact analysis	1	2	3	4	5

Part VI: Information about Demand Environment:

6.1 In the situation where research institution is commercializing newly generated technologies directly to end-users, to what extent do you agree with the following statement (Please circle your rank (1 to 5 – from strongly disagree to strongly agree): 1 =strongly disagree; 2 = tend to disagree; 3 = neither agree nor disagree; 4 = tend to agree; 5 = strongly agree).

Reasons for commercializing research results direct to end-users?	Ranking by agreement				
1. The technology requires sophisticated facilities for multiplication hence majority of entrepreneur have no such capacity.	1	2	3	4	5
2. The technology requires high skilled personnel, which is expensive to be employed by entrepreneur.	1	2	3	4	5
3. Potential market for the technology is not well established, entrepreneurial cannot take risk	1	2	3	4	5
4. Lack of institutional guideline for licensing the research result to entrepreneurial.	1	2	3	4	5
5. Lack of entrepreneurs skills among the responsible personnel	1	2	3	4	5

Thank You For The Cooperation

Appendix 4: Survey questionnaire for commercializable agricultural technologies from R&D in Tanzania

Name of the Institution____
Name of researcher (Innovator) ____

Part I: General Questions

1.1 Name of the technology ____
1.2 The technology belong to subsector ______________________________
1.3 When did you start developing your technology?, year ________________
1.4 When was technology development finished? Year ____________________
1.5 Number of researchers involved ____________ ______________________
1.6 Who sponsored technology development?______________________________
1.7 Does your organization have Institutional Intellectual Property policy?_________
1.8 Who is the owner of the technology?________________________________

Instructions in filling the questionnaire: mark with "√" against your choice of preference. It is allowed to mark more than one choice.

Part II: Profile of your technology

2 What is the characteristic of your technology or invention?

□ Knowledge embedded in practice
□ Knowledge embedded in physical product
□ Knowledge embedded in process
□ Knowhow
□ Others (specify)……………..…….

2.1 What is the status of Intellectual Property Rights (IPR) protection of your technology? □ Protected □ Not protected □ Not sure

2.2 If answer to Q 2.3 above was protected:

(a) What form of protection was used?

□ Patent □ Plant Breeders Right □ Trademark
□ Copyright □ Trade secrete □ Others specify________

(b) When was the IPR strategy developed_________________________________
____

(c) Who was responsible for preparing claims_____________________________

(d) Who covered the necessary costs involved ____________________________

2.3 If answer to Q 2.3 above was not protected, what was the reason? Mark the appropriate answer (s).

- Not aware of the existence of Intellectual Property Right (IPR)
- Not aware of IPR protection procedures
- No enough funds allocated for the protection and transfer of the TO
- No institutional IP policy that encourages protection and commercialization
- Donor not interested with protection
- Others (specify)______________________________________

2.4 How do you judge on the accessibility of technology to entrepreneurs and end users?
 Public good Private good Mixed good

2.5 Do you consider the technology that you developed to be highly sophisticated such that it needs highly specialized personnel to produce or multiply? Yes
 No

2.6 Does the technology you developed have potential for numerous applications?
 Yes No

2.7 Who are the targeted end users of your technology?______________________

Part III: Technology Development and Transfer

3.1 What was the motive or drive for researching and developing your technology

- Request from entrepreneur
- Research curiosity
- Directives from above
- Feedback from end-users of the previous technology
- Researchers perception of the existing problem
- National Agenda (priority area)
- Donor's priority agenda
- Others (specify)……………………

3.2 What was the source of new idea, design or initial materials for your research?

- Researchers' creativity
- Improvement of the existing technology
- Reverse engineering
- Patent document
- Discovery
- Gene bank (give the name………………)
- Others (specify)………………………………………………….

3.3 How was your technology developed?

- Cross breeding
- Variety Selection
- Adaptation
- Validation
- Designing
- Others (specify)………

3.4 Who was involved at different stages of technology development and their responsibilities?

Stages of technology development	Name stakeholders (institution /individual organization/community)	What was the key role of the stakeholder
Proposal development		
Project implementation		
Performance assessment at different stages		
Quality control		
Market opportunity evaluation		
Technology transfer and commercialization		
Multiplication / manufacturing		
Dissemination		
Impact assessments		
At all stages		
Others (specify)………		

Could you give any concrete example about the main added value of the stakeholder involvement for your technology?

____

3.5 Were you allocated enough resources for the transfer of your technology?

 Yes No

3.6 What is the unique element of the technology that you developed, the end user will be prepared to pay more.

 More profitable Ease to Operate Healthy Safety to consumer's Social benefit (color, taste, cultural compatible etc) Environmental friendliness others (specify)_____________________

3.7 Did you adequately explain the benefits (unique element) of your technology to potential technology recipients (entrepreneurs / end users)? Yes no

3.8 If the answer to Q 3.7 above was yes, how did you do it:

(a) To the entrepreneurs?

 Exhibitions Brochures Training Seminar Presentation Others (specify) _______________________

(b) To the Technology Transfer Intermediaries (TTI)?

 Memorandum of Understanding Brochures

 Disclosure Agreements Presentation

□ Others (specify) ____

(c) To the end users?

□ Exhibitions □ Brochures □ Training Seminar

□ Presentation □ farmer field days □ Others (specify) _________________

3.9 Are there any existing arrangements in your organization that was involved in promoting, transfer or commercializing the technology that you developed?

□ Yes □ No □ not sure

3.10 If the answer to Q 3.9 was yes:

(a) Mark the appropriate facility in the list below.

□ Incubator □ Technology Transfer Office □ Entrepreneurship unit

□ Exhibition □ Social economic & Farming system

□ ZIELU □ Project or special fund

□ Others (specify)_____________________________

(b) What was the role played by the facility you chose in (a) above to enhance transfer of your technology____

3.11 Are there any existing incentives scheme to researchers for successful transfer and commercialization of their technologies? □ Yes □ no

3.12 If the answer to Q 3.11 was yes, did you (or your organization) receive any kind of incentive for your innovation (technology)? □ Yes (me / my organization) □ No

3.13 Did your organization allocate time for you to participate in transferring technology that you developed. □ yes □ no

3.14 Did your research project allocate adequate funds for the transfer and commercialization of research results (technology)? □ Yes □ No

Part IV: Technology scaling–up and commercialization

4.1 Does your technology have standardized components for industrial application?

□ Yes □ No

4.2 If the answer to Q 4.1 above was yes was your technology transferred to any technology recipient □ Yes □ No

4.3 If the answer to Q 4.2 above was yes:

(a) Who was the recipient of your technology when finalized?

Entrepreneurs: □ Farmer's group □ Formal business (eg company..) □ NGOs

Technology Transfer Intermediary: □ NGOs □ Local Government Authority □ Processing company

Others(specify) ____________

(b) Give name (and address if possible) of recipient(s)____________________
____

(c) What mechanism was used to transfer the technology from your organization to the recipient?

Licensing	Exhibitions,	Direct sell of the product
Memorandum of Understanding	Informal (eg consultancy),	Brochure
On site demonstration	Training	Others (specify) ____

(d) Does your technology include other knowledge (for maintenance, application, operation, knowhow) that needed to be transferred together with the technology to the entrepreneur and users? Yes No
 Not sure

(e) If the answer to Q 4.3 (d) above was yes:
a. Give examples………………………………………
b. How was it transferred?
 Training Consultancy Staff attachment
 Brochure Others (specify…………………

(f) How was your technology multiplied or manufactured?……………………………

(g) How was your technology disseminated from sources to end-users?............………

4.3.1 If the answer to Q 4.1 above was no: How was your technology utilized? Outline ………………………………………………………………………

4.4 By Government/ private/NGO) to establish support mechanism for facilitating transfer and commercialization of your technology? Yes No

4.5 If the answer to 4.5 above is yes: what is the mechanisms:
 Tax exemption Credit facilities Project / program
 Support from stakeholders eg processing industry
 Government subsidy eg Voucher scheme) Others Specify……………

4.6 Does your technology have well established national (quality) standards?
 Yes No

4.7 If the answer to 4.7 above is yes:
(a) Has your technology certified before being taken to consumers?
 Yes No
(b) Mention regulatory bodies responsible for regulating the standards for your technology………………………………………………………………
Mention policy and act that is operational to your technology
…………………………………………………………………………………………
…………………………………………………………………………………………
.

If the answer to 4.7 above is no, what is your suggestion regarding quality control for your technology to ensure its effectiveness and to safe guard health of end user and adverse environment impact?
……………………………………………………………………………………………
……………………………………………..……………………………………

Part V: Demand Environment

5.1 Do you consider that the transfer (and commercialization) of your technology to the end user was successfully? □ Un successful □ Partially successful □ Successful

5.2 If the answer to Q 5.1 above was successful or partially successful?

(a) How did you measure the extent of success?

□ Available in most of the input shops □ Supplied to selected farmers during trials
□ Supplied to selected farmers during on farm demonstration
□ Accessible from early adopters (farmer – farmer)
□ Financial gain from sells □ National recognition (eg. award)
□ License with entrepreneur □ Impact on policy
□ Others …………………………………………………………………

(b) Which one of the following induces the demand?

□ Competitive market price
□ Existing demand for the related products in the market
□ Substitutability of the technology
□ Government subsidies to the technology
□ National policy priority agenda
□ Comparative advantages
□ Others (specify) ____

5.3 If the answer to 5.1 above is un successful or partially successful what could be the reason?____
____
_

5.4 5.4 What can be done to improve the situation?
____

Thanking you in advance for your time and kind

Appendix 5: Dimensions of characteristics of agricultural technology in an innovation system perspective

Characteristics	Subcategories
Physical	Soft part (knowledge of application e.g. seed rate) Hard part (physical products e.g. seeds) Level of sophistication: from a simple seed rate to biotechnology based technologies. Associated technologies: food processing protocol and associated processing machine
Economic	Private: excludable (access can be denied to those who have not paid for the product) and or rivalry (one person's use reduces the availability of a good or service to others) Public: non excludable and non rivalry Mixed: technologies with potential of expressing both public and private features depending on farming system such as: In subsistence and semi-subsistence farming, which is mainly small-scale, farmers may select seed from previous harvests particularly for OPVs and legumes but not be easy for large commercial farming. Stage of technology development: when a variety is released, initially the available amount of seed is so small such that they can only be accessed through seed multipliers even for subsistence farmers.

Appendix 6: Types recipients of technologies with different characteristics from R&D institutions and their contributions in innovation process

Characteristics of technology			Number of tech (%)	Recipients of technologies from R&D	Roles
Physical	**Level of sophistication**	**Economic**			
Physical product (hard part)	Simple	Private	22	*Enterprises:* R&D, LGSs or private firms	Mass multiplication
		Mixed	69	Intermediary; NGOs, LGAs, R&D	Facilitate transfer, start-ups or demand articulation
	High level	Private	3	*Intermediary*: R&D	Facilitate spin-off and demand articulations
Protocol (process/ Formula)	High (for associated technologies)	Private	6	*Intermediary:* R&D, NGOs	Facilitate access of associated technologies
Knowledge of use (soft part)	Simple	Public (physical)	94	*Intermediary:* R&D (ZIELU) and LGAs (Ext services)	Diffusion of knowledge
		Public (protocol)	6		

Appendix 7: Systemic problem based on technology characteristics – structure analysis of an innovation system

Characteristics	Subcategories	Structural element	Systemic problem
Physical	Soft part	Actors	Actors problems
		Interaction	Interaction problem
		Institutional	Institutional problems
		Infrastructural	Infrastructural problems
	Hard part	Actors	Actors problems
		Interaction	Interaction problem
		Institutional	Institutional problems
		Infrastructural	Infrastructural problems
Economic	Private good	Actors	Actors problems
		Interaction	Interaction problem
		Institutional	Institutional problems
		Infrastructural	Infrastructural problems
	Public good	Actors	Actors problems
		Interaction	Interaction problem
		Institutions	Institutional problems
		Infrastructure	Infrastructural problems

Adapted from Wieczorek *et al*., 2012

Appendix 8: Interview guide for semi structured interview with Officers in charge of the identified innovation intermediaries

General information:
Company/Agent:
……………………………………………………………………………………
Name and position of interviewee:……………… …………………….
Main function/ servicers / product offered:……………………………………………………
Owners of organization (individual / association/ group)
When started ………………….. what was the motive………………………………
What is your source of fund is it adequate?………….. ………………………..

Sourcing technology
What kind of technology are you dealing with?
Could you give a list of all type of technologies you are handling and their sources?
How do you know the existence of new relevant technology in R&D institutions?
What was the motive for starting dealing with kind of technology?
What are procedures and mechanism used to receive technologies from innovators / R&D institutions?
Do you have adequate knowledge about the technology your dealing? How did you get it?
Can you describe the most challenges that you are faced in sourcing technology?
Manufacturing / multiplication of product from the technology
What are the arrangements and procedures involved in manufacturing/multiplication/production of product from the technology?
Can you describe the most challenges that you are faced in production processes?
Product supply:
Who are your customers, are you selling direct to consumers or through agents?
Could you give list of agents and their contacts?
Can you describe the most challenges that you are faced in delivering your products to customers?
Do you know well your clients, how did you know them? Do you have market expert ?/ business plan?

Self assessment
What is output of your work?
How do you assess extent of reaching the intended consumers?
How do you measure? Could you give evidence?
Does your organization equipped with necessary expertise / skills for dealing with production of the product and distribution? (Marketing, Business, Technical, Communication …)
If no where and how do you source necessary expertise?
Are there any support from government in facilitation transfer and commercialization of the product? (Example voucher scheme ….)

What are your future plan, opportunities and strategies?

Are there any kind of documentation related to your operations and achievements, can I access them?

Could you allow me to visit your activities and/or partners if any?

Appendix 9: Checklist for Key Informant Interviews – Local Coordinator (Agricultural Extension Officer) and staff from VECO and MUVI

Section one: Overview of cassava subsector
Historical background:
What was the situation / problem at all stages: production, processing and marketing
Actors involved, how were selected and their roles (including the initial intervention before VECO)
Any capacity building to stakeholders
What is the situation now (successive interventions)
Who are the users of cassava technologies / products (clean cassava cutting and intermediary products)
Any conflict / problem among the actors emerged and how was resolved,
At District level any evaluation or reports (what are the official - indicators used for evaluation by extension / researchers, learning - lessons)

Section two: Commercial family farmers
Steps: what was the first step/source of ides/any problem
Who are the main actors and their roles.
Attached staff – HR: what are other professional services has been provided? And credit?
Who provide them under what arrangements (MoU, contracts, / any incentive?)
Any capacity building: extension, researcher, farmers, processers, MVIWATA etc)
Any organization or LGA adopted the model (what are your judgments)

Appendix 10: Checklist for Key Informant Interviews – Leaders of Farmers' Group

Section one: cassava seed multiplication

Brief history of the group
Who develop the plans, and modalities for the group activities
Commercialization of cassava cuttings: Development of cassava seedling market , data on trend of production, what is the consumers' package
How is the organization link with quality control at the market
Revolving fund: who provide and how is it managed
How to you link with market, local and external (in any way possible)
Verify the role of MVIWATA in lobbying for DADPs on machines?/ to be a priority crop
What are main benefits of members of group?
What changes has happened in their farming system, life, relation ship
How do you categories the VECO and other actors, can you separate them (source, carrier, facilitator).
Who are the main customers of cuttings (how do you categories) Why people are willing/ not willing to buy cuttings?
What makes cassava cutting a commodity?
What are the future trend in catting business (why?)

Field observation Evaluation

Cassava seed farms, data collection and management
Cassava processing units
Other resources for the 25 and 75 groups
Any agreements and contacts with other partners eg MVIWATA, LGA, others (advice)

Section two: Collective market

Who develop the plans, and modalities
Commercialization of cassava flour, data on trend of production, costumes what is the package
How is the organization link with quality control at the market
Revolving fund: who provide and how is it managed (if any)
Simple cooperate to multiple commodity company: nay synergy
How to you link with market, local and external (in any way possible)
The branding?
Problem solved through collective action
What are main benefits for uses of the market?
What changes has happened in the marketing strategies from the field?
How do you categories the contribution from VECO
Who are the main customers of cassava flour (how do you categories)
What makes cassava flour a commodity? What is the selling point of cassava flour
What are the future trend in QCF business (why?)
Profiles of members – how are they ranked in the village (poor or well off)
Any individual adpted the same strategy outside the project ?

Field observation
The market center and transaction
Evaluation (local, project, external)
Unclear image (overlap in roles??)

Section Three: Stakeholder Platform
Who are the members? Who are they selected?
What are man benefits of members of group?
What changes has happened in their farming system, life, relation ship
How do you categories the VECO and other actors, can you separate them (source, carrier, facilitator).
What are the future trend in leadership and facilitation?

Field observation
Minutes / proceedings of the workshops
Evaluation (local, project, external)

Appendix 11: Types and alignment of system actors for cassava innovation in Mkuranga District in Tanzania

Characteristics of technology			Recipients of technologies from R&D	Roles
Physical	**Level of sophistication**	**Economic**		
Clean cassava planting materials	Cassava cuttings (Simple)	Mixed	Innovation intermediary (VECO)	Facilitate establishment of start-ups (CSMF) for seed multiplication, demand articulation, innovation network formation and innovation process management
	Agronomic practices (simple)	Public	*Innovation Intermediary (VECO)* Government Extension staff	Facilitate extension staff in acquiring and diffusion of knowledge: support training, demonstrations, FFS
Processing Dried cassava	Associated processing machines (complex and expensive)	Private	*Enterprises: engineering firm*	Multiplication of processing machines
			Innovation Intermediary: VECO	Facilitate access machine to users: revolving funds, hire purchase arrangements and facilitate establishment of CFFC and DMBC.
	Processing techniques (simple)	Public	*Innovation Intermediary (VECO)*	Facilitate diffusion of knowledge: support training to users and machine operators and field demonstrations.

Appendix 12: The Innovativeness and Inter-Organizational Linkage Problems in the Tanzanian Agricultural Sector: A Tool to Evaluate performance of technological innovation system

Definition of the key terms

1. Innovation is putting of the new thing into the market place
2. Innovation system is the concept that emphasizes the flow of technology and information among people, enterprises and institutions as a key to an innovative process. It comprises the actors and their interactions, which are needed in order to turn an idea into a process, product or service in the market.
3. Demand-oriented research: research problems are determined by researchers but considering the users
4. Demand-driven research: research problems are determined by users' demands.

Introduction

How to stimulate sustainable oriented technological innovation has been a common debatable question among innovation scholars. Consequently scholars have come up with a systemic policy framework developed after combining structural and functional analyses, that help to identify the systemic problems and suggest the systemic instruments that would address these problems. However, the results from this study have reveled that characteristics of technology have influence on both structural and functional dimensions of the technological innovation systems particularly in the SSA countries. Therefore, for effective results, the developed systemic policy frameworks should also include the dimension of characteristics of technology.

This question checklist combined the three dimensions of technological innovation system (TIS) (characteristic - structural – functional) aiming at evaluating its performance and sustainability. The checklist can be used to build a set of questions for any specific technological problem or opportunity that is worthy investigating. The questions themselves may be simple, but when used as part of the checklist, they become a powerful tool for analyzing for the effectiveness and sustainability of TIS (functioning and proposal).

This tool can be used in a cyclic manner. The cycle starts when the characteristics dimension of technology are used to determine the structural and functional dimension of TIS. Then, the three dimensions of TIS (characteristic - structural – functional) are coupled to identify the potential systemic problems. Guided by the established systemic goals, systemic instruments can be developed or improved towards addressing the identified problems. When new systemic instruments are put into action, the process starts again.

Part One: The Dimension of characteristics of technology of the system

1. What are the physical characteristics of the technology?

☐Physical product ☐Information ☐Process

2. What is the level of complexity / sophistication

☐ High ☐ Media ☐Low

3. If it is a physical product (Hard)
   a. How is the technology multiplied and disseminated?..
   b. Who are the actors involved
      i. Multiplication ……………………………………………………………..
      ii. Dissemination ……………………………………………………………..

4. If it is a process (soft), are there any associated technologies?
   a. If the answer is yes what are the technologies?...
   b. How is the technology multiplied and disseminated?..
   c. Who are the actors involved …………………………………………………
      i. Multiplication ……………….……………………………………………..
      ii. Dissemination ……………………………………………………………..

5. If it is information (soft),
   a. How is the technology multiplied and disseminated?..
   b. Who are the actors involved ……………………...……………………………..
      i. Multiplication ……………………………………………………………..
      ii. Dissemination ……………………………………………………………..

6. What are the economic characteristics of the technology? (Public, private or mixed)

………………………………………………………………………………………

Part Two: Structural dimensions of the system (adopted from Wieczorek and Hekkrrt, 2012)

7. Actors involved:

Civil society: …………………………………………………………

Companies: …………………………………………………………

Knowledge institutions: …………………………………………………………

Government: …………………………………………………………

Other parties: …………………………………………………………

8. Institutions:

Hard: …………………………………………………………,

Soft: …………………………………………………………

9. Interactions:

Networks: …………………………………………………………

Individual contacts …………………………………………………………

10. Infrastructure:
Physical: ……………………………………………………….
Knowledge: ……………………………………………………….
Financial: ……………………………………………………….

Part Three: Functional dimension of the technological innovation system (adopted from Wieczorek and Hekkrrt, 2012)

Function 1, Entrepreneurial activities:
Are there enough entrepreneurs/business?
What is the quality of entrepreneurship?
What types of businesses are involved?
What are the products?
What varieties of technological options are available?
Are there any entrepreneurs leaving the system?
Are there new entrepreneurs/businesses?

Function 2, Knowledge development:
Is the knowledge basic or applied?
Are there many projects, research, patents and articles?
Which actors are particularly active?
Who finances the knowledge development?
Does the technology receive attention in national research and technology programs?
Are there enough knowledge users?

Function 3, Knowledge dissemination:
Are there strong partnerships?
Between whom?
Is the knowledge development demand-driven?
Is there space for knowledge dissemination?
Is there strong competition?
Does the knowledge correspond with the needs of the innovation system?
Have any licenses been issued?

Function 4, Market formation:
What does the market look like?
What is its size (niche/developed)?
Who are the users (current and potential)?
Who takes the lead (public/private parties)?
Are there institutional incentives/barriers to market formation?
Must a new market be created or an existing one be opened up?

Function 5, Resources mobilization:
Are there sufficient financial resources for system development?
Do they correspond with the system's needs?

What are they mainly used for (research/application/ pilot projects etc.)?
Is there sufficient risk capital?
Is there adequate public funding?
Can companies easily access the resources?

Part five: Systemic instruments (adopted from Wieczorek and Hekkrrt, 2012)
Systemic instruments can be developed when the systemic problems are identified which in turn will guide the proper selection of strategies and tools that will effectively influence the functions of the innovation system. The following are examples of instruments basing on the established; goals that the systemic instruments should focus on to ensure a successful innovation system discussed in Chapters 3 & 4.

Goals of systemic instruments and Examples of individual goals

Goals of systemic instruments	**Examples of individual goals**
Stimulate and organize the participation of various actors	Non profitable public private partnerships
Create space for actors' capability development	Technology platforms, stakeholders platform, pilot projects
Stimulate the occurrence of interaction	Innovation intermediation and brokerage,
Prevent too strong and too weak ties	Demonstration centers, political tools (awards), incentives for innovative projects, risk capital, technology promotion programmed
Secure the presence of (hard and soft) institutions	Awareness building measures such as lobbying, education campaign, verification trials
Prevent institutions being too weak or too stringent	Regulations (private and public)
Stimulate the physical, financial and knowledge infrastructure	Stakeholders analysis, need assessments
Ensure that the quality of the infrastructure	