e-Agriculture revisited: A systematic Literature Review of Theories, Concept, practices, methods, and future trends

ABSTRACT

Agriculture is one of the dominant fields that shape the socioeconomic development of any country. Technological advancements and innovations served as tools to share knowledge and practices of agricultural activities and make better lives for farmers, traders, policy makers, and the overall society. It is evident that Knowledge has become a very important factor in production, food security, education, poverty alleviation, and other millennium development goals. This paper, points out the a gap on how the existing body of knowledge about e-agriculture is built in terms of research policies, theorization, methodological tools, success/failure, and future trends. Aiming to fill this gap, our paper offers a systematic review of the e-agriculture literature based on Heeks (2006) that help understanding the linkages between the needs assessment, adoption of ICT in agricutlrual value chains, outreach/limitations of ICT in agricultural, diffusion of e-agricutlrual applications, and the impact of these technological innovations on the society.

1. INTRODUCTION

This review tends to understanding the impact, limitations and potential of E-Agriculture in delivering agricultural and rural development (ARD) in developing or low income countries. This will be achieved through evaluating evidences from various literature concerning the need, adoption, usage, diffusion, extension and impact of e-agriculture solutions, technologies & innovations through a critical and systematic review of various literatures including both practitioner and academic sources.

Research Objectives:

The objectives of this study are:

- To provide some analysis of literature and also synthesis of research concerned with e-agriculture in developing countries based on needs & adoption, output & impact, diffusion & extension.
- To classify and also analyse the conceptual approaches for understanding e-agriculture as used in the literature obtained.
- To assess the methodologies that were used to conduct research studies in E-Agriculture from the literature obtained
- To Identify some key research trends and gaps relating to the methodologies, concepts, evidence presented, questions raised, issues addressed and to also provide an agenda for future research.

Research Questions:

The following are the research questions raised for the purpose of guidance, they are:

- What does the literature say concerning e-agriculture projects in developing countries based on needs & adoption, output & impact, diffusion & extension?
- What are the methodologies, conceptual approaches and how were they used in the literature obtained?

- What are the gaps, shortfalls, issues and questions raised from analysing the methods used in the various literature?
- What are the future trends of e-agriculture in developing countries?

Framing and Methodology:

Based on Heeks (2006), we framed our review into a system of e-agricultre deployment strategy, including needs assessment & adoption process, and impact evaluation. Then, we added an extra stage for system sustainability and foresight analysis. Within each stage, we mapped the theorization and methodological tools that have been used in the published peer reviewed journal articles.

The review is categorised according to these interconnected parameters in the life cycle model:

- *Adoption & Needs*: This aims to understand why the technology was adopted i.e what was the need i.e needs of the poor, needs of the society and also entails understanding the factors that either initiate or restrict the adoption of a technology in a region or country.
- *Diffusion & extension*: This aims to discuss how some technologies or practices have spread across to farmers in many regions.
- *Output & Impact*: The identification and measurement of the tangible costs and benefits of use of technology such as in the provision of transactions or information and the evaluation of broader productivity or welfare gains or threats that result from the application of technologies and sustainable impact.
- *Sustainability and Foresight analysis*: This stage covers the future trends and the expected outcomes of e-agriculture initiative witin five years of full implementation. It draws scenarios of potential challenges and benefits to be recognised in the future.

In terms of methodological audit, we followed a variety of quantitative, qualitative, and mixed methods used along different stages of the e-agriculture lifecycle that is discussed above.

- Quantitative studies - These will include research articles which depend on survey instruments, field experiments or studies that analyse secondary data.
- Qualitative studies - These encompass the research articles which build case studies from various regions.
- Some studies with mixed methodology will also be included for the research.
- Studies with Experiments or conceptual approaches

Orginality and Contribution:

Our systematic literature review contributed to the rising needs to build research knowledge and draw research ploicies and trends for ICTD studies. Our attempt complements other attempts in m-finance (Duncombe, 2012), and in automated agriculture Aker (2011), and ICT at the Base of the Pyramid (Mohamad et.al, 2015). Alltogether, serve the wider academic argument of how we can make better lives using ICTs (Walsham, 2012).

Paper Outline:
Following the introduction section, this paper explains the initial selection and screening of the literature. Then it demonstrated the relevant studies that covered different stages of e-agriculture lifecycle and builds a systematic insight of key concepts and processes at each stage. Later, a detailed analysis of theories and methods is provided to draw future trends and research policies that can be followed by ICTD researchers and professionals.

2. SYSTEMATIC LITERATURE REVIEW: A DISCUSSION

Based on Heeks (2006), we framed our review into a system of e-agricultre deployment strategy, including needs assessment & adoption process, and impact evaluation. Then, we added an extra stage for system sustainability and foresight analysis. Within each stage, we mapped the theorization and methodological tools that have been used in the published peer reviewed journal articles.

As shown in Table 1, we followed a historical selection journal papers addressing the e-agriculture in a variety of developing contexts. In doing so, we searched the top 5 ICTD journals according to their citation records that is listed in Appendix 1.

Table 1: Historical Selection of e-agriculture papers in top ICTD Journals

Year	No of articles	Country
2005	1	Tanzania
2008	1	Sri Lanka
2009	5	North Africa, Sub-Sahran Africa, and Malaysia
2010	2	India, Bangladesh
2011	5	India, Uganda, Tanzania
2012	4	Kenya, India
2013	1	Brazile, Thailand
2015	6	Ethiopia, India, Congo, and Nigeria
Total	25	-

2.1. Systemic Review of E-Agriculture Lifecycle

2.1.1. Adoption & Needs:

Singhal et.al (2011), discusses the use of a mobile-based android application known as '*Krishi Ville'* that was designed to supply farmers with information such as weather forecasts, agricultural commodities and agricultural news. Singhal and his team perceive agriculture as mean of livelihood for almost two thirds of the population in India and it has also been the most important sector for India as it contributes close to 20% of India's GDP. Indian farmers of which the majority are small scale farmers are often unable to gain access to valuable information that could help them to increase their lead and also help to better the prices of their produce. Mobile phones have become essential devices for everyone regardless of age

groups and android has also been the most popular operating system of choice for a large population of people in the world with a large install base. Therefore, the researchers thought of using these technologies to solve the problem of farmers in the region.

However, such technological advances often fails to meet the needs for agricultural activities due to a number of socio-political factors such as regulatory frameworks, Government control, lack of awareness and relevant financial support (Gupta, 2012). The Indian farmers, for instance, rely on governmental loans and money sharks to afford automating their agricultural activities. Though, employing cheap labour found to be their preference against using expensive technological advances that are difficult to sustain.

Another remark in ICT adoption, is the development of "*Ethiopia commodity exchange (ECX)"* as an agricultural information system that disseminates market information to small scale farmers and other market actors through a mobile based Market Information System (MKIS) in Ethiopia (Alemu & Negash, 2015). This platform supply farmers and traders from the region with real-time information about the corps supply and demand, market prices, and auctions. In doing so, it makes market transactions more transparent, fair trading price, and allows farmers to better decide their cropping patterns to meet market demands. However, the number of users who adopt such technologies was relatively low and the researchers seemed it fit to conduct a study in order to find out the factors that affect the adoption and use of such technologies. Alemu & Negash collected their evidence using a closed-ended questionnaire distributed to a stratified sample of stakeholder groups who use MKIS. This questionnaire was designed based on a well known model called "*the unified tertiary acceptance and use of technology (UTAT)*". The questionnaire included 35 questions devided into two sections and eight constructs such as performance, intention to use, motivation, and demographic information. The participants were farmers and traders in ECX which included small scale farmers, merchants, brokers and import-exporters who trade using MKIS. Out of 110 distributed questionnaires 93 were returned and a Partial Least Square (PLS) was used to analyse the data. The results obtained from the study indicated that performance expectancy, social influence and facilitating conditions were the most significant constructs on behaviour intention to adopt MKIS and the study also revealed the influence of moderator variables on the main constructs towards usage and intention behaviour of MKIS in context of agricultural commodity exchange. The study was in line with similar studies and validates UTAT model in context of agricultural commodity exchange in low income country.

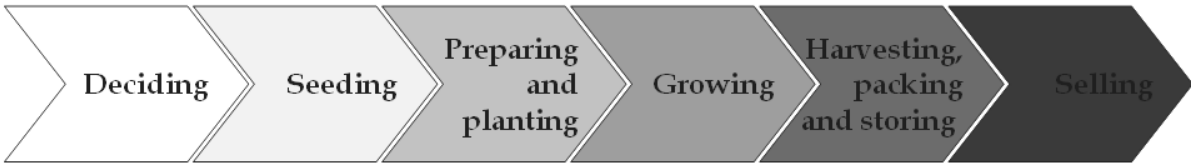
Matous et.al (2013) addressed the socio-political factors that affect e-agriculture adoption in Ethiopia and its ecosystem. Factors such as high taxation rates, poor infrastructure and land policies were found significant and negatively affect the expected yields of automation and digitalised agricultural initiatives. The study also emphasised on the role of NGOs to facilitate successful adoption of initiative and rebalance the dominant power of governments and private corporations who usually manage such projects in either political or financial terms.

Biswas & Prakash (2015) also proposed an agricultural based "*sensorics and indicative system technology*" for the Indian region, the system was designed to read soil moisture levels, standing water levels, PH levels of soil, Humidity & temperature. The technology was adopted to provide farmers in the region with a cheaper but smarter farm managing utility.
In the developed countries there are better established supportive systems to farmers through supportive banks, government subsidies and private investors. Therefore, developed countries are more likely to have automated and capital intensive farming leading to more yields, while

in developing countries such as India the capital supportive system is less developed. Farmers have little capital of their own, borrowing is difficult and incurs high interest rates thus farming is labour intensive (Kobby, 2015)

De Silva & Ratnadiwakara (2008) is one of the most cited papers in field that documented the adoption of ICTs in Sri Lankaian agricultural initiative. Farmer seemed to be motivated toward the efficiency of using payment platforms suc as PayPal to conduct agricultural transaction. They aslo used logitstic and e-commerce websites to reduce their cost and shorten the lead time along the agriculture value chain (See Figure 1). The aim of adopting the technology was to enable a reduction in transaction costs in agriculture. Along the value chain various stakeholders get involved from farmers to wholesalers to processors to supermarkets or exporters etc. The researches were limited to the segment from the decision to plant and ending at the sale of production. Their fieldwork was also restricted to a group of smal-holder vegetable farmers in rural Sri Lanka were used to identify and measure unobservable transaction costs dealing with information search. The logical starting point in understanding the total information related transaction costs faced by the farmer is to understand the demand for information at each point of exchange by disaggregating the agricultural value chain to a series of activities.

Figure 1: Agricultural Value Chain



Adopted from De Silva & Ratnadiwakara (2008; p10)

A questionnaire survey was distributed to a random sample of farmers. The selected farmers had the option of growing a variety of vegetable crops and also being able to sell at Sri lanka's primary wholesale produce market or smaller local markets in the same geographic region as the farmers. 10 farmer associations out of 89 were selected then from each association at least 30 farmers were chosen who grew the following crops in the previous season Tomato, onion, eggplant and chili. Measures were taken to ensure that there was an even distribution of the farmers of all the crops.

It is estimated that at least 8000 farmers belong to each association. The study revealed there was possibility of dramatic reduction of transaction costs when ICT is used to reduce information search costs to enable a greater participation of farmers in commercial agriculture as opposed to subsistence farming which forces farmers in the developing countries into poverty.

According to the Worldbank Sri Lankan agriculture is affected by Civil conflicts, tsunami, weak strategies, policies and the Government's poor delivery of services in the rural areas where there are many farmers whom engage in subsistence farming and rely on government support to improve their farming. Nevertheless, the country has benefitted from some initiatives by the department of agriculture for extension education and the world bank in 2016 has approved $125 million credit which is meant to assist the Sri Lankan agricultural

sector to become more efficient, attractive and modern. The project beneficiaries will include 50,000 farming households who will benefit directly from the project's grant program, technical & business training. (Worldbank, 2016)

With the implementation of various innovative solutions especially mobile based information systems in economic activities such as agriculture Gichamba & Lukandu (2012) did a case study in Kenya about frameworks for developing mobile agricultural solutions that designers and developers use to create solutions. The research looked at how various agricultural mobile systems were implemented. Agriculture is one of the key economic activities of the people in Kenya as is the case in most African countries, the most active agricultural activity in Kenya is dairy farming. Despite the fact that agriculture is one of the backbone economic activities in Africa, many farmers encounter problems such as effective ways to record farm input expenses, farm produce data, tracking expenditure on farm chemicals & livestock medicals, receive information from various stakeholders. All the stated problems can be solved using technology such as mobile phone solutions. The methodology for the study was documentary exploration, observation, questionnaires and field interviews, purposive sampling was used for selecting participants. Data was obtained from 150 farmers using questionnaires, 2 agricultural officers, 4 milk processors, 10 veterinary officers and 2 agro-veterinary dealers using interviews. Bodies such as the Ministry of agriculture, Kenya dairy board and communications commission of Kenya were also used to obtain information on agriculture and mobile technology. The questionnaires included 15 questions with both open and closed ended questions and the answers were analysed using statistical package for social sciences (SPSS) after that data cleaning, descriptive analysis and cross tabulation were done to identify inconsistencies, associations among variables. Results showed that 96% of the interviewees had mobile phones and other participants all had phones which showed 100% penetration. However, the results also showed a wide variety of mobile phone brands and models (See Table 2):

Table 2: Brands of Mobile Phones used e-agriculture inititative in Kenya

Brand	**%**
Nokia	56.3
Motorola	17.0
Samsung	15.0
Ericsson	5.5
ZTE	2.3
LG	2.3
MI	2.3
Dorado	4.7
IPhone	0.8
Bird	0.8

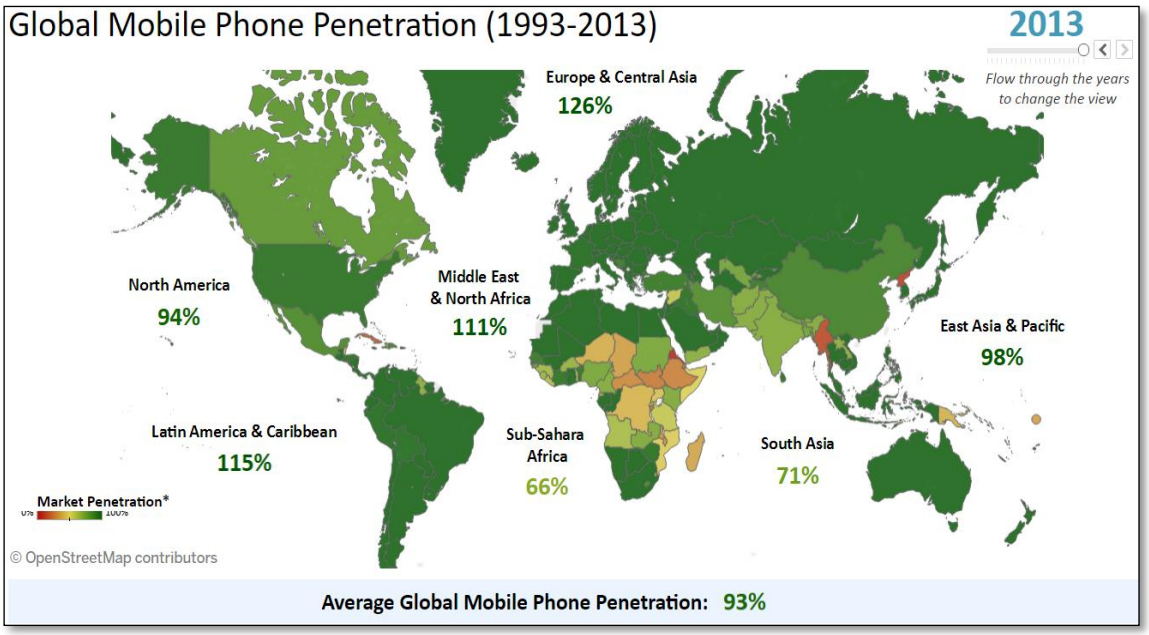
Adopted from Gichamba & Lukandu (2012; p2)

Another variable obtained from the result is the network failure rate which showed 61% of the respondents' network hardly fails while 17% showed failure once per month, 8% said failure happens once per week or per 2weeks and 6% said their network fail daily which shows that majority of the service providers in the country have implemented measures that facilitate the deployment of mobile solutions. Additionally, 54 % of the mobile phones had

internet access while 46% of the mobile phones are not data capable which means if a mobile solution is to be designed for this group it needs to use other means of communication such as SMS since it has no internet capability. 51 % of the mobile phones were java enabled while 49% were not. After obtaining the information needs from the field study conducted, the proposed mobile agriculture architecture was designed to accommodate the stakeholders in the dairy industry, whose needs were identified in this research. The model offers an interaction platform between the farmer and other key stakeholders of the dairy industry, (e.g. the milk processor, the veterinary doctor, the agricultural officer and the government). Each of the involved entities in the architecture needs to use a mobile equipment to communicate with the core system via a mobile telecommunication network.

Although the Kenyan Government has made efforts towards revitalising Agriculture over a decade ago the country still faces challenges in the sector. Conflicts, ethno-linguistic fragmentation & ethno based politics, inequality has affected the region. If the Government in Kenya improves the telecommunications sector it will greatly improve the adoption and development of solutions that will utilize the technology (Poulton & Kanyinga, 2014).

Figure 2: Data showing mobile phone penetration over the years worldwide



Adopted from Cartesian (2015; p12)

2.1.2. Extension & Diffusion:

According to Abdulai & Huffman (2005), various literatures show that the diffusion of agricultural technologies vary significantly along time and space and it is puzzling why some very profitable agricultural technologies are not adopted especially in livestock farming. The authors further explained that although, research institutions have made exciting scientific discoveries and also developed new technologies for farmers in developing countries the adoption of such technologies have been rather stalemate and incomplete. The researchers

went on to explain the diffusion of cross-bred cow technology through a unique sample of farmers in Tanzania. The objective of the study was to develop a farm-level model of the long-term adoption rate for crossbred-cow technology, using a hazard function or duration model to describe the new dataset collected specifically to test the model, and to also report new empirical results. A survey using a questionnaire was carried out on 406 farmers which were randomly selected in the Iringa and Mbeya regions in Tanzania, two visits were each made within a period of 7 months for each respondent and data was gathered. The results of the research showed that a farmer's adoption of cross-bred technology depends positively on the proximity of his farm to other users, on his schooling, and on his access to credit and contact with extension agents.

To successfully use mobile technology in aiding development efforts there is need to fully understand the impact of mobile phone diffusion, adoption, perceived impacts, uses, and reinvention of uses. Some benefits that can be obtained from using ICT in the developing countries are increasing the knowledge of people on market information, enhancing the effectiveness of development activities, improving transportation coordination, researchers argue that ICT with their roles as complementary tools can help in achieving development objectives which can assist in the effectiveness of outreach programs. Hosman also stressed the importance in conceptualising the Utility of ICT in relation to social structure and that merely providing technology does not create the need for it nor foster the culture to use or comprehend the issues or challenges that are efficiently addressed with the aid of technology. Martin & Abbott conducted a research in the Kamuli district of Uganda which has an approximate population of about 707,000 people and land area of approximately 1,700 square miles, it is also considered to be among the poorest districts in Uganda. Over 80% of the working population engage in subsistent agriculture, an agricultural based organisation (non-governmental) known as VEDCO has been working in Uganda since 2004 to strengthen the capabilities of the rural people by supporting development activities, collaborative training to improve natural resource management practices, agriculture, diversify income sources, build assets, nutrition & health, achieve food security. VEDCO attempts achieving its development goals by training community leaders namely rural development extensionists (RDEs), community nutrition & health workers and also forming farm groups. According to a study by VEDCO about 42% of 306 farming households in the district own a mobile phone as of 2008, later in 2010 VEDCO included goals to collect and disseminate market information in addition to disease outbreaks, HIV/AIDS management, farmer trainings and meeting via SMS in a 5yr strategic plan. Understanding the use of mobile phones to aid in development requires an adequate knowledge of the current uses and perceived impacts of mobile phones, as well as an assessment of the opportunities and barriers reinforced by the local social structure. Interviews were conducted on 90 mobile phone owners who are holders of small to medium sized among the interviewees were 50 women and 40 men whom are actively involved in the agricultural development based farm groups in the district. Results of the interview showed that respondents indicated the use of mobile phones for coordinating access to market information, agricultural inputs, monitoring financial transactions, and consulting with agricultural experts (Martin & Abbott, 2011; Hosman, 2010).

In a review by Aker (2011), it shows that, Agriculture may serve as a vital means for improving the economic wellbeing of developing countries but even with that still, yields in the countries have lagged far behind those of the developed countries for decades. One potential explanation for this stagnating growth in yields is the underutilization of improved agricultural technologies, which has remained relatively low in developing countries. Some of the potential mechanisms for improving yields is through the use agricultural technologies

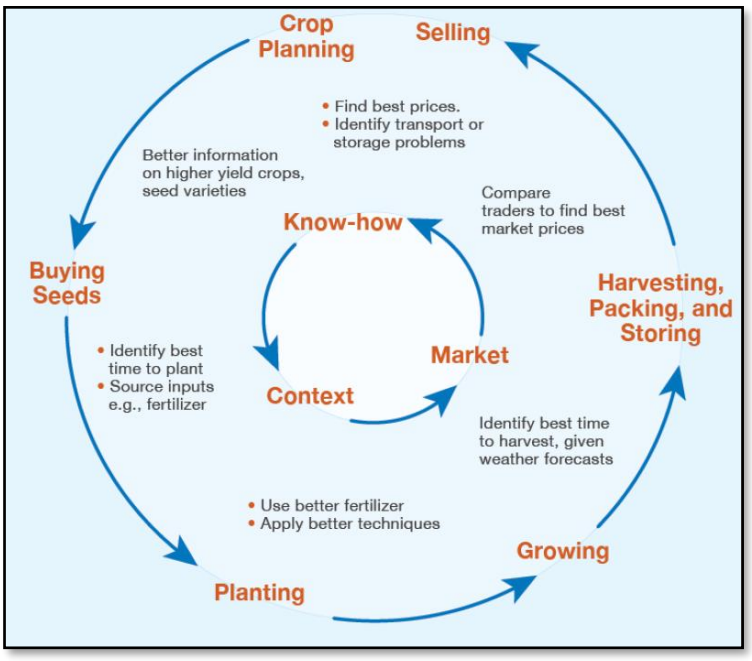
such as the ones for seeds, fertilizers and new cropping techniques. Some public sector programs have also tried overcoming information related barriers to technological adoption through the provision of agricultural extension services. Most of these programs have been mostly criticized because of their sustainability, limited scale and impact. The rapid spread of mobile phone coverage in the developing countries has presented a unique opportunity to facilitate technological adoption through the use of ICT based extension programs. The review outlines some potential mechanisms through which ICT could facilitate the adoption of agriculture and provide extension services in the developing countries, it also reviewed some existing programs on using ICT for agriculture categorised by text, voice, internet & mobile money transfers and also the type of services provided, identifying the potential constraints to the programs in terms of design and implementation and the impact of the programs on the knowledge of farmers, welfare and technological adoption.

2.1.3. Output & Impact:

Kashem (2010) focused on determining the extent of the use of mobile phones by farmers when receiving agricultural information from input dealers, a survey was conducted the and data was obtained from 76 farmers who are mobile phone users in 8 selected villages of two unions under Sadar Upazila of Mymensingh district in Bangladesh during 12 September to 15 October 2009. To ascertain the extent of the usage of mobile phones by the farmers in receiving agricultural information a questionnaire was used in 4 major aspects, such as the quality of the inputs, availability of inputs, market price of the inputs, and also the appropriate amounts of the inputs were covered. Among the questions asked to the Farmers were whether their contacts with the input dealers were regular, occasional or not at all (based on the number of times per season). More than half (54 percent) of the farmers had medium use of mobile phones in receiving agricultural information while 14 and 32 percent of them had low and high use of mobile phones, respectively.

Mittal et.al (2010), conducted a research on the impact of mobile phones in Indian Agriculture, the research looked into the impact of mobile phones on the crop sector and particularly on small farmers. According to the paper infrastructure, availability of agricultural inputs and poor access to agricultural information are some of the major constraints on the growth of agricultural productivity in India and the rapid growth of mobile phones and mobile enabled information services provides a means to overcome existing information asymmetry, it also partially bridges the gap between the delivery and availability of agricultural inputs and infrastructure. The methodology of the research involved field investigations conducted in Uttar Pradesh, Rajastan, Maharashtra, New Delhi and Pondicherry. The field investigations involved focused group discussions, individual interviews with fishermen, farmers, labourers, traders and other businesses involved in agricultural sector. The team conducted 46 individual interviews in 11 districts and also 20 villages and 14 focus group discussions. About 187 farmers were interviewed in which 152 were small scale farmers with less than 6 acres of land. The key finding of this research is that mobile phones can act as a catalyst to rejuvenate the collapsing extension services in the country. However, this does not in any way dilute the need for urgent and significant improvements in supporting infrastructure and capacity building to realise much needed productivity gains in agriculture.

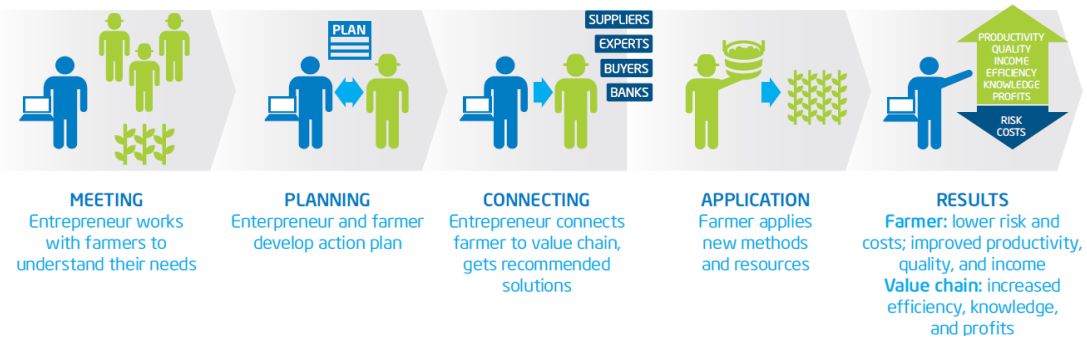
Figure 3: Farmer's Information Needs



Information needs of farmers by Mittal et.al (2010; p5)

E-agriculture initiatives bring together a wide array of regional and local stakeholders in order to form a value chain that is mutually beneficial. Intel (2012) conducted a successful e-agricultural project in Odisha, India. The project demonstrated how technology could be used to address and improve the livelihoods of small farmers in developing countries. The methodology employed was a case study with interviews and group discussions. In just one year the project helped over 6000 farmers to increase their incomes by more than 300% and also created job opportunities for local entrepreneurs. The project aimed to connect the farmer and other stakeholders effectively in the value chain, to strengthen the local agricultural system and improve productivity for everyone in the agriculture value chain including small farmers. Organizations and governments that care about farming can learn from and apply the e-Agriculture model that proved successful in Odisha. It provides a unique opportunity to support small farmers in developing countries and potentially increase food security, create jobs, and support long-term economic growth. The model is shown in Figure 4.

Figure 4: The livelihood model of e-agriculture



Adopted from Intel (2012)

2.2.Theorization of e-agriculture studies:

The framework takes inspiration form Farquhar and Surry (1994) adoption analysis approach which considers the adoption process from the broader perspective of both user-perception and organization attributes, resulting in a plan for carrying out the adoption of technology that is rooted in an organizational context and addresses issues of concern to the intended user. Another inspiration was from two theories by Rogers (1995) which are Innovation decision process theory which contains the five stages of diffusion process and Perceived attributes theory. Finally, is the traditional top down approach in which administrative mandate is used in introducing a technology and administrative perceptions, decisions and strategies drive adoption and diffusion. Successful adoption is highly dependent on the degree, stability and wisdom of administrative sponsorship. The framework will use the development lifecycle approach.

2.2.1. Adoption and impact study

Stage- Needs
It is evident that because of the dynamism of agriculture, farming practices experience changes continually. The changes might be market, technological, political, environmental thus there is need for strategies to be refined in order to accommodate the changes that are experienced. For the adoption, diffusion or extension of any technology to begin there is need for the organisation or body to conduct an adoption study to analyse, assess and identify adoption patterns, adoption rate, trends, Factors that influence farmers & impact of an agricultural technology in an area. It is highly important to also conduct a needs assessment of the farmers in the specific region to understand their needs in order to meet the needs in the new technology. Organisations and researchers ought to frequently obtain a measure of the outcome of projects they have undertaken to ascertain the impact and also obtain useful data to be able to refine and improve their strategies and help technology transfer agencies, agricultural researchers, NGOs & extensionists for future projects. But most organisations hardly do that. It is also very important to identify the priorities of farmers and also enlist widespread participation of community members to investigate and promote innovations. (CIMMYT, 1993)

2.2.2. Sharing the results

Stage-Needs
It is also important to provide the results of the adoption and impact study to the various stakeholders that are involved in the diffusion and extension of the agricultural technology.

To know whether the methods they have been using have been effective or lacklustre and to gauge their performance in the transfer, diffusion and extension of various technologies to measure their performance and make adjustments and improvements where necessary. The results of the adoption study can be used to improve the relationship between stakeholders, it is essential to achieve a good communication between various stakeholders from researchers, extensionists and policy makers. E.g. If farmers are unable to make use of a new technology because they lack inputs, then the party responsible for providing and distributing the inputs which are policymakers can be notified. (CIMMYT, 1993).

2.2.3. Knowledge & Persuasion

Stage- adoption

Creating awareness of a technology in terms of Knowledge diffusion might be difficult but there is a need for the potential adopters of a technology to properly be informed of the innovation that the new technology will provide to users. After having the knowledge of the technology the potential adopters need to also be persuaded to adopt the technology by making them aware of the value, benefits and outcome of using the agricultural technology in terms of increased output, cutting costs, time saving and other things. Another important way of persuading adopters is a good price and also requires the support of opinion leaders to support it. Media outlets can also be utilised for persuading and enlightening potential adopters especially through advertisements, social media and informative videos. Another great point of persuasion is that the degree to which a particular technology is seen or perceived from a user's point of view in terms of complexity should be eliminated in such a way that users would find it easy to adopt and use (Rogers, 1995; Farquhar & Surry, 1994).

2.2.4. Demonstration & Training

Stage- adoption

There is a need for a demonstration of a new agricultural technology to farmers to show them properly how it works, how to use it and to also remove any notion of complexity from potential adopters of the technology by teaching them in simple terms and in a language that is understandable by the farmers. Several seminars and workshops should be conducted to properly demonstrate and train farmers. (Shapira et.al, 1996)

2.2.5. Mentoring & Technical assistance

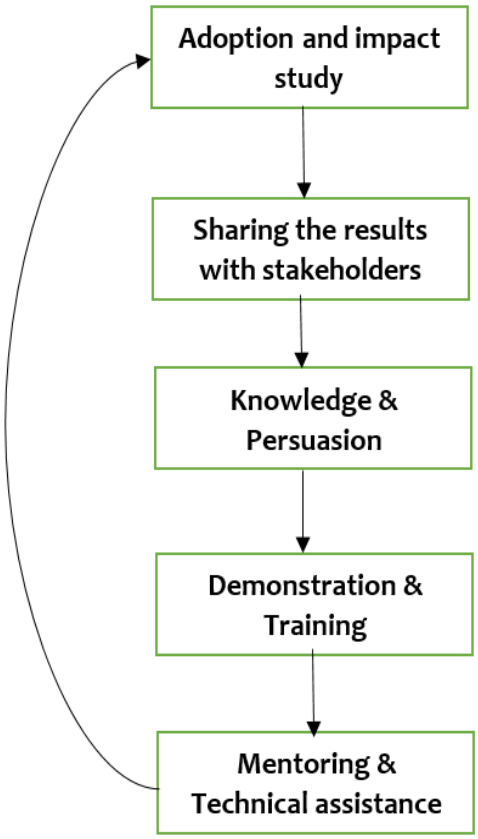
Stage- extension/ impact

After the commencement of many agricultural programs in the developing countries most farmers do not longer have sufficient support when they use a new technology or innovation and they are often left to fend for themselves. This happens mostly due to organisations abandoning such projects, lack of funds to continue supporting such activities by many institutions, corruption. Financial support is needed in such agricultural programs in order to sustain the post activities after deploying a technology to farmers, Loans, grants, fund raising campaigns and government support should be seeked by institutions to further sustain post activities of agricultural programs (CIMMYT, 1993)

2.2.6. Initial Adoption & output analysis

Stage-extension, Impact & output

Shortly after adoption, institutions should endeavour to conduct adoption analysis early to know the performance of the new technology or innovation, and assess areas of improvements, communicate the areas of improvements to the necessary stakeholders to take imminent actions. It is also essential to know whether it is meeting the needs of the necessary stakeholders and the impact in the community. (CIMMYT, 1993)



Framework for adoption, diffusion & extension of technology

2.3.ANALYSIS AND CATEGORISATION OF MODELS

This section aims to analyse and categorise the various, models, conceptual approaches and methodologies used from various projects as used in the reviewed literature to identify methodological issues. It will aim to answer the following questions of the research study:

- What are the methodologies, conceptual approaches and how were they used in the literature obtained?
- What are the gaps, shortfalls, issues and questions raised from analysing the methods used in the various literature?

The section will use the following criteria to analyse the methodologies:

- The setting of the study
- How was the Sample size obtained if any?
- Was the field study cross sectional or longitudinal?
- What was the methodology(s) used?
- Was the methodology robust enough? what are the strengths or shortfalls?
- What conceptual approach was adopted?

2.3.1. Quantitative approach using questionnaire & UTAT model:

Alemu & Negash (2015) used a quantitative approach through the use of questionnaires based on a UTAT model in Ethiopia to find out the factors that affect the adoption of marketing information systems by farmers, traders and other parties. A questionnaire was the right thing to use because questions needed to be asked in order to know about the factors that affect the adoption of MKIS and gather empirical evidences but questionnaires could lead to bias. Interviews and observations (especially observations) also needed to be conducted to know the real reasons why a phenomenon exists rather than what people say. No much information about how the sample size for the study used was obtained but it is recommended to use a sample size table to obtain an optimal sample size for a quantitative study. (RA, 2006)
The UTAT model or Technology acceptance model was ideal because the model aims to explain the user intentions to use an information system and also subsequent usage behaviour.

2.3.2. Quantitative approach using questionnaire & Value chain analysis:

In De Silva & Ratnadiwakara (2008 & 2013) a study was conducted on using ICT to reduce costs of transactions in a particular segment of the agricultural value chain in Sri Lanka, a quantitative approach using a questionnaire was used to gather data and the participants were farmers in the rural area of Sri Lanka. As Sri Lanka is a developing country and the research was conducted in a rural area there might be problems in filling the questionnaire as farmers in the region might not be educated and end up not likely to complete and understand the questions properly. In such cases they should be helped when filling the questionnaires or interviewed in local dialect. The sample size chosen was fair among farmers of various crops the participants were selected from a random sample of farmers grwoeing different type of crops and from different farmer associations. The conceptual approach identified in the study is transaction costs based on the works of Singh (2008) and others with some value chain analysis.

2.3.3. Quamtitative approach using a questionnaire, hazard function or duration model:

Abdulai & Huffman (2005) used a mixed methodology using a questionnaire, hazard function or duration model to explain the diffusion of cross-bred cow technology through a unique sample of farmers in Tanzania. A questionnaire was used to gather data from farmers, again the region was a rural area and the farmers there may not be well educated
To answer questions properly in the questionnaire but nevertheless the hazard function or duration model was ideal in understanding the phenomena over a period of time which implies that the study was longitudinal. The sample size for the study was obtained using random sampling. The conceptual approach used was diffusion theory based on Colombo & Mosconi (1995) and Karshenas & Stoneman (1993).

2.3.4. Qualitative approach using field investigations such as focus groups and interviews:

Mittal et.al (2010) conducted a research to find out the impact of mobile phones in Indian agriculture, the methodology employed is focus groups and interviews in 11 districts in India

which involved farmers, fishermen, traders, labourers and other businessmen. The approach was adequate because the region was a rural area and interviews and group discussions were the right choice because the literacy level might be low and questionnaires wouldn't have worked, the interviews and group discussions would enable a better understanding of what is being expected of the participants. The sample size was obtained by selecting participants from various farming segments, districts and villages but no further explanation on how the selection was done. Information needs modelling was the conceptual approach adopted looking at needs of farmers, fishermen, labourers, traders and other stakeholders and various sources for which information can be obtained.

2.3.5. Mixed approach using interviews & thematic analysis:

In the Kamuli district of Uganda, Martin & Abbott (2011) also did an interview of 90 mobile phone owners who are holders of small to medium sized among the interviewees but also used a thematic analysis which is quantitative. Using a mixed approach would enable the revealing in greater detail different needs and motivations. Interviews are useful for obtaining detailed information, perceptions & opinions and a true picture of what is happening can be obtained. Interviews were conducted through an interpreter that is conversant in both the local dialect and English which was adequate. Sample was obtained from an even spread of farmers in the district. The study was cross-sectional and was done within a period of a month. The theoretical framework for the research was based on two conceptual approaches used by the researchers, one was diffusion theory based on Rogers (2003) and Information and communication technologies for development (ICTD) based on Duncombe & Heeks (2002), Donner (2008) and others.

2.3.6. Quantitative approach using Questionnaires

Kashem (2010) conducted a survey focused on determining the extent of the use of mobile phones by farmers when receiving agricultural information from input dealers, data was obtained from 76 farmers who are mobile phone users in some villages under Sadar Upazila of Mymensingh district in Bangladesh using questionnaires. Using Questionnaires can lead to bias while Interviews give some first-hand opinions from participants. The researchers should have used a mixture of both to achieve a better result. Information search costs was the conceptual approach identified.

2.3.7. Mixed approach using documentary exploration, questionnaires, observation and field interviews

Gichamba & Lukandu (2012) used a mixed approach in a research they conducted in Kenya using documentary exploration, questionnaires, observation and field interviews in gathering the necessary information needs of various stakeholders of the agricultural sector to design a framework for developing mobile solutions. The methodology included a mixture of both quantitative and qualitative approaches ranging from documentary evidences, questionnaires, interviews and observation which is robust enough and allows in-depth understanding and corroboration of a phenomenon while also eliminates the weaknesses that is prevalent when using each approach on its own. Purposive sampling was used to select participants whom are various stakeholders in the dairy farming sector.

The conceptual approach identified from the study included that of information needs modelling.

Qualitative approach using interviews and group discussions
Intel (2012) gathered information from various stakeholders using interviews and group discussions in a district in India, interviews provide an in depth understanding of a phenomenon while focus groups provide a broader range of information About personal or group perceptions and feelings. There was no information about how the sample size was obtained but a large number of participants were involved. The conceptual approach identified is value chain analysis.

Note* some articles were not analysed as they are mainly experiments or demos to showcase technology.

Table 3: Categorisation of Methodologies and Conceptual Approaches

Lifecycle	Conceptual approaches	Authors & Year	Methodology	Techniques	Type of Data
Needs	Information Needs modelling	Gichamba & Lukandu (2012)	Mixed	Documentary evidence, Questionnaire & interview	Mixed
		Mittal et.al (2010)	Qualitative	Focus group discussions & interviews	Primary
Adoption/use & Extension	Value chain / supply analysis & transaction costs	De Silva & Ratnadiwakara (2008)	Quantitative	Questionnaire	Primary
		Intel (2012)	Qualitative	Group discussions & Interview	Primary
	Technology acceptance model	Alemu & Nagash (2015)	Quantitative	Questionnaire	Primary
Impact	Diffusion theory/ ICT4D	Abdulai & Huffman (2005)	Quantitative	Questionnaire	Primary
		Martin & Abbott (2011)	Mixed	Interview & Thematic analysis	Primary

Output		Aker (2011)	Qualitative	Desk study	Secondary
	Micro economic modelling- Transaction costs, information search costs	Kashem (2010)	Quantitative	Questionnaire	Primary

Note* some articles were not included as they did not have a significant theoretical contribution

3. CONCLUSION

After reviewing various literatures and the evidences from them it is evident that farmers in the developing countries have faced many challenges such low literacy, poverty, low agricultural education, little capital, high interest rates, lack of agricultural input, high interest rates, social influences, lack of advisory services & market information which has highly affected the adoption of ICT solutions, their farming activities and most importantly their output. Various evidences from the literature reviewed also showed that ICT has offered a lot to agriculture and the penetration of mobile devices over the world has provided a large means of developing new solutions for farmers in terms of providing advisory services, monitoring the farm, providing market information, managing records, weather information and other benefits which impact the knowledge of farmers, welfare and technological adoption. It also brings development to the rural areas which are often neglected in many low income countries. These developments occurred through many E-agricultural projects that have been initiated by government, NGOs and private investors. The sustainability of such programs after deployment of the solution has tend to be problematic in many cases because of lack of funding from the government and other stakeholders, it leaves farmers helpless. In the case of diffusion & extension of technologies many organisations tend to ignore adoption analysis, which is very important for understanding the impact, perceptions and social structure of an area & technology used before deploying new ones. This study has provided a framework for the diffusion and extension of technology which stresses on adoption analysis.

In terms of methodologies used in the various literature reviewed researchers have used Quantitative, Qualitative, and mixed approaches in their methodologies. Many researchers tend to stress the use of questionnaires to gather data in areas which are not fully literate and might end up obtaining data roughly or incomplete and therefore, questionnaires should be accompanied with interviews in local dialect to obtain better data from participants. It is recommended to use a mixture of data collection techniques when conducting field investigations to eliminate the weakness of each technique and to obtain a broader data for better analysis.

In contributing to theories many of the papers reviewed have contributed to theory. The papers have adopted a number of conceptual approaches such as TAM (Technology acceptance model), diffusion theory, ICT4D (information and communications technology for development), Value chain analysis, information needs modelling, transaction costs and others which is impressive.

The future trend of E-Agriculture tends to be dependent on high investment by Government especially at the national level through budget allocations, NGOs, Private sector &

international organisations investment in agriculture by bringing new innovations to low income countries.

References:

Abdulai, A. & Huffman, W. E., 2005. The diffusion of new agricultural technologies: The case of crossbred-cow technology in Tanzania. *American Journal of Agricultural Economics*, *87*(3), 645-659.

Aker, J. C., 2011. Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics*, *42*(6), pp. 631-647.

Alemu, D. & Negash, S., 2015. Mobile information system for small-scale rural farmers. In *Technological Innovation in ICT for Agriculture and Rural Development (TIAR), 2015 IEEE* (pp. 79-83). IEEE.

Biswas, A. & Prakash, S., 2015. Farming technology for India agriculture based sensorics and indicative systems. In *Technological Innovation in ICT for Agriculture and Rural Development (TIAR), 2015 IEEE* (pp. 72-78). IEEE.

CIMMYT Economics Program., 1993. The Adoption of Agricultural Technology: A Guide for Survey Design. Mexico, D.F.: CIMMYT.

Colombo, M.G. and Mosconi, R., 1995. Complementarity and cumulative learning effects in the early diffusion of multiple technologies. *The Journal of Industrial Economics*, pp.13-48.

De Silva, H. & Ratnadiwakara, D., (2008). Using ICT to reduce transaction costs in agriculture through better communication: A case-study from Sri Lanka. *LIRNEasia, Colombo, Sri Lanka, Nov*.

De Silva, H., & Ratnadiwakara, D. (2013). ICT Policy for Agriculture Based on Cost Approach. *Technology, Sustainability, and Rural Development in Africa*, 323.

Donner, J., 2008. Research approaches to mobile use in the developing world: A review of the literature. *The Information Society*, *24*(3), pp. 140–159.

Duncombe, R. and Heeks, R., 2002. Enterprise across the digital divide: Information systems and rural micro-enterprise in Botswana. *Journal of International Development 14*(1), pp. 61–74.

Duncombe, R., 2012. Mobile Phones for Agricultural and Rural Development: A Literature Review and Suggestions for Future Research. *The European Journal of Development Research*, *28*(2), pp. 213-235.

Farquhar, J.F, and Surry, D.W., 1994. Adoption analysis: An additional tool for instructional developers. Education and Training Technology International, 31, 1, pp. 19-25.

Gichamba, A. and Lukandu, I. A., (2012). A model for designing M-agriculture applications for dairy farming. *The African Journal of Information Systems*, *4*(4), p. 1.

Guest, G., Bunce, A. and Johnson, L., 2006. How many interviews are enough? An experiment with data saturation and variability. *Field methods*, *18*(1), pp.59-82.

Gupta, G. (2012). What are the factors that affects agriculture in India? Retrieved [online] preservearticles.com. Avalable at http://www.preservearticles.com/2011101215204/what-are-the-factors-that-affects-agriculture-in-india.htm [Accessed 16 Feb. 2017].

Heeks, R. (2006) Theorizing ICT4D research', *Information and Communication Technologies and International Development*, 3 (3), pp 1–4.

Hellstrom, J., (2010). The Innovative Use of Mobile Applications in East Africa. *SIDA Review* 2010:12, SIDA, Stockholm, Sweden. URL http://www.sida.se/publications

Hosman, L., 2010. Policies, partnerships, and pragmatism: Lessons from an ICT-in-education project in rural Uganda. *Information Technologies & International Development*, *6*(1), pp. pp-48.

Intel, (2012). *eAgriculture: Using Technology to Empower Farming Communities, Innovative project creates sustainable agricultural ecosystems in rural India*. 1st ed. [ebook] Bangalore, India: Grameen Intel Social Business, pp.2-5. Available at: http://www.intel.de/content/dam/www/public/us/en/documents/corporate-information/eagriculture_program_cs.pdf [Accessed 15 Feb. 2017].

Karshenas, M. and Stoneman, P.L., 1993. Rank, stock, order, and epidemic effects in the diffusion of new process technologies: An empirical model. *the RAND Journal of Economics*, pp.503-528.

Kashem, M. A., 2010. Farmers' use of mobile phones in receiving agricultural information towards agricultural development. *M4D 2010*, 80.

Lantzos, T., Koykoyris, G. & Salampasis, M., 2013. FarmManager: An Android application for the management of small farms. *Procedia Technology*, *8*, 587-592.

Martin, B. L. and Abbott, E., 2011. Mobile phones and rural livelihoods: diffusion, uses, and perceived impacts among farmers in rural Uganda. *Information Technologies & International Development*, *7*(4), pp. pp-17.

Matouš, P., Todo, Y., and Mojo, D., 2013. Roles of extension and ethno-religious networks in acceptance of resource-conserving agriculture among Ethiopian farmers. *International Journal of Agricultural Sustainability*, *11*(4), pp. 301-316.

Mittal, S. Gandhi, S. & Tripathi, G., 2010. *Socio-economic impact of mobile phones on Indian agriculture* (p. 53). New Delhi: Indian Council for Research on International Economic Relations.

Poulton, C. and Kanyinga, K., 2014. The politics of revitalising agriculture in Kenya. *Development Policy Review*, *32*(s2), pp. s151-s172.

Rao, S. 2006., Note on the use of data collected by sensors. CEDT Technical Report.

Research Advisors, (2006). *Sample Size Table*. [online] Research-advisors.com. Available at: http://research-advisors.com/tools/SampleSize.htm [Accessed 21 Feb. 2017].

Revisionworld. (2007). Title. Retrieved February 16, 2017, [online] revisionworld.com. Avalable at https://revisionworld.com/gcse-revision/geography/agriculture/factors-affecting-farming [Accessed 16 Feb. 2017].

Rogers, E., 2003. *Diffusion of innovations.* New York: Simon & Schuster.

Shapira, P. and Rosenfeld, S., 1996. An overview of technology diffusion policies and programs to enhance the technological absorptive capabilities of small and medium enterprises. *Background paper prepared for the Organization for Economic Cooperation and Development Directorate for Science, Technology and Industry (http://www. prism. gatech. edu/~ jy5/pubs/oecdtech. htm)*.

Singhal, M. Verma, K. & Shukla, A., 2011. Krishi Ville—Android based solution for Indian agriculture. In *2011 Fifth IEEE International Conference on Advanced Telecommunication Systems and Networks (ANTS)* (pp. 1-5). IEEE.

Walsham, G. (2012). Are we making a better world with ICTs? Reflections on a future agenda for the IS field. *Journal of Information Technology*, *27*(2), 87-93.

World bank, (2016). *Sri Lanka to Modernize Agriculture to Create Jobs, Access Markets and Increase Productivity*. [online] World Bank. Available at: http://www.worldbank.org/en/news/press-release/2016/06/28/sri-lanka-to-modernize-agriculture-to-create-jobs-access-markets-and-increase-productivity [Accessed 16 Feb. 2017].

Yoon, S. (2015). *The Rise of Mobile Phones: 20 Years of Global Adoption*. [online] Blog.cartesian.com. Available at: http://blog.cartesian.com/the-rise-of-mobile-phones-20-years-of-global-adoption [Accessed 23 Feb. 2017].

Appendix 1:

ICT4D Journal Citation Table

	Journal	2005 Score	2008 Score	Overall Score
1	Information Technology for Development	2.94	1.58	***2.26***
2	Electronic Journal of Information Systems in Developing Countries	2.69	0.81	***1.75***
3	Information Technologies and International Development	1.82	1.55	***1.69***
4	Asian Journal of Communication	1.19	0.4	***0.80***
5	African Journal of Information and Communication	0.87	0.44	***0.66***
6	International Journal of Education and Development Using Information and Communication Technology	0.77	0.39	***0.58***
7	Journal of Health Informatics in Developing Countries	n/a	0.42	***0.42***
8	Information Development	0.4	0.37	***0.39***
9	International Journal on Advances in ICT for Emerging Regions	n/a	0.28	***0.28***
10	African Journal of Information & Communication Technology	0.24	0.06	***0.15***
11	South African Journal of Information Management	0.26	0	***0.13***
12	International Journal of Information Communication Technologies and Human Development	n/a	0.11	***0.11***
13	African Journal of Information Systems	n/a	0.06	***0.06***
14	Asian Journal of Information Technology	0.04	0	***0.02***
15	Asian Journal of Information Management	n/a	0	***0.00***
–	International Journal of ICT Research and Development in Africa	n/a	n/a	***n/a***
	-			
	World Development	8.96	6.04	***7.50***

	Information Systems Journal	7.62	2.89	***5.26***
	Human-Computer Interaction	5.34	4.06	***4.70***
	The Information Society	5.98	3.23	***4.60***
	Journal of International Development	2.49	1.46	***1.97***