

**NEW TECHNOLOGIES FOR DISSEMINATING AND COMMUNICATING AGRICULTURE  
KNOWLEDGE AND INFORMATION:  
CHALLENGES FOR AGRICULTURAL RESEARCH INSTITUTES IN TANZANIA**

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**ABSTRACT**

This paper explores how a wide range of Information and Communication Technologies (ICTs) available in Agricultural Research Institutes (ARIs) if used effectively by agriculture researchers can improve agriculture productivity in Tanzania. A structured questionnaire and telephonic interviews were used to collect data from a randomly selected sample of 64 respondents made up of agricultural researchers, agriculture managers and other agricultural stakeholders in the selected institutes. Data were analyzed using statistical tools. The results indicate that ICTs tools are available in ARIs for the day to day research activities. However, utilization of agriculture journals is very limited due to unreliability and poor connectivity of the Internet and frequent power cuts. Results also show that the uses of specialized ICT devices have not taken a great recognition in agriculture activities which is attributed by low investment of ICTs that can be used for teaching and learning modern agriculture productivity techniques in institutes under this study. Among the challenges hindering the use of ICTs in ARIs includes: inadequate computers and the supporting technological infrastructure, lack of electricity needed to operate computers, unreliable Internet connectivity and lack of systematic ICTs investment; low coordination of agriculture stakeholders due to institutional diversity and department fragmentation. This study recommends that the Government of Tanzania (GoT) should formulate and implement ICT for Agriculture (ICT4A) projects based on a researched conceptual framework related to ICT4A use and Information and Communication Management (ICM) in ARIs in Tanzania.

**Keywords:** ICT tools, agricultural, research institutes, Tanzania, knowledge, learning, teaching.

**1. BACKGROUND INTRODUCTION**

Agriculture is the engine of economic growth, development and improved livelihood in African countries including Tanzania (Worldbank, 2007; Nyagahima, 2010). Agriculture is the mainstay of the Tanzanian economy contributing to about 24.1% of GDP, 30% of export earnings, 65% of raw materials for industries and employs about 75% of the total labour force (Kapange, 2002; Angello and Wema, 2010; URT, 2013). Agriculture is important in economic sector because of food production, foreign exchange earnings, provides livelihood to more than 70% of the population and controls inflation, since food contributes about 50% of the inflation basket (Ngaiza, 2012). In the foreseeable future, agriculture will remain to be a key to the country's economic and social development. The Government of Tanzania has

formulated various policies and initiatives to improve agriculture productivity and sustain smallholder farming. The established policies and initiatives includes: Kilimo Kwanza (agriculture first), Famogata, MKUKUTA, subsidized farm inputs Program, Southern Block Agriculture Development, MKUZA, TASAF, Tanzania Feed the Future Initiative, the Government of Tanzania (GoT) Comprehensive Africa Agricultural Development Programme Compact (CAADP), Agricultural Sector Development Support Programme (ADSP) and the USAID-Tanzania Agriculture Productivity Programme (USAID-TAPP) (MAFSC, 2009;URT,2013; Sanga *et al.*, 2013b; USAID, 2011).

The Government of Tanzania through the National Agriculture Policy (URT, 2013) is also committed to bring about a green revolution and the use of ICTs in the transformation of agriculture from subsistence farming to commercialization and modernization through crop intensification, diversification conceptualization, infrastructural development and applying innovative ways in the agricultural value chains (URT, 2013).The adoption of new production techniques driven by development in ICT which has lead to increased agriculture productivity and output of this sector are also some of the output of the Tanzania development vision 2025. Various donors including the United States Agency for International Development (USAID) provide funds for using ICT for agriculture (ICT4A) in Africa's development including Tanzania. USAID has already established a portfolio of ICT investments for long term natural resource planning in support of location based information services such as remote sensing, Geographic Information Systems (GIS), Global Positioning Systems, and Internet mapping (USAID, 2007).

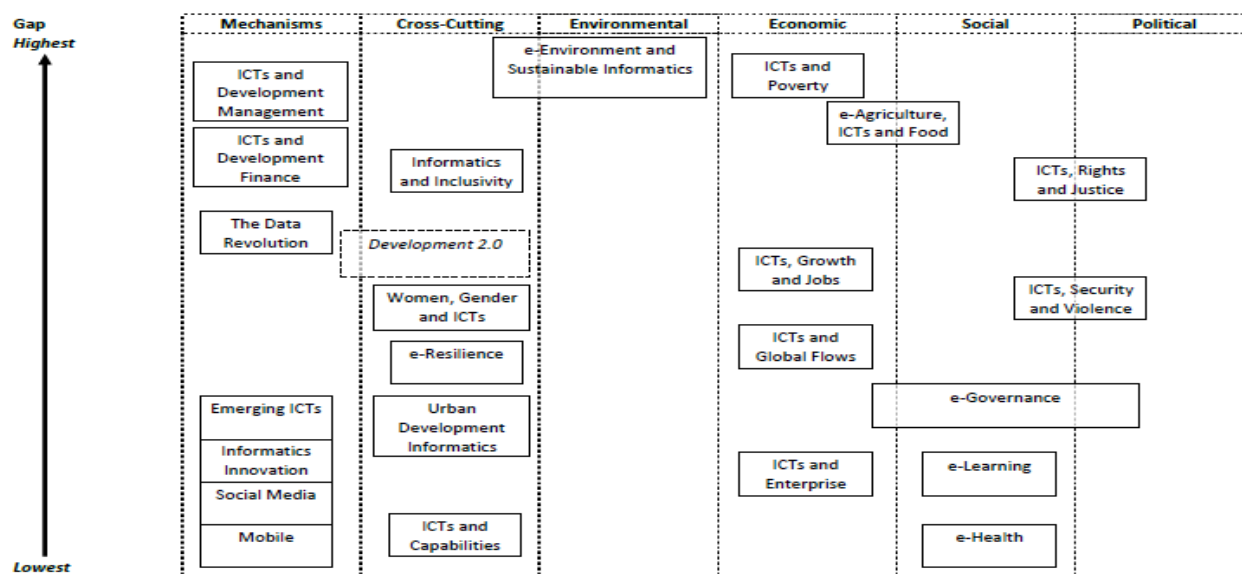
Despite the essentials of agriculture in economic development and various agriculture initiatives by the Government of Tanzania, the sector has remained abysmally poor due to unproductive systems of agriculture practices which includes low productivity of land, labour and production inputs, underdeveloped irrigation potential, limited capital and access to financial services, inadequate agricultural technical support services (IMF, 2006; ESRF, 2006), poor rural infrastructure; infestations and outbreaks of crop pests and diseases, erosion of natural resource base and environmental degradation (URT, 2008; URT, 2013; Mtega and Msungu, 2013). Other factors contributing to limit the contribution of agriculture sector to poverty eradication is the poor network of agricultural information services (Mtega and Msungu, 2013). Weak linkage among actors in the sector has been mentioned as another limiting factor to the accessibility and usage of agricultural knowledge and information among farmers (Shao, 2007; URT, 2008; Komwihangilo *et al.*, 2010). Agricultural knowledge normally is produced by agricultural researchers done at ARIs, universities and Line Ministries. Also; agriculture knowledge is produced by farmers themselves. This is type of knowledge is termed as indigenous agriculture knowledge (Lwoga, 2010). Even though farmers have indigenous knowledge but agricultural research has a major role to play in increasing productivity and profitability of the agriculture sector through development of scientific knowledge to generate improved technologies for the production systems in agriculture (Kapange, 2003). Also, ARIs are important in validating agriculture indigenous knowledge which needs to be transferred to farmers and other stakeholders in agriculture. Researchers from ARIs and other stakeholders complement with their effort by transferring knowledge using various communication channels (including ICTs) to the end-users (farmers).

ARIs are so important in the implementation of ICT based solutions for agricultural extension services. The applicability of ICT in extension services has been researched by a number of scholars (Richardson, 2004; Colle, 2005; Sanga, Churi, and Tumbo, 2007; Eicher, 2007). However agricultural innovations and agricultural technologies are mainly produced from ARIs (Sanga *et al.*, 2007) but not much is documented on how a wide range of ICT tools related to crop variety, land use, soil health, soil nutrients requirement, irrigation and

weather forecasting are being utilized in ARIs. Previous study by Angello and Wema (2010) only focused on the usage of e-resources by livestock researchers in Tanzania. Other previous studies explored the role and the use of ICTs in agriculture but did not show how do researchers in these institutes utilize ICT tools to improve farmers' agriculture productivity (Kaaya, 1999; Tumsifu, 2002; Mtega and Msungu, 2013). This study therefore fills this gap in knowledge by first exploring the level of ICT tools availability in ARIs and how researchers utilize the identified ICTs in their research and teaching.

The ultimate goal for ICT integration in ARIs is towards improving research and teaching productivity. This study seeks to complement studies which reported on conventional ways of information dissemination to farmers. Literature review not only noted the role of radios and mobile phones, but also, the need for the technical personnel (i.e. agriculture researchers, agriculture technologists) to be intuitive in designing and developing proper ICTs which are well timed, packaged to appeal to the end user (farmers), and delivered in a socially and cultural appealing manner (Temu and Msuya, 2004). The recent paper by Heeks (2014) provides a map (Fig.1) of future ICT4D research priorities and identifies 16 informatics research gaps for a post-2015 world development agenda. Among the research gap is an e-agriculture which is described alongside the more general need for Development Informatics (DI) research to break out of the "ICT4D bubble" and engage more with the development mainstream in agriculture using ICTs. It puts emphasis for further research on using ICT4A with the following objectives: to improve agricultural productivity and sustainable incomes; to manage and improve agricultural supply chains; to address food security, malnutrition and hunger; to address issues related to ICTs for land degradation, land management, and land rights and tenure (Heeks, 2014). From Heeks' map of future ICT4D is where the need of this study also came in order to fill this research gap of improving agriculture productivity using ICTs.

**Figure 1: Map of Post-2015 Development Informatics Research Priorities (Heeks, 2014)**



### 1.1 Significance and Study Objectives

Agriculture researchers from ARIs play an active part in the development of ICTs for the farming community to apply new technological farming practices which can raise agriculture productivity and eradicate poverty in Tanzania. It is well known that, if new farming techniques using ICT tools are effectively used, then agriculture productivity can be raised in

a way that can help to eradicate poverty in Tanzania (URT, 2013). It is, therefore, very important that agriculture productivity must be supported by ICTs that are developed by agriculture researchers from ARIs.

The significance of this study is towards informing agriculture researchers' readiness towards effective use of the available ICTs for agriculture research activities which would improve agriculture productivity in the country. The study also gives a clear picture of understanding of ICT4A to agriculture policy makers, agriculture managers and other stakeholders involved in the agriculture value chain. From this study, the current status of the use of ICTs by ARIs to increase agriculture productivity has been documented. This has added the literature on the subject as per specific objectives set for the study.

The overall objective of the study was to investigate how agriculture researchers in the selected ARIs utilize effectively a wide range of ICTs in their researches. Specifically, the study intended to:

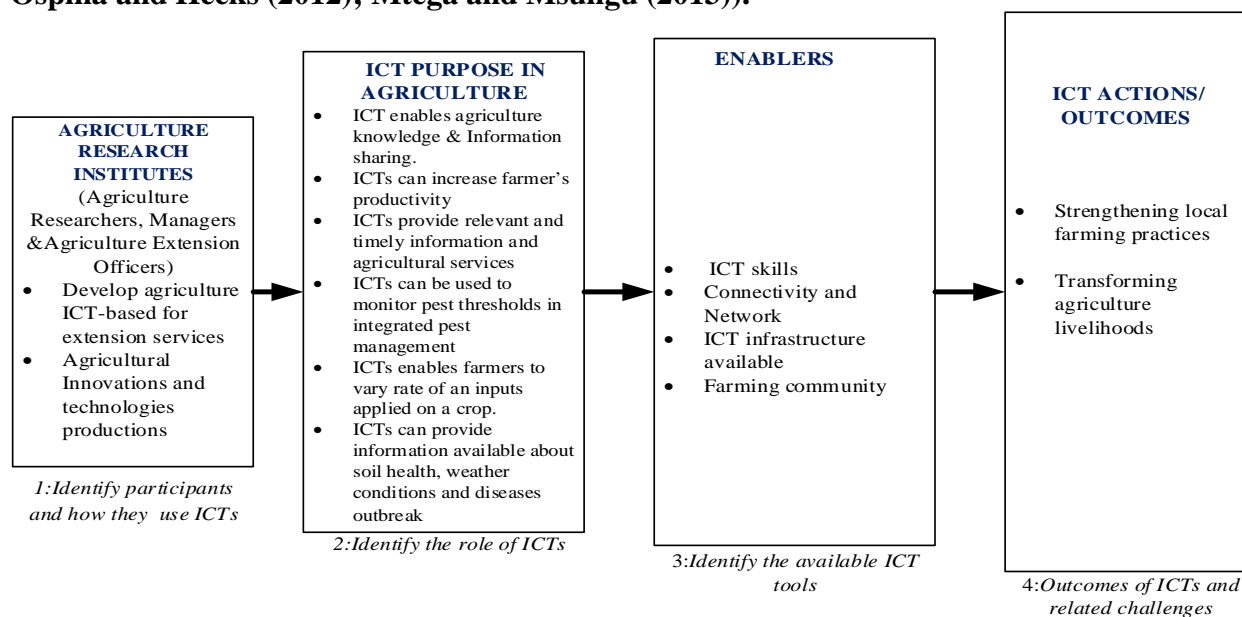
- a) Explore ICT tools availability in the ARIs
- b) Examine how agriculture researchers in the ARIs are using ICTs.
- c) Assess challenges which hinder the implementation, integration and effective use of ICTs in ARIs.
- d) Establish strategies that could overcome the challenges identified in (c).

In order to answer the mentioned specific objectives, the study adopted the modified Ospina and Heeks (2012) and Mtega and Msungu (2013) frameworks.

## **2. CONCEPTUAL FRAMEWORK**

The conceptual framework is a key part of a research design which consists of concepts, assumptions, expectations, beliefs and theories that support and informs someone's research (Miles & Huberman, 1994; Robson, 2011). The modified conceptual framework from Ospina and Heeks (2012) and Mtega and Msungu (2013) guided this study. The framework shows the role played by agriculture researchers from ARIs and the purpose of the ICTs developed in agriculture development. The framework also shows the role of ICTs in strengthening the local farming practices, transforming their agricultural production and therefore eradicating poverty through agriculture ICT-based solutions. The framework guided the study in examining how agriculture researchers are using the enablers or ICT tools available in the ARIs for their agriculture activities (Fig.2).

**Figure 2: The role of ICTs in improving agriculture productivity (Modified from Ospina and Heeks (2012); Mtega and Msungu (2013)).**



Agriculture researchers from ARIs are responsible to involve participatory in the development of ICT-based solutions for agriculture extension services and ICT for the farming community in general with the assistant of ICT experts. The developed ICTs from ARIs can facilitate agriculture knowledge and information sharing as well as increasing farmers' agriculture productivity. However, for ICTs to be effective, the required ICT infrastructure, network connectivity and the necessary skills to use different ICT tools should be available in ARIs (Ospina and Heeks, 2012). effectively use of ICTs can strengthen local farming practices and transform livelihoods of farmers and other actors (stakeholders) who are directly or indirectly involved in the agriculture value chain (Mtega and Msungu, 2013). By using this framework, we were able to develop a realistic and relevant research questions, select appropriate methods for the research, and identify potential validity in drawing our conclusions.

## 2.1 ICT Perspective in Improving Agriculture Productivity

The development of ICTs in ARIs has come to stay and its importance has been translated into huge potentials in terms of playing a key role not only in enhancing networking and sharing of knowledge and information, but also enhancing field data monitoring and gathering in agricultural research processes (Akpabio et al., 2007; Sarwatt and Mollel, 2010; Glendenning and Ficarelli (2012); Agu, 2013). ICTs are making it easier for ARIs to link with farmers in documenting, packaging and understanding their needs. In line with this, researchers from ARIs provide precise ICT applications and tools that meet farmer's needs (e.g. to monitor market prices, weather conditions, new pest control measures) and to provide such information in a form and format that the farmer can consume (Awuor et al., 2013). ICTs also make it possible to consult a much wider and more dispersed network of stakeholders such as farmer groups, technical experts, research professional, and policy makers. ICTs are making agricultural research more inclusive and at the same time more focused on development goals, because they change how, where and to whom information flow should be disseminated and communicated. Information can flow in many directions; it can be highly dispersed and accessible, and it can be highly targeted, location specific, and location aware (Ballantyne et al., 2010). ICTs have created more informal way of

communicating research outputs and offer new potential to the developing country institutions, national research centers and ARIs to participate in a worldwide digital knowledge economy (Kirsop et al., 2007). The role of ICTs is to contribute to different type of reforms that are urgently needed to empower and support small-scale farmers of developing countries (including Tanzania) who seek to respond successfully to food security, market development, and climate change challenges (Christoplos, 2010). ICTs tools such as digital soil maps provide extensive soil information that can be stored and accessed online. GPS, satellite imagery, remote sensors, and aerial images help to assess soil and land variations information which can be disseminated quickly using mobile applications and the Internet (Grasso, 2009). With this array of ICTs tools, precision farming can be employed to optimize crop and livestock management (Worldbank, 2011). Thus after soil data are collected, analyzed, and reflected in digital soil maps, results need to be shared with policy makers, scientists, and farmers, who would otherwise not have such detailed information on soil fertility in their respective farming communities.

ICT can be used to monitor pest thresholds in integrated pest management, provide relevant and timely information and agricultural services, map agro biodiversity in multiple-cropping systems, forecast disasters, and predicting yields (Bilange, 2013). Crop losses diminish as farmers receive relevant and timely information on pests and climate warnings through SMS technology (Bilange, 2013). ICT can also lead to more optimal use of farm inputs by increasing producers' knowledge on how to use and manage water, equipment, improved seed, fertilizer, and pesticide (Bilange, 2013; Khan, 2014). ICT can be used to match cultivars to appropriate environments, increase the understanding of genotype-by-environment interactions, and adapt cropping strategies to the changing climate (Worldbank, 2011; Bilange, 2013; Khan, 2014). Variable rate technologies (i.e. technologies that enable farmers to vary the rate of an input applied to a crop using components like computer, software, differential GPS receiver, and controller), GIS, GPS, satellite imagery, and other data collection technologies have increased the information available about soil health, weather conditions, and disease outbreaks, making very site-specific farming possible (Worldbank, 2011). The key to using these technologies for data analysis (i.e. data mining or mediation software) and information dissemination (i.e. mobile phones and radio) are essential to reach smallholders farmers effectively and boost their productivity (IICD, 2006; Worldbank, 2011). Dissemination and communication of agriculture knowledge and information also includes the crucial agriculture human component and extension agents and farmers themselves who must transmit and share knowledge. From this literature review, there is a need of doing situation analysis for ARIs found in Tanzania to fill the identified gaps in knowledge.

### **3. RESEARCH METHODOLOGY**

The study involved a mixed research approaches where by both random and non-random sampling techniques were employed in selecting the study area and participants.

#### **3.1 Study Area**

The study was conducted in twelve ARIs located in seven regions of Tanzania mainland. These regions includes: Morogoro, Dar Es Salaam, Tanga, Kilimanjaro, Mbeya, Mtwara and Arusha.

#### **3.2 Research Design**

A cross-sectional research design was employed and a structured questionnaire based on online survey tool was used for data collection. Before distributing questionnaire to respondents, the instrument was pre-tested by agriculture researchers working at Sokoine

University of Agriculture (SUA). The copies of questionnaire and interview's questions were sent to them in order to determine the ambiguity and relevance of the questions. The procedure was strategically adopted in order to ensure the matching of research questions and sample of respondents. In other meaning, to have a relevance of respondents towards addressing research objectives and research questions (Bryman, 2008). Agriculture researchers from SUA reported that, the questions were clear, unambiguous and relevant to the research being conducted. The instrument was then piloted and adjustments were made with the support of two academic researchers with expertise in survey study approaches and a particular emphasis and attention was given to overall structure of wording and presentation of the interview items. The final questionnaire was distributed from March to August 2014 using survey online tool to 64 agriculture researchers in the selected research institutes through their e-mails for data collection. The survey instrument consisted of structured and open questions to collect data about demographic characteristics of respondents, agriculture research activities conducted in Tanzania, ICT tools available, specialized ICT hardware and software available for agriculture research activities (experiments), ICTs for data collection, analysis and information management used by agriculture researchers in ARIs as well as challenges attributed to poor integration of ICTs in ARIs. However, the questions were designed and formulated from the conceptual framework as well as from the literature covered above. Questionnaires were based on online survey tool due to the fact that it was the cheapest and the easiest method to implement. The method was also chosen due to limited fund and time.

### 3.3 Study Population and Sampling Frame.

The study population consisted of agriculture researchers, agriculture managers and other agriculture professionals in the selected ARIs. Tanzania has seven agricultural zones, each with at least one agricultural research centers as shown in Table 1.

**Table 1: Tanzania Agricultural Zones with their research mandates**

Zone	Regions Covered	Zonal Centre	ARI	Research Mandate
CENTRAL	Dodoma, Singida	Mpwapwa	Hombolo, Makutupora	Sorghum, Millet and Grapes
EASTERN	Dar es Salaam, Pwani, Morogoro, Tanga	ARI-Ilonga	Ilonga, KATRIN, Cholima/Dakawa, Mlingano, Kibaha, Mikocheni	Maize, rice, sorghum and millet, grainlegumes, horticulture, soil and water management, horticulture, sugarcane, root and tubers, spices, coconut, biotechnology
LAKE	Kagera, Mwanza, Shinyanga, Mara	ARI-Ukiriguru	Ukiriguru, Maruku	Phaseolus Beans, Grain legumes, Root and Tubers, sorghum and millets, rice, bananas,
NORTHERN	Kilimanjaro, Arusha, Manyara	ARI-Selian	Selian, Hort-Tengeru	Wheat and Barley, Bananas, Horticulture, Maize, Phaseolus beans, irish potatoes, sweet potatoes
SOUTHERN	Mtwara, Lindi	ARI-Naliendele	Naliendele	Cashewnut, Oilseeds, cassava

SOUTHERN HIGHLANDS	Mbeya, Iringa, Rukwa, Ruvuma	ARI-Uyole	Uyole, Kifyulilo	Maize, Phaseolus beans, wheat, pyrethrum, horticulture, rice, irish potatoes
WESTERN	Tabora, Kigoma	ARI-Tumbi	Tumbi, Seatondale	Agroforestry

**Source:** Directorate of Research and Training, Ministry of Agriculture, Food Security and Cooperatives (MAFSC)

Non-probability sampling technique (purposive sampling) was employed in selecting twelve ARIs from the list of ARIs found in Tanzania. Purposive sampling was used because it ensures balancing of group sizes when multiple groups are to be selected and deliberate selection of sample units that conform to some predetermined criteria, based on the judgment of the researcher (Black, 1999). However, the selection of these ARIs considered those that has official websites and could be able to contact a number of researchers during data collection. A total of 64 agriculture researchers in the research institutes were selected for this study. The list of the selected ARIs and the number of researchers is shown in Table 2.

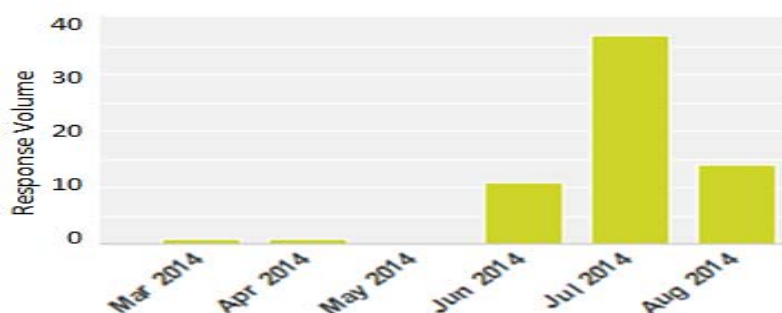
**Table 2: A List of Selected ARIs for this Study**

No	Agricultural Research Institutes	N	%	Region
1	Ilonga Research Institute	5	7.8	Morogoro
2	Tobacco Research Institute of Tanzania (TORITA)	5	7.8	Morogoro
3	Mikocheni Agricultural Research Institute	3	4.7	Dar es Salaam
4	Chollima Agro-Scientific Research Centre (DAKAWA)	1	1.6	Morogoro
5	Mlingano Agriculture Research Institute (MARI)	6	9.4	Tanga
6	Tea Research Institute of Tanzania (TRIT)	6	9.4	Tanga
7	Tanzania Pesticide Research Institute (TAFORI)	7	10.9	Morogoro
8	Tanzania Coffee Research Institute (TaCRI)	5	7.8	Kilimanjaro
9	Naliendele Agriculture Research Institute (NARI)	9	14.0	Mtwara
10	Agriculture Research Institute KATRIN (IFAKARA)	10	15.6	Morogoro
11	Tengeru Agriculture Research Institute (TARI)	4	6.3	Arusha
12	Uyole Agriculture Research Institute	3	4.7	Mbeya

### 3.4 Duration

This research was conducted from March to August 2014. Figure 3 shows the response volume of respondents during data collection.

**Figure 3: Response Volume of Respondents from March to August 2014**





### **3.5 Data Collection**

#### **3.5.1 Primary Data**

Primary data was collected through interviews and questionnaires distributed online using survey tool. Questionnaires were used to collect data from respondents in the selected ARIs. The qualitative information required was obtained from in-depth telephonic interviews from 5 agriculture field officers, 8 agriculture managers and 20 agriculture researchers in the selected ARIs. The interviews were conducted purposively to identify the factors which affect the availability and effective utilization of ICT tools by agricultural researchers and technologists in their ARIs.

#### **3.5.2 Secondary data**

Secondary data were collected by using other data collection research methods from sources such as research reports from ARIs, data from the Ministry of Agriculture Food Security and Cooperative, seminar papers, articles from journals and conference proceedings and the Internet. The use of questionnaires, interviews and other relevant literature provided the grounds for thorough comparisons of the data and assisted in looking for validity and reliability of study findings.

### **3.6 Data Analysis**

The analysis of the quantitative information, applied the descriptive statistics tools such as percentages, frequencies, and graphical representation. In testing association between innovativeness and ICT adoption, cross-tabulation was used. For qualitative data, pattern matching technique was used where the information collected was arranged in groups with similar meanings. However, in drawing conclusions, emerging patterns was matched and analyzed. This is the advantage of the mixed research methods used in this study which allowed triangulation of research findings.

## **4. Results and Discussion**

After data analysis and using our research framework, we were able to identify and present respondents' social-economic characteristics such as sex, age, education, years of their research experience, employment status and their research area of specialization. The next step was to present how agriculture researchers from ARIs are using ICTs which was investigated through their research activities. We then presented the ICTs available in ARIs and finally presented the challenges hindering integration of ICTs in ARIs before concluding our remarks.

### **4.1 Characteristics of Respondents**

Results in Table 3 indicates that 60.94% (39) were males agriculture researchers and 39.06%(25) were females which shows that males are more dominant in agriculture research activities than females. 65.62%(42) had age distribution ranging from 21-40 years with majority of them having completed MSc. degrees i.e. 45.31%(29) as the highest level of education which indicates a high level of literacy among agriculture researchers. Agwu and Chah (2007) argue that for ICT utilization, elderly people are less interested in the use of hi-tech ICT devices for research activities. However, 50%(32) had 1 to 7 years of research experience and 62.50%(40) of the respondents being employed permanently in their ARIs. This research experience indicates high accumulation of agriculture research knowledge and skill, which has a significant impact on the utilization of agricultural technologies.

Table 3: Demographic characteristics of respondents (N=64)

S/N Item	Gender	N	Percentage (%)
<b>1. Sex</b>	Males	39	60.94
	Females	25	39.06
<b>2. Age in years</b>	21-40	42	65.62
	41-50	13	20.31
	51-60	6	9.38
	>60	3	4.69
<b>3. Highest Level of Education completed</b>	Diploma	6	9.38
	Bachelors	21	32.81
	Masters	29	45.31
	Phd	8	12.50
<b>4. Years of Research experience</b>	1-7	32	50.00
	8-14	19	29.69
	15-21	6	9.38
	22-30	6	9.38
	>30	1	1.56
<b>5. Employment Status</b>	Permanent	40	62.50
	Contract	19	29.69
	Visiting	5	7.81

#### 4.2 Agriculture Research Activities Conducted in Tanzania

Table 4 shows different agriculture research activities conducted in the selected ARIs as teaching, research and outreach sites. Results indicates that researchers are confined in farming system and extension with 50.57%(32) followed by crop and soil science management with 39.68(25) and food science & technology with 8.10%(23). This results is in line with the National Agriculture Policy (2013) goals and other public-private partnership initiatives by the Government of Tanzania which aim to enhance crop productivity and profitability in a sustainable manner in order to ensure food security and poverty reduction. In addition, results also indicate that Tanzania through ARIs is committed to strengthen pest and disease surveillance as well as to provide system and control mechanisms in agriculture activities (URT, 2013). However, the results show that ARIs are diversified into different areas of agriculture research activities in order to complement their major mandate which were established to undertake.

**Table 4: Research Activities Conducted by Agricultural Researchers in Tanzania**

S/N Research Activities	N	Mean
1. Agronomy	13	20.63
2. Food Science & Technology	24	38.10
3. Plant Protection and Pathology	21	36.51
4. Forest Conservation and Management	18	28.57
5. Farming system and Extension	32	50.57
6. Food Quality and Control	18	28.57
7. Crop and Soil Science management	25	39.68
8. Agriculture engineering and pest management	23	36.51

### 4.3 ICT Tools Available in the ARIs

Table 5 shows ICT tools availability in the ARIs under this study. Results indicate that basic ICTs are available in ARIs. The range of devices are as follows: Video recorder 70.69%(41), Digital Camera 66.10%(39), Computer 61.67%(37), Internet 63.93%(39), GIS 73.12%(41) and Remote Sensing 72.22%(39). These devices have high rating indicating that are most widely used by researchers in their daily agriculture research activities.

**Table 5: Level of ICT tools availability in ARIs**

S/N Item	Available in the Institute % (N)	Personally available % (N)	Not Available % (N)	Total	Average rating
1. Remote Sensing	72.22(39)	7.41(4)	20.37(11)	54	2.52
2. Video recorder	70.69(41)	20.69(12)	8.62(5)	58	2.62
3. Digital Camera	66.10(39)	28.81(17)	5.08(3)	59	2.61
4. Computer	61.67(37)	36.67(22)	1.67(1)	60	2.60
5. Internet	63.93(39)	32.79(20)	3.28(2)	61	2.61
6. GIS	73.12(41)	12.5(7)	14.298	56	2.59
7. GPS	68.97(40)	5.17(3)	25.86(15)	58	2.43
8. International Online databases (e.g. EBSCO, AGORA)	64.15(34)	9.43(5)	26.42(14)	53	2.38
9. Local Online database (e.g. Tanzania online)	74.07(40)	5.56(3)	20.37(11)	54	2.54
10. CDROM (TEEAL, Agricola, CAB Abstracts, Silver plate)	75.44(43)	8.77(5)	15.79(9)	57	2.60

These research activities are related to documentation and recording of research events, farm field monitoring and developing geographical information on research area location using GPS/GIS. Results indicate the presence of international online databases tools like AGORA (Access to Global Online Research in Agriculture) which provides free or very low-cost access to 2,400 journals on food, agriculture, and related sciences to institutions in 107 countries including Tanzania and TEEAL (The Essential Electronic Agricultural Library) which provides a package of content that institutions can run on their own networks

(Worldbank, 2011). However, through telephonic interviews which lasted for 20-25 minutes, 24 out of 33 respondents who were interviewed argued that, the access to these journals is very limited due to unreliable and poor connectivity of the Internet and frequent power cuts in their ARIs.

The results also indicates that 75.44% (43) of agriculture researcher agreed to have CD-ROMs in their ARIs, 15.79%(9) are not available in their institutes while 8.77%(5) have their own CD-ROM. However, when questioned the effective utilization of those CD-ROMs through interviews, the majority responded that, most of the available CD-ROMs were out of date and even, the few up to date CD-ROMs available in their institutes becomes difficult to use them because of low emphasis and lack of training on how to use them. This result is in line with Angello and Wema(2010) who reported that researchers did not use the e-resources available in their institutes because of neither being sensitized nor trained on the availability and use of the e-resources. Despite the availability of computer in these ARIs but through interviews, agricultural researchers said that there was no common computer laboratory and only few agricultural experimental laboratories are available in the institutes. 36.67 %(22) researchers acknowledged using mostly their personal available computers like laptop.

#### **4.4 Specialized ICT Hardware Devices Available for Agriculture Research Activities (Experiments) in ARIs.**

The agricultural sector is confronted with the major challenges including: water shortages, declining soil fertility, effects of climate change and rapid decrease of fertile agricultural lands due to urbanization, drought, erosion and pests (Stienen, *et al.*, 2007; Awuor *et.al*, 2013). Key improvements in farming systems could stem from information about pest and disease control, especially digital early warning systems, ICTs to measure soil properties for creating digital soil maps, new varieties, new ways to thresh and clean plot samples in order to optimize production and regulations for quality control (Stienen, *et al.*,2007). Exploring the presence of these experimental devices in ARIs is of vital importance because agriculture researchers are key users of these ICTs in their daily research for enhancing agriculture productivity (Sanga *et al.* 2013a).

Table 6 shows the ICT devices available for experimental researches in the ARIs. Results indicate that many specialized hardware devices are not available in ARIs for agriculture research activities and some of researchers did not know a number of useful agriculture hardware for their research activities. However, among few devices available in the selected institutes includes: moisture content analyzer (46.3%), digital early warning network (39.3%), digital soil thermometer (61%), field sensor (49.1%) and digital PH meter (39%). Despite the presence of these devices in the ARIs, one of the senior agriculture researcher officer through interview stressed that, the devices like PH meter and soil thermometer are not digital and the available devices are inadequate in number. The results also indicates that agriculture research activities are most confined in determining soil properties like acidity and alkalinity, to measure and analyze moisture content in order to determine how crops can be handled for processing and storage. Results also indicates that, the digital early warning network is also used by researchers and it was reported that, in Tanzania's lake zone, farmers from 10 districts who participated in the digital early warning network have been trained to recognize symptoms of cassava mosaic disease and cassava brown streak disease (Worldbank, 2011).

**Table 6: Experimental ICT Hardware Devices Available in ARIs.**

S/N ICT device	Available in the Institute % (N)	NA % (N)	I don't know the device%(N)	Total	Average rating
1. Single Earhead Thresher	35(21)	50(30)	15(9)	60	2.20
2. Multicrop Plot thresher	23.6(13)	61.8(34)	14.5(8)	55	2.09
3.Digital Balance	38(21)	49.1(27)	12.7(7)	55	2.25
4.Digital Microscope	30.9(17)	54.5(30)	14.5(8)	55	2.16
5.Precision Plot drill	13.0(7)	59.3(32)	27.8(15)	54	1.85
6.Digital PH meter	39.0(23)	40.7(24)	20.3(12)	59	2.19
7.Digital Vernier Caliper	30.9(17)	50.9(28)	18.2(10)	55	2.13
8.Moisture Content Analyzer	46.3(25)	33.3(18)	20.4(11)	54	2.26
9.Photo Spectrometer	39.3(22)	46.4(26)	14.3(8)	56	2.25
10.Digital Early Network	39.3(22)	41.1(23)	19.6(11)	56	2.20
11.Digital Soil Thermometer	61(36)	27.1(16)	11.9(7)	59	2.49
12.Field Sensor	49.1(28)	35.1(20)	15.8(9)	57	2.33

Despite the potential of different ICTs in agriculture research in ARIs in Tanzania, this results indicates that, the use of these tools have not taken a great recognition in agriculture activities which may be because of low investment of ICTs in ARIs.

#### **4.5 ICTs for Data Collection, Analysis and Information Management Used by Agriculture Researchers in ARIs**

ICT is widely used to collect data and data visualization with the choice of technology depending on the kind of data needed. Surveys can be administered electronically and researchers can interact and collaborate with each other using web 2.0 tools. Information from online research collaboration can be recorded and analyzed using a variety of ICT tools (Worldbank, 2011). Table 7 shows that a wide range of ICTs are available in the selected ARIs for data analysis and visualization. The data analysis tools are rated higher with 96.08% followed by data visualization software with 78.43% and Web 2.0(72.55%) tools which enhance collaborations among researchers in their agriculture research activities. According to literature survey, example of the most innovative uses of ICT in agriculture for data analysis are in modeling, simulation, visualization, and cloud computing (do Prado, Luiz and Filho, 2010; Li and Zhao, 2010; Hori, Kawashima and Yamazaki, 2010). ICTs are vital for developing models of crop performance in environments where yields are reduced by climate stress and increasing climatic variability (Sanga, Sumari and Tumbo, 2013). Such models offer an important means of evaluating the potential for new cultivars to adapt to climate stress and climate change and to assess food import needs and export potential.

**Table 7: ICTs Used for Data Collection, Analysis and Information Management in ARIs.**

S/N ICT device	Available in the Institute % (N)	NA % (N)	I don't know the device % (N)	Total	Average rating
1. Data Visualization Software(Arc GIS,ArcView)	78.43(40)	11.76(6)	9.8(5)	51	2.69
2. Data Analysis Software(SPSS,SAS)	96.08(49)	0.00(0)	3.92(2)	50	2.92
3.Herbanium Management System	52(26)	34(17)	14(7)	50	2.38
4.Seed Variety Software	56(28)	30(15)	14(8)	50	2.42
5.Remote Sensing	54(72)	30(15)	16(8)	50	2.38
6.Web 2.0	72.55(37)	23.53(12)	3.92(2)	51	2.69

However, a total of 32 respondents (Table 7) under this study were not aware with some of the tools like seed variety software, herbarium management system, remote sensing and highlighted that, they never used such software for their agriculture research activities. The availability of data analysis and visualization software implies that agriculture research activities in the selected ARIs are data oriented and there is a need for data analysis to be generated from experimental research.

#### 4.6 Challenges Affecting the Integration and Effective Use of ICTs in ARIs

Despite the commitment by the Government of Tanzania in partnerships with other NGOs and private sectors through different policies and initiatives to increase agriculture productivity through ARIs, the agriculture research system particularly in the ARIs is faced with a number of challenges. Agriculture researchers and agriculture managers pointed out a number of challenges that attribute to poor integration and effective use of ICT tools in ARIs. Respondents under this study were also able to identify some challenges inhibiting the ICTs implementations in the selected ARIs. The following are the challenges hindering ICT integration, implementations and effective use of ICTs in ARIs which were given by respondents:

- a) Inadequate computers and supporting technological infrastructure
  - Lack of electricity needed to operate computers due to power cuts and unreliable Internet connectivity.
- b) Trained human resource with computer use and research information management skills within the ARIs are few
  - Major problem in Tanzania and most of the ARIs cannot retain competent and skilled staffs who are attracted to better career prospects in the private sector.
- c) There is lack of systematic ICTs investment by ARIs and their funders
  - This is attributed due to low budget allocation for the ICT infrastructure by the Government.
- d) Limited laboratories to conduct agriculture research experiments related to ICT4A.
  - Lack of skilled personnel among agriculture researchers to use some ICTs tools for agriculture research activities due to limited training conducted in the ARIs.
- e) Low coordination among stakeholders in the agricultural research system due to institutional diversity and department fragmentation.
- f) Lack of an institutionalized network among institutes and the apex body which is supposed to formulate and conduct the process of ICTs integration in ARIs.

- g) Poor ICT strategies and inefficiency of the current institutional structures, arrangement and management in the agricultural research system in Tanzania hinders the effective integration of ICTs in ARIs.
- h) Lack of collective archives and accessible online institutional research information repositories as much of the data from field trials in the visited institutes resided on the shelves of research institutes.
- i) Lack of incentives in the ARIs to undertake individual ICT-enabled research that deviates from traditional paths and uses newer ICTs for agricultural research.
- j) Ineffective communication channels for publishing research output.
  - This is because of low funding and other factors attributed to low staff morale, and narrow opportunities for their professional growth.
- k) Lack of appropriate ICT policies and standards for monitoring, evaluating and assessing the potential of institutionalizing the ICT integrations in ARIs in terms of agriculture infrastructure, telecommunications, hardware and software, on-line services, connectivity, security, content management and professional capacity.
- l) Lack of commitment and accountability of policy-makers and agriculture managers who can develop the ICT capacities in ARIs.
  - This is due to weakness in monitoring and nurturing the sustainability of few existing ICT investments.

## 5. CONCLUSIONS AND FUTURE WORK

This study intended to explore the availability of ICTs in ARIs and how agriculture researchers utilize effectively a wide range of ICT tools related to crop variety, land use, soil health, soil nutrients requirement, irrigation, weather report, awareness about crops, pollution control, pest and disease control and new farming techniques. The study also intended to assess challenges which hinder the integration and effective use of ICTs in ARIs.

The results indicate that ICT tools like GPS, GIS and Internet and Digital Cameras are available in ARIs for the day to day agriculture activities. However, utilization of agriculture journals is very limited due to unreliable and poor connectivity of the Internet and frequent power cuts in ARIs. Results also show that the uses of specialized ICT hardware devices have not taken a great recognition in agriculture activities which is attributed by low investment of ICTs in all institutes for agriculture productivity. Most of the institutes indicated to have data analysis and visualization software which implies that agriculture research activities in the selected ARIs are data oriented and there is a need for data analysis to be generated from experimental research. The results from this study matches some of the results found by Ojesanmi et al., (2014) in their analysis of integrating ICTs in ARIs and the needs for research development in southwest zone of Nigeria.

Among the challenges hindering ICT integration, implementations and effective use of ICTs in ARIs includes: inadequate computers and supporting technological infrastructure, lack of electricity needed to operate computers due to power cuts, unreliable Internet connectivity; lack of systematic ICTs investment portfolio in ARIs; poor coordination of different stakeholders in agricultural research system; poor strategies; lack of collective and accessible online institutional research information repositories; limited experimental laboratories to conduct agriculture research experiments and lack of skills among agriculture researchers to use some ICT tools for agriculture research activities due to limited training conducted in the ARIs.

In order to have effective use of ICTs in ARIs, this study recommends the following: ARIs should have strategies to ensure 24 hours -7 days access to the Internet with no power cuts; the Government of Tanzania should implement projects aiming at financing the procurement of specialized ICT tools in ARIs for agricultural research activities, this should

match with strengthening and improving capacity building and provide seminars and training; formulate conceptual frameworks related to ICT use and Information and Communication Management (ICM) in ARIs; develop agriculture strategic policies and its master plan for ICTs integration in agricultural research system to a national level. Continuous training on technical know-how and the exchange of information is a must and should be maintained by realization of the opportunities afforded by ICTs in agriculture productivity (Koutsouris, 2006; Stienen, *et al.*, 2007).

### **5.1 Study Limitations and Directions for Future Research**

This study was limited to exploring ICT tools availability and how agriculture researchers are using ICTs in the ARIs. Although ARIs play a major role in developing, testing, researching and scaling up ICT-based solutions for agriculture productivity and are very central in the agriculture sector, other major agriculture stakeholders like farmers, agriculture extension officers as well as private sectors involved in the agriculture development context need to be involved in future research for much investigation and deeper understanding of ICTs impact in different agriculture value chains development. However, a more realistic model of technology transfer to farmers and a cross-section approach to agricultural information is what brings a successful integration of ICTs in ARIs and adoption of agriculture technologies in the farming community. This realistic model and cross-section approach needs an improved awareness to all actors in the agriculture value chain (agriculture researchers, agriculture extension workers and farmers). Future study need to focus in identifying the extent agriculture researchers participate with farmers in developing agriculture technologies related to ICTs with the inputs from farmers themselves using participatory approaches like Farmer Participatory Research (FPR) (Ashby, 1987; Selener, 2007), Participatory Learning and Action Research (PLAR) (WARDA, 2007), Participatory Communication (PC) (Selener, 2007), Participatory Information and Communication Technology Development (PICTD) and Participatory Video (PV)(Yoon, 2007; Gadhi *et al.*, 2007).

### **5.2 Limitations in Research Methods**

This study used limited online survey and telephonic interview methods. The survey was meant to generate a bird's eye view of agriculture researchers on the research questions (Appendix A) which were complemented with a more comprehensive telephonic interviews. Time and resource constraints were the main reasons for such a restricted study sample size. Therefore, another area for future research will use a larger sample size that will be more representative and also using other research methods like focused group discussions and researchers observations. Therefore, the current research serves as a pilot and foundation for suggested future studies.

However, this study contributes to the deepening of theoretical understanding of the current availability and utilization as well as challenges of integrating ICTs in ARIs in Tanzania. The analytical generalizations which can be drawn from this study's contribution are in the field of agricultural informatics which is of great importance in improving research capability of ARIs as well as socio-economic transformation of farmers through improved communication of agriculture research knowledge.

### **ACKNOWLEDGMENTS**

We would like to convey our sincere thanks to Mr. Peter Matata, a Senior Agricultural Research Officer at Tumbi Agricultural Research Institute and Mr. Damian Mtenga from Tanzania Coffee Research Institutes (TaCRI) for providing valuable contributions in this research. Many thanks to reviewers of this paper for their comments and suggestions, we appreciate your contributions.



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## APPENDIX A

1. What is the name of your Agricultural Research Institute (ARI)?
2. What is your sex?
  - a) Male b) Female
3. What is your age?
  - a) 21-30 b) 31-40 c) 41-50 d) Above 60
4. What is the highest level of education you have completed?
  - a) Diploma b) Bachelor's Degree c) Masters' Degree d) Phd
5. How many years of research experience do you have?
  - a) 1-7 b) 8-14 c) 15-21 d) 22-30 e) 31-40 f) More than 40 years
6. What is your research area of specialization in agriculture? (At least **ONE** )
  - a) Food science and Technology
  - b) Plant protection and pathology
  - c) Forest conservation and management
  - d) Farming system and extension
  - e) Food quality and control
  - f) Agriculture engineering

- g) Pest management
- h) Crop and soil management

7. What is your rank in doing research? i.e. Professor, research fellow etc
8. What are the specialized hardware devices available for agriculture research activities in your institute?

ICT tool	Available in the institute	Not available	I don't know this device
Single Earhead thresher			
Multicrop plot thresher			
Digital balance			
Digital Microscope			
Precision plot drill			
Digital Oven			
Digital PH Meter			
Digital Venier Caliper			
Moisture Content Analyzer			
Photo spectrometer			
Digital early network			
Digital soil thermometer			
Field Sensor			

9. What is the level of ICT tools availability for your daily agriculture research activities in your institute?

ICT tool	Available in the institute	Personally available	Not available in the institute
Remote Sensing			
Video recorder			
Digital Camera			
Computer			
Internet			
GIS			
GPS			
International online agriculture databse (e.g., EBSCO, AGORA)			
Local online agriculture database(e.g., Tanzania online)			
CD-ROM (e.g. TEEAL, Agricola, CAB Abstracts,			

10. What are the specialized ICT software available for agriculture research activities in your institute?

ICT tools	Available in the institute	Not available	I don't know this device
Data visualization software (Arc GIS, ArcView)			
Data analysis software (SPSS, SAS,)			
Cool Edit/ Dream Weaver			
Herbarium Management System			
Seed variety software			
Web 2.0			

11. Are there any training workshops or conferences conducted at your institution or anywhere in Tanzania regarding agriculture research activities using ICT?  
a) Yes b) NO
12. If the answer is "YES" in (11) above, how often are these training/conferences conducted?  
a) Weekly b) Monthly c) Once per year d) Once every two years
13. What are the challenges affecting the integration and effective use of ICTs in your agriculture research institutes and agriculture sector in general?
14. Do you develop ICT based solutions for agriculture related to crops, soil health, soil nutrients etc with inputs from farmers?
15. For many years, agriculture remains to be the economic backbone of Tanzania, what the government of Tanzania can do to improve the agricultural research activities in your institution and the agriculture sector in general?
16. How often do you use effectively ICT tools available in your institute like CD-ROMS etc for your research activities?