African Journal of Science, Technology, Innovation and Development, 2015
Vol. 7, No. 2, 73–83, http://dx.doi.org/10.1080/20421338.2015.1023651

Routledge
Taylor & Francis Group

Characteristics of agriculture technology and application of an agricultural innovation system in Tanzania

Athman H. Mgumia[a]*, Amon Z. Mattee[b] and Beatus A.T Kundi[c]

[a]*Tanzania Commission for Science and Technology (COSTECH), Dar es Salaam, Tanzania*
[b]*Department of Agricultural Education and Extension, Sokoine University of Agriculture, Morogoro, Tanzania*
[c]*Department of Mechanical & Industrial Engineering, College of Engineering & Technology (COeT), University of Dar es Salaam, Tanzania*
**Corresponding author email: mgumia2@yahoo.com*

The globalisation of the world economy and advancements in science, including the 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 commercialisation. 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 commercialised by business enterprises, 60% needed intermediation interventions. Features of agricultural innovation system have been incorporated particularly under 'projects' implemented by R&D or NGOs, which is an indication that the coverage and sustainability is subjective. Thus, government interventions in promoting agricultural innovations should focus on both operations and policy issues for effective incorporation of innovation system.

Keywords: Innovations, system of innovation, characteristic of technologies, Tanzania

JEL classification: O30, O55, O32, O33, Q16

Introduction

For decades, the agricultural sector has witnessed a number of changes in the context of promoting technological changes in responding to emerging challenges. Farmers have been progressively unable to engage profitably in agriculture for a number of reasons, including: limited access to technology, advances in technology (e.g. biotechnology), climate change, the 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 model to the 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, Eicher 2006). For example, in developed countries where the agricultural research and service provision is privatised, agricultural technologies are behaving in the same way as industrial technologies. In developing countries, particularly sub-Saharan Africa (SSA), on the other hand, since the liberalisation reforms of 1980s, the actors of agricultural innovation have expanded. The NARS which were established in many SSA countries (Taylor 1991), are now made up of a conglomeration of private and public sectors, NGOs, government agencies and civil society organisations, and the technologies are characterised not only by their physical features (physical product and knowledge of application) but also by their 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 2002, Carlson et al. 2002) and functions (Hekkert et al. 2007, Johnson 2001). Other scholars of system studies have analysed innovation systems from the view of systemic problems (Smith 2000, Klein-Woolthus et al. 2005). Nevertheless, systemic problems were limited to those within the description of the system (Carlsson et al. 2002) which includes the components, the relationships and attributes of components, and also the attributes of relationships, as argued by Wieczorek et al. (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 characteristics is also crucial to highlight the essential features of an agricultural innovation system suitable for a specific country, in this case Tanzania, and emphasises the need for institutional change for agricultural research organisations to contribute more effectively to innovation.

This paper contributes to filling this gap by exploring the kinds of actors (and their roles) that have been engaged in the innovation process for agricultural technologies with different characteristics (physical and economic) in Tanzania. Specifically, the study aimed at answering the following research questions: What are the characteristics of technologies generated from R&D 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 the characteristics of agricultural technologies, actors involved and their roles?

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 an 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 of 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.

Agriculture innovation systems: evolution of the concept

The term *innovation* is conceptualised differently as a product, a process or a new way of applying knowledge. While some scholars tend to adopt the 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 conceptualised as 'anything new introduced into an economic or social process' (OECD 1997, 12). A *system*, on the other hand (including innovation system), is constituted 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 the '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 (organisational and institutional analysis) 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 the system of innovation theory in agriculture research and innovation processes, hence progressively shifting from linear model towards multiple, interactive and learning-based systems of innovation. The major focus in the NARS reform agenda includes: governance, decentralisation, stakeholder participation, emerging funding mechanisms and strengthening of system linkages (Chema et al. 2003, 11–16, Clark et al. 2002) as well as knowledge and information systems (World Bank 2006), which led to the emergence of 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 organisations enterprises, and individuals focused on bringing new products, new process, and new forms of organisations into economic use, together with the institutions and policies that affects 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, in contrast to NARS, offers a framework which accommodates flexible, multiple and evolving roles of actors that are determined by the nature of their task, skills and resources available, including high degree of market integration.

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

The structural/infrastructural analysis views the AIS as an innovation support infrastructure (Vellema 2008, cited by Klerkx, et al. 2012), which offers possible linkages and relationships among the diverse actors in AIS (Figure 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, is trying to identify the missing components or components that are not interacting amicably (Hekker et al. 2007). Based on the generic functions of innovation systems (Lundvall 1992, 2), the analysis involves knowledge/technology development, entrepreneurship activities (in this case multiplication and dissemination) and economic utilisation.

Features of agricultural technologies: excludability, rivalry and appropriability

Liberalisation of private economic initiatives in Tanzania which included privatisation of agricultural technologies from public research institutions such as seed and fertiliser (Skarstein 2005, 341) led to the emergence of public/private sector relationships in agriculture. Though technologies embodied in the agricultural practices (such as recommended seed rate, soil and water conservation) have little market value, and are considered as 'public good', which anyone could use without diminishing the value (Van den Berg 2001, Fulton and Gray 2007), in many SSA, there are exceptions regarding the appropriability of newly 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 recognised in addition to the two classic groups, public and private goods (Muraguri 2006, 2).

Therefore, although the private sector appeared to be the most effective provider of goods and services because of its stronger links with clients (Carney 1995, 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 if market failure will necessitate the public sector to provide, regulate or subsidise research results to end users (Hall 2001, 5, Pineiro 2007). The term rivalry is used for goods and services that one person's use or consumption reduces their availability, while excludability refers to the capture of property right to knowledge (Van den Berg 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 2001, 5, Van den Berg 2001, 7).

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)

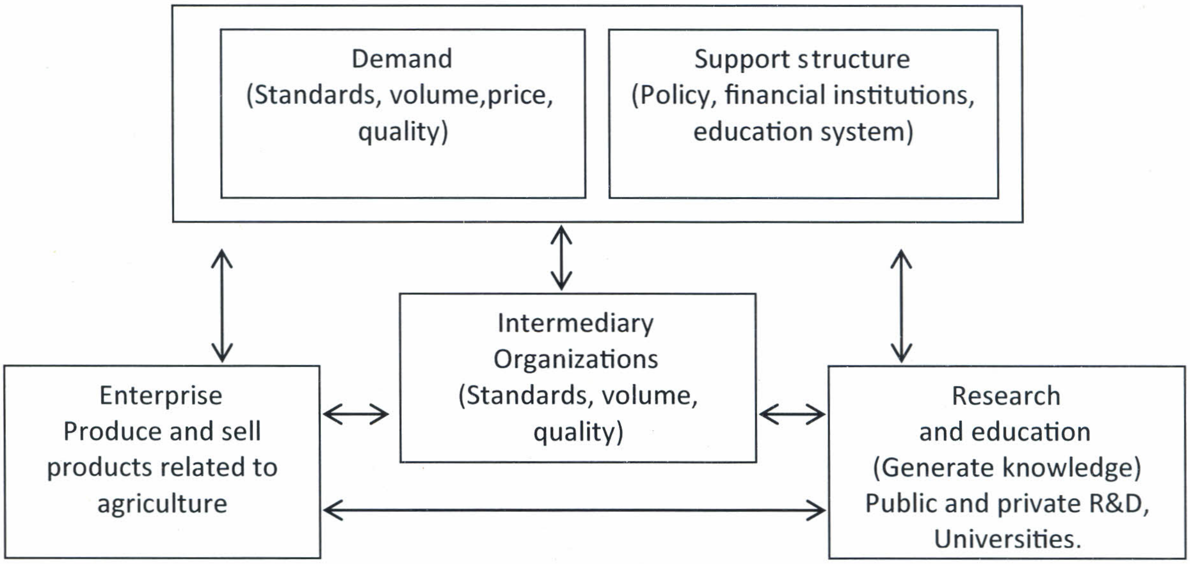

Figure 1: Possible actors in the agricultural innovation system. Adopted from CABI/CTA/KIT/VRLIE/WUR (2006), Rajalahti et al. (2008, 4), Arnold and Bell (2001, 279).

of 2010, emphasises the commercialisation 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 sector relationships, 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 Unit (ZIELU) was formed to enhance communication between research and Local Government Authorities (LGAs), farmer groups/networks, the Agricultural Sector Lead Ministries (ASLMs), national level organisations and institutions. Parallel to ASDP, NARS adopted the Client-Oriented-Research and Development Approach (CORDEMA) in 2003 in order to contribute 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 a few studies on multisectorial system of innovation (Malerba and Mani 2009), the focus of most studies on innovation systems is inclined towards industrial technologies, mainly effective knowledge sharing (Szogs and Lugano 2006, Szogs 2010), role of mediator organisations (Szogs 2008, Szogs et al. 2011) and cluster initiatives (Diyamett 2009).

Methodology

Tanzania has 16 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 soil researches in relation to their respective ecological zones. Initially, the study intended to survey all research centre, however, 13 out of the 16 centres were visited, the other three could not be reached because of logistical difficulties. In addition, the study included three private Agricultural Research Institutions (ARIs) dealing with two major cash crops: coffee and tobacco, and Sokoine University of Agriculture (SUA). This made a total of 17 research institutions surveyed by the study.

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 commercialisable technologies generated in all the 17 research institutions, followed by identifying the researchers responsible for the development and dissemination or commercialisation of each of the technologies. Commercialisable technologies in this case included technologies in the form of physical products, designs or formulations that require either manufacturing or multiplication before dissemination, for example, planting materials such as seed or seedlings and agro-chemicals. Commercialisable technologies also included practices or protocols that require special facilities or equipment in order to be effectively utilised. Therefore, a list of all commercialisable technologies generated by each research institution between 1995 and 2010 and their associated developer/disseminator was established. Phase Two involved administering questionnaires to each of the researchers associated with each of the identified technologies. In this case, all generated technologies were surveyed. Reliability and validity of data were achieved by administering questionnaires through personal interviews to ensure that respondents achieved a uniform understanding of terms used in the questions, and also for clarification as deemed necessary. In addition, documentary review especially on reports was used for validating data from the questionnaires.

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 (c^2) test was employed at 5% level of significance (Pallant 2005), to see if any association existed between the 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 categorisation (Kvale 1996). Results were cross-tabulated whereby answers from different questions were summarised in tables and correlated. Materials from the survey were related to the analytical framework of this research (as described in above).

Results and discussion

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

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

Physical feature	Economic features			Total
	Public good	Private good	Mixed good	
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%)

47 technologies could not be easily accessed. Seventy-eight (90%) of the 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 differed significantly (c^2 = 87.000, p = 0.0001). Most (94%) of the technologies were physical products and the remaining were sets of procedures or protocols governing the 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 needed 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) who showed that only few agricultural technologies fall neatly under either public or private goods while the majority were mixed goods.

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 in 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 (2001), relates market failure with a situation whereby the private sector is either non-existent 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 in the unavailability of the technologies for the majority of farmers, for example *in vitro* propagated banana seedlings. This is synonymous with systemic failure, a situation whereby firms and/or sectors fail in adapting to new a technological development due to low levels of knowledge and ability to learn (Smith 2000, 95).

Roles of different actors involved in agriculture innovation

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

Stage One: Technology development

At this stage, six key actors were identified, and, except for the business enterprises, the roles of all actors 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 mobilisation 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 was obliged to identify, contracting or consulting business firms who

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

Actors	Roles	Percentage of technologies*
R&D institutions:	Source of research idea and technology development	100
Researcher	Verification of technology performance	
	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 staff* mobilise the community to participate and provide field supervision on trials and demonstrations	84
Extension service	*Farmers* contribute in kind (land and labour) and evaluate the performance and acceptability of new technology	
Regulatory bodies	Quality assurance	69

*Percentage of technologies that benefited from roles performed by the actor would 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 ideas. This is different from the early mechanism of agricultural innovation (technology transfer) under NARS whereby the 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 the privatisation of some 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 the agricultural knowledge infrastructure but also established new roles for the R&D institutions.

The outcome of interaction of actors in the technology development stage caused 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 the concurrent interaction of more than one supplier of different products and services (Case 1). This challenge requires a new institutional and organisational 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 organisations 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 researchers, 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 Organisation (NGO), 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 the Coastal Region.

Stage Two: Multiplication of developed technologies

Despite the fact that the surveyed technologies required business enterprises to do the multiplication before dissemination or commercialisation, the findings (Table 2b) indicate that only 35 (40%) of the technologies were multiplied by business enterprises. The responsibility for mass production of the remaining 52 (60%) technologies, were left to five different actors namely R&D, farmers' 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 and 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

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

Actors	Roles	Percentage of technologies *
Business enterprises	Mass production of technology for selling	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.

enterprises that could afford to do the job. Hence, the idea was to establish a *spin-off* business where the expertise and facilities from the owner of the technology can easily be accessed. As for the involvement of the LGAs, this was governed by the Local Government Reform Programme (URT 1998) and the Agricultural Sector Development Programme (ASDP) (URT 2003), 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).

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 its 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 organisation, 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 the 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, 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 organisations that are involved indirectly in

Table 2c: The actors involved in technology dissemination and commercialisation 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:		83
	Direct selling or distribution through training and demonstrations	36	
	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	
			28
	Establish credit /revolving fund	6	
	Subsidising products from business enterprises (multipliers)	5	
	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	
	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

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 commercialisation

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 1, 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 includes R&D, LGAs, farmer groups, NGOs and business enterprises; the second category included actors who were specialised in handling technology in the form of information. These actors were Zonal Information and Extension Units (ZIELU), 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 specialised 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 information.

The third category of actors supported the dissemination/commercialisation 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 support 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 commercialisation 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.

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 commercialisation) 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

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, fertiliser 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	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	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

22 (25%) were handled by actors under the enterprise domain and sometimes motivated by subsidies (Table 3). Mixed good 60 (69%) on the other hand, were managed through the intermediary domain that facilitated establishment of enterprise (Table 3). The three (3%) technologies that needed sophisticated techniques were commercialised through specific business (spin-off enterprises) established at R&D institutions. This implies that characteristics of technology influenced both type of actor and their roles, and interaction within the agriculture innovation system.

The notable findings in Table 3 were that some actors were flexible, taking multiple roles needed for innovation. For example, LGAs and R&D 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 as 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, hence a question of sustainability emerged. The challenge is whether the existing R&D and LGAs institutional framework can facilitate the link and coordination of these different domains (entrepreneurs and intermediary).

Conclusions and recommendations/policy implications

The objective of the study was to identify characteristics of agriculture technologies generated by R&D in Tanzania, and 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 technologies were in the category of physical products and mixed goods. Very few surveyed technologies were in the form of protocol and pure public and private goods. Being pure public or mixed goods, the technologies were less attractive to entrepreneur. 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) 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 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 are navigating from being a source of knowledge, intermediary organisation to a business enterprise. 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 institutionalised and the emerging innovation intermediation roles are not yet officially recognised 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 the rational public support to innovation intermediaries.

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

Acknowledgements

We thank the Tanzanian Commission for Science and Technology (COSTECH) for funding this study. We would also like to extend our sincere gratitude to the anonymous reviewers of this paper for their invaluable comments.

References

Anandajayasekeram P. (2011), The role of agricultural R&D within the agricultural innovation systems framework. Prepared for the ASTI/FPRI-FARA Conference, Accra, Ghana, 5–7 December.

Arnold E and Bell M. (2001), Some new ideas about research for development. In *Partnership at the leading edge: A Danish vision for knowledge, research and development.* Copenhagen: Danish Ministry of Foreign Affairs.

Bozeman B. (2000), Technology transfer and public policy: A review of research and theory. *Research Policy* 29: 627–655. http://dx.doi.org/10.1016/S0048-7333(99)00093-1.

CABI/CTA/KIT/VRLIE/WUR (2006), Training of Trainers (TOT) workshop for ACT Experts on Agricultural science. Technology and innovation (ASTI) systems, 2nd- 6th October 2006. Accra. Ghana. In Agwu AE, Dimelu MU, and Madukwe MC (eds.) (2008), Innovation system approach to agricultural development: Policy implications for agricultural extension delivery in Nigeria. *African Journal of Biotechnology* 7 (11): 1604–1611.

Carney D. (1998), Changing public and private roles in agricultural service production. London, Overseas Development Institute. Working paper 81. P75. Available at http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6996.pdf.

Chema S, Gilbert E and Roseboom J. (2003), A review of key issues and recent experiences in reforming agricultural research in Africa. Research Report 24. The Hague: ISNAR. Available at *ftp://ftp.cgiar.org/isnar/publicat/pdf/RR-24.pdf.*

Clark N. (2002), Innovation systems, institutional change and the new knowledge market: Implication for Third World agriculture development. *Economics of Innovations and New Technologies* 11: 353–1863. http://dx.doi.org/10.1080/10438590200000004.

Diyamett B. (2009), Building systems of innovation in an African setting: the cluster initiatives development approach. *African Journal of Science, Technology, Innovation and Development* 1: 167–189.

FAO (Food and Agriculture Organization) and World Bank (2000), Agricultural Knowledge and Information Systems for Rural Development (AKIS/RD): Strategic Vision and Guiding Principles. Rome and Washington, DC: FAO and World Bank. Available at: http://www.esd.worldbank.org/extension/.

Fulton, M. and Gray, R. (2007), Toll goods and agricultural policy, CAIRN Policy Brief. *Canadian Agricultural Innovation Research Network* Number 9.

Hall A, Bockett G, Taylor S, Sivamohan MVK and Clark N. (2001), Why research partnerships really matter: innovation theory, institutional arrangements and implications for developing new technology for the poor. *World Development* 29: 783–797. http://dx.doi.org/10.1016/S0305-750X(01)00004-3.

Hall A, Mytelka L and Oyeyinka B. (2006). Concepts and guidelines for diagnostic assessments of agricultural innovation capacity. The UNU-MERIT *Working Paper Series* 17. Maastricht: UN University.

Hall A, Mytelka L and Oyeyinka B: Innovation system: implications for agricultural policy and practice. ILAC Brief 2.ILCA. International Livestock Centre for Africa, Addis Ababa, Ethiopia, 2005.

Hall A, Sulaiman VR, Clark N and Yoganand B. (2003), From measuring impact to learning institutional lessons: an innovation systems perspective on improving the management of international agricultural research. *Agricultural Systems* 78(2): 213–241. http://dx.doi.org/10.1016/S0308-521X(03)00127-6.

Hekkert MP, Suurs RAA, Negro SO, Kuhlman S and Smits REHM. (2007), Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting and Social Change* 74(4): 413–432. http://dx.doi.org/10.1016/j.techfore.2006.03.002.

Hermans F, Stuiver M, Beers PJ and Kok K. (2013), The distribution of roles and functions for upscaling and outscaling innovations in agricultural innovation systems. *Agricultural Systems* 115: 117–128. http://dx.doi.org/10.1016/j.agsy.2012.09.006.

Hounkonnou D, Kossou D, Kuyper TW, Leeuwis L, Nederlof ES, Röling N, Sakyi-Dawson O, Traoré M and van Huis A, (2012), An innovation systems approach to institutional change: smallholder development in West Africa. *Agricultural Systems* 108: 74–83. http://dx.doi.org/10.1016/j.agsy.2012.01.007.

Howells J. (2006), Intermediation and the role of intermediaries in innovation. *Research Policy* 35: 715–728. http://dx.doi.org/10.1016/j.respol.2006.03.005.

Kavia FY, Mushongi CC and Sonda GB. (2007), Factors affecting adoption of cassava varieties: a case of Cassava Mosaic Disease tolerant varieties in Lake Zone regions – Tanzania. 8th African Crop Science Society Conference, El-Minia, Egypt, 27–31 October 2007. Vol. 8: 1875–1878.

Kilelu CW, Klerkx L and Leeuwis C. (2012). Unravelling innovation platforms – insights from co-evolution of innovation in a smallholder dairy development program in Kenya. 10th European IFSA Symposium, Denmark. Available at: http://ifsa.boku.ac.at/cms/fileadmin/Proceeding2012/IFSA2012_WS2.2_Kilelu.pdf.

Klerkx L and Leeuwis C. (2008), Matching demand and supply in the agricultural knowledge infrastructure: experiences with innovation intermediaries. Food Policy 33(3): 260–276. http://dx.doi.org/10.1016/j.foodpol.2007.10.001.

Klerkx L and Leeuwis C. (2009), Establishment and embedding of innovation brokers at different innovation system levels: insights from the Dutch agricultural sector. *Technological Forecasting and Social Change* 76(6): 849–860. http://dx.doi.org/10.1016/j.techfore.2008.10.001.

Klerkx L and Gildemacher P. (2012), The role of innovation brokers in agricultural innovation systems. In World Bank (2012), *Agricultural Innovation Systems: An Investment Sourcebook*. Washington, DC: World Bank. pp. 211–230. http://dx.doi.org/10.1787/9789264167445-19-en.

Kvale S. (1996), *Interview: an introduction to qualitative research interviewing*. Thousand Oaks, CA: Sage. pp. 187–204.

Leeuwis C. (ed.) (2004), *Communication for rural innovation: rethinking agricultural extension*. Oxford: Blackwell Science. http://dx.doi.org/10.1002/9780470995235.

Lundvall B-Å. (1992), *National systems of innovation. Towards a theory of innovation and interactive,* learning. London: Pinter.

Malerba, F and Mani, S. (2009), *Sectoral systems of innovation and production in developing countries: actors, structure and evolution.* Cheltenham: Edward Elgar Publishing.

Muraguri L. (2006), Private right and public goods: conflict in agriculture R&D. In: *DIME Conference and Intellectual Property Rights for Business and Society*, 14–15 September 2006. Available at: www.dime-eu.org/files/active/0/Muraguri.pdf.

OECD (1997). *National innovation systems*. Paris: OECD (Organization for Economic Cooperation and Development).

Pallant J. (2005), *SPSS survival manual: A step by step guide to data analysis using SPSS for Windows (Version 12),* 2nd ed. Milton Keynes: Open University Press.

Ortiz O, Orrego R, Pradel W, Gildemacher P, Castillo R, Otiniano R, Gabriel J, Vallejo J, Torres O, Woldegiorgis G, *et al.* (2013), Insights into potato innovation systems in Bolivia, Ethiopia, Peru and Uganda. *Agricultural Systems* 114: 73–83. http://dx.doi.org/10.1016/j.agsy.2012.08.007.

Ngwediagi P. 2009. Establishment of a plant breeders' rights system in Tanzania: achievements and challenges. In: CAS-IP NPI. 2009. Institutionalization of Intellectual Property Management: Case Studies from four Agricultural Research Institutions in Developing Countries. Rome: CAS-IP Available at: http://www.wipo.int/edocs/lexdocs/laws/en/tz/tz010en.pdf.

Perez Perdomo, S.A., Klerkx, L. and Leeuwis, C. (2010), *Innovation brokers and their roles in value chain-network innovation: preliminary findings and a research agenda.* Montpellier: CiradInra-SupAgro.

Pineiro M. (2007), Agricultural innovation systems: situation, prospects and research needs. International Service for National Agricultural Research. Available at: http://www.scidev.net.

Rajalahti R. (2009), Promoting agricultural innovation systems approaches: the way forwards. Available at: http// knowledge.cta.int/en/content/view/full/9564.

Rajalahti R, Janssen W and Pehu E. (2008), Agricultural innovation systems: from diagnostic toward operational practices. Agricultural and Rural Development Discussion Paper 38. Washington, DC: World Bank.

Rivera WM, Qmar MK and Mwandemere HK. (2005), *Enhancing coordination among AKIS/RD actors: an analytical and comparative review of country studies on agricultural knowledge and information systems for rural development (AKIS/RD)*. Rome: FAO. Available at http://www.fao.org/docrep/008/y9087e/y9087e00.HTM.

Rutatora DF and Mattee AZ. (2001), Major agricultural extension providers in Tanzania. *African Study Monographs* 22: 155–173,.

Sempeho G. (2004), Reform of agricultural research and technology dissemination systems in East Africa: Tanzanian experience. Paper presented during ASAR ECA/NARS/ World Bank retreat, Addis Ababa, Ethiopia, 26–28 February 2004.

Sibuga KP. (2008). SADC implementation and coordination of agricultural research and training (ICART): Situation analysis of agricultural research and training in the United Republic of Tanzania. Available at: http://www.sadc.int/fanr/agricresearch/icart/inforesources/situationanalysis/TanzaniaSitAnalysisFinalRport.pdf

Skarstein R. (2005), Economic liberalization and smallholder productivity in Tanzania. From promised success to real failure 1985–1998. *Journal of Agrarian Change* 5: 334–362. http://dx.doi.org/10.1111/j.1471-0366.2005.00104.x.

Smith K. (2000), Innovation as a systemic phenomenon: rethinking the role of policy. *Enterprise and Innovation Management Studies* 1: 73–102. http://dx.doi.org/10.1080/146324400363536.

Smits R and Kuhlmann S. (2004), The rise of systemic instruments in innovation policy. *International Journal of Foresight and Innovation Policy* 1: 4–32. http://dx.doi.org/10.1504/IJFIP.2004.004621.

Spielman DJ, Ekboir J, Davis K and Ochieng CMO. (2008), An innovation systems perspective on strengthening agricultural education and training in sub-Saharan Africa. *Agricutural Systems* 98: 1–9. http://dx.doi.org/10.1016/j.agsy.2008.03.004.

Sumberg J. (2005), Systems of innovation theory and the changing architecture of agricultural research in Africa. *Food Policy* 30: 21–41. http://dx.doi.org/10.1016/j.foodpol.2004.11.001.

Szogs A. (2008), The role of mediator organizations in the making of innovation systems in least developed countries. Evidence from Tanzania. *International Journal of Technology and Globalisation,* 4(3), 223–237. Available at http://www.Inderscience.com.

Szogs A. (2010), Technology transfer and technological capability building in informal firms in Tanzania. Thesis for the degree of Doctor of Philosophy. Lunds University, Helsingborg.

Szogs A and Wilson L. (2006), Effective knowledge sharing: the Tanzanian Industrial Research and Development Organization as mediator between the foreign and local sector. *KM4D Journal* 2(1): 92–104 Available at: www.km4dev.org/journal

Szogs A, Cummings A and Chaminade C. (2011), Building systems of innovation in less developed countries: the role of intermediate organizations supporting interactions in Tanzania and El Salvador. *Innovation and. Development*, 1: 283–302. http://dx.doi.org/10.1080/2157930X.2011.615601.

Taylor TA. (1991), Organization and structure of National Agriculture Research system in Anglophone sub-Saharan Africa. Working Paper No. 38. The Hague: International Services for National Agriculture Research. Available at http://eprints.icrisat.ac.in/12992/1/RP%206765.pdf.

Tenywa MM, Rao K, Tukahirwa JB, Buruchara R, Adekunle AA, Mugabe J and Wanjiku C. (2011), Agricultural innovation platform as a tool for development oriented research: lessons and challenges in the formation and operationalization. Learning Publics. *Journal of Agriculture and Environmental Studies* 2: 118–146.

Thornton P, Dyer K, Lawson A, Olney G, Olsen H and Pennarz J. (2011), Joint Irish Aid and DFID country programme evaluation Tanzania 2004/05–2009/10. Irish Aid/ Department for International Development. Available at: http://www.oecd.org/countries/Tanzania/48156699.pdf.

Umali DL and Schwartz L. (1994), Public and private agricultural extension: beyond traditional frontiers. World Bank discussion paper 236. Washington, DC: World Bank.

United Republic of Tanzania (URT) (1998), '*Local Government Reform Program, Policy Paper on Local Government Reform'*, Ministry of Regional Administration and Local Government. Dar es Salaam: Government Printers.

United Republic of Tanzania (URT) (2003), Agricultural Sector Development Programme Framework and Process Document. Available at www.agriculture.go.tz/.../English%20docs/ASDP.

United Republic of Tanzania (URT) (2010), *National Research and Development Policy*. Dar es Salaam: Ministry of Communication, Science and Technology.

Van den Berg and Margree, H. (2001), The agricultural knowledge infrastructure: public or private? An exploratory study about evolving public and private goods and roles. Available a: http://www.fao.org/sd/2001/KN1103a_en.htm.

Vellema, S. (2008), Postharvest innovation in developing societies: the institutional dimensions of technological change. *Stewart Postharvest Review* 4 (5): 1–8.

Wieczorek AJ and Hekkert MP. (2012), Systemic instruments for systemic innovation *problems*: A framework for policy makers and innovation scholars. *Science and Public Policy* 39: 74–87. http://dx.doi.org/10.1093/scipol/scr008.

Wilson, R. (1997), Technology transfer in public sector and academic research Institutions'. *A Joint Trade & Industrial Policy Secretariat (TIPS) & Deve lopment Policy Research Unit (DPRU)* Newsletter December 1997 Volume 4.

Klein Woolthuis RK, Lankhuizen M and Gilsing V. (2005), A system failure framework for innovation policy design. *Technovation* 25: 609–619. http://dx.doi.org/10.1016/j.technovation.2003.11.002.

World Bank (1994), *Adjustment in Africa: reforms, results, and the road ahead*. A World Bank policy research report. New York: Oxford University Press. P308) Available at: http://documents.worldbank.org/curated/en/1994/02/440376/adjustment-Africa-reforms-results-road-ahead.

World Bank (2006), 'Enhancing agricultural innovations: How to go beyond Strengthening research systems'. Washington, DC, USA. Available at: http://siteresources.worldbank.org/INTARD/Resources/Enhancing_Ag_Innovation.pdf.

World Bank. (2008), World Development Report: Agricultural for Development. In Sumberg, J., (2005), Systems of innovation theory and the changing architecture of agricultural research in Africa. *Food Policy* 30: 21–41.