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REVIEW

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# Adoption of ICT innovations in the agriculture sector in Africa: a review of the literature

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**Abstract**

According to the latest World Economic Forum report, about 70% of the African population depends on agriculture for their livelihood. This makes agriculture a critical sector within the African continent. Nonetheless, agricultural productivity is low and food insecurity is still a challenge. This has in recent years led to several initiatives in using ICT to improve agriculture productivity. However, a systematic review of the evidence categorized by the various aspects of the topic is lacking. This study investigates the state of the art of ICT innovations within the agriculture sector in Africa. To achieve this, we reviewed the literature published from 2010 to 2019 in which ICT innovations were discussed. Our search in four major literature databases yielded 779 papers, of which we selected 23 primary studies for a detailed analysis. The analysis shows that the main ICT technologies adopted are text and voice-based services targeting mobile phones. The analysis also shows that radios are still widely used in disseminating agriculture information to rural farmers, while computers are mainly used by researchers. Though the mobile-based services were aimed at improving access to accurate and timely agriculture information, the literature review indicates that the adoption of the services is constrained by poor technological infrastructure, inappropriate ICT policies, and low level of user skills, especially of farmers, in using the technologies.

**Keywords:** ICT innovation, Africa, Agriculture, Systematic literature review

## Introduction

The agriculture sector in Africa is less developed and food insecurity is still a challenge. Though the continent has enormous natural resources, and the agricultural potential is high, many countries are still net importers of food. An African competitiveness report [1] revealed that the continent imports about US$25 billion worth of food crops annually. According to the authors, the level of value addition and processing of agricultural commodities is also low and post-harvest losses are high (in sub-Saharan Africa averaging about 30 percent of total production). Agriculture, however, remains a significant sector within the continent. It is the main source of income for the majority of its rural population. The agriculture sector accounts for almost two-thirds of the total employment and about 75% of domestic trade [2]. With most of the rural population depending on agriculture for their livelihoods, the growth and development of the sector are critical.

The growth and development of the agriculture sector can be achieved through the effective deployment of Information Communication Technology (ICT). ICT has been a significant contributor to the growth and socio-economic development in countries, where ICT is deployed effectively [3]. The effective integration of ICT in the agriculture sector in developed countries has led to tremendous improvement in agriculture value chain

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efficiency and productivity, while ICT uptake in agriculture in sub-Saharan Africa took a sluggish start and a major transformation of the sector has yet to take place.

In recent years, efforts to transform the sector have led to the propagation of several mobile-based applications and services. A recent digitalisation report [4] revealed that 33 million smallholder farmers in Africa are currently reached by digital applications as of 2019 and this is projected to reach 200 million by 2030. These applications are diversified, targeting advisory and information services, market linkages, financial access, and supply chain management, with advisory and information services dominating the market [4]. Bilali and Allahyari [5] assert that ICT-based innovations can improve rural livelihoods and empower smallholder farmers in developing counties by enhancing their connectivity and increasing access to accurate and timely agriculture information. For example, Esoko (https://esoko.com/, accessed on 12 July 2021) which is a technology platform in a number of African countries uses a combination of mobile and web services to improve access to extension services and market information. This reduces the costs of searching for market information and provides real-time weather and extension advice to farmers, which helps farmers to make informed decisions.

Innovative ICT solutions ranging from computers, radio, television, and mobile phones to advanced technologies such as blockchain, artificial intelligence, cloud computing, Internet of Things (IoT) and big data analytics are among the current trends [6]. These disruptive ICT trends hold the potential to contribute to sustainability transitions in agriculture by increasing efficiency, enhancing transparency, and traceability [5, 6]. Remote sensing using satellite technologies, and geographical information systems can be used to increase agricultural output [7]. For example, monitoring and timely information gathering of soil data can help in determining the physical and chemical properties of the soil, and hence the type of crop that can be grown to ensure maximum crop yield. Furthermore, data analytics can be used to provide predictive insights in farming operations, drive real-time operational decisions, and redesign business processes [8]. With ICT recognized as a significant contributor to the growth and development of agriculture, its application in recent years has gained increasing attention in many developing countries.

There are few literature reviews done on ICT innovations in developing countries. A systematic mapping study by Zewge & Dittrich [9] conducted to describe the state of the art of ICT for agriculture research in developing countries reviewed journal and conference papers published between 2006 to 2014. The study identified mobile phones, computers, telecentres, and the internet as the main ICT innovations in developing countries with the mobile phone being the preferred technology, especially in rural areas. The authors further assert that appropriate ICT design solutions that take social, as well as technical issues into account, are still scarce. Similarly, the findings by Lwoga and Sangeda [10] revealed that there is limited use of user-centred design research in the development of ICT applications.

Previous studies, such as by Zewge and Dittrich, have addressed in detail the different theoretical underpinnings and the relevant ICT disciplines involved in the topic of ICT innovations in Africa. We were, however, unable to find a systematic literature review that explicitly identified essential aspects of the topic such as the stakeholders, the sectors, and the challenges. This study, therefore, aims, to assess the current state of adoption of ICT innovations within the agriculture domain in Africa and provide additional insights into the challenges encountered in the adoption of ICT. To achieve this, we performed a Systematic Literature Review (SLR) to make a comprehensive and rigorous review of the existing literature. The review of literature on ICT innovation within the continent is valuable to contribute to the existing body of knowledge.

## Related work

ICT innovation is crucial for the agricultural sector of Africa and as such several studies were conducted on the topic over the past several years. In 2011, Aleke et al. [11] studied the adoption of ICT innovations (such as access to the internet, computers, and online portals) by small agribusinesses operating in indigenous communities in Nigeria. They found out that social imperatives play a crucial role among indigenous communities. Thus, the right balance must be maintained between the effort put in the design of ICT solutions and addressing social factors, such as language and traditional life, to enhance the willingness to adopt ICT innovations. In 2012, Lee et al. [12] identified co-innovation as a new innovation paradigm, where diverse stakeholders from the business ecosystem contribute to new ideas and approaches for generating new solutions. Co-innovation includes, according to the authors, engagement, shared experience, and co-creation. Their findings are consistent with the findings of Aleke et al. who concluded that strong government support and active social networks within and outside one's own circle support the adoption of ICT innovations.

The need for addressing concerns related to climate change, food security, and rural livelihood has been found by past studies as drivers for ICT innovation in developing countries. ICT innovations are considered to be part of climate-smart solutions that provide improved food

security and rural livelihoods. Scherr et al. [13] describe various large-scale programs that were supported by international organizations, such as the Great Green Wall Initiative, which used comprehensive regional land use management information systems. The authors described the use of ICT solutions such as remote sensing technology and diverse databases (such as land use and other social, economic, and ecological information) to support multi-stakeholder planning, governance, spatial targeting of investments, and monitoring.

More recently, Zewge and Dittrich [9] performed a systematic mapping study of journal and conference papers published between 2006 and 2014 and observed that the rapid proliferation of ICT in the developing world has been considered as an opportunity for supporting rural communities. Besides, the authors also observed that only a few of the scientific publications are related to ICT for agriculture though some African countries (such as Kenya and Uganda) have achieved a good level of adoption of ICT innovation among their farming communities. This fact contrasts significantly with the fact that more than 80% of the labor force is engaged in agriculture. In a similar study, Lwoga and Sangeda [10] reviewed existing SLR studies published on ICT and development between January 1990 and July 2017. Their review of reviews indicates that there is limited evidence on the long-term contribution of ICT use on livelihoods, inclusiveness, wellbeing, and freedom in developing countries, suggesting the need for further study on the appropriate and sustainable use of ICT for development. A review study that attempted to address the lack of a robust theoretical basis is done by Molina-Maturano et al. [14]. They studied constraint-based innovations used for promoting sustainable development among the poor by reviewing the relevant literature from 2007 to 2019. They highlighted the importance of ICT innovations for sustainable development and the need for further research on the integration of the diverse popular frameworks used for studying this topic.

Less recent than the works of [9] and [10] is the survey conducted in 2010 across many countries (and across 2095 households, 108 villages spread over 15 sites in 12 countries of West and East Africa and South Asia) by Förch et al. [15]. The research survey focused on identifying adaptation and mitigation practices, technologies, and policies for food systems that are pro-poor. They shared important "lessons learned" on how to obtain baseline data for rural populations in agricultural systems, which indicates that the study of innovations in general faces the lack of usable and quality data.

As newer technologies appear, the research on ICT innovations targeted the latest developments. An example of such a study targeting the rapid growth of mobile phones and their role in delivering timely, convenient, and cost-effective (in comparison to using traditional agricultural extension services) weather and market information to farmers in Ghana is conducted by Etwire et al. [16]. They found, however, that farmers' decisions to adopt mobile phone-based weather and market information is significantly influenced by their contacts with agricultural extension agents and farmer-to-farmer extension services, which supports Aleke et al. observation that social imperatives play an important role. Similarly, and more recently, Mujeyi et al. [17] have studied the impact of the adoption of personal ICT gadgets, such as radios, phones, and televisions in relation to the adoption climate smart agriculture. Their findings indicate that the adoption of climate smart agriculture and access to information through radio, TV, and mobile phones, have a positive impact on the welfare of farmers and recommend that access to timely information and forecasts as an essential aspect of ensuring the welfare of households. The adoption of ICT innovations is also found to be crucial in maximizing farm-level uptake and diffusion of other innovations such as biological control innovations [18].

The effects of policy related issues, particularly those related to tariffs, on the trade of African agricultural food products were studied by Santeramo and Lamonaca [19, 20]. Policy choices imposed by importing countries, such as tariffs, require African exporters to use ICT systems that enable them to provide the required transparency information. The authors describe how the lack of such a capacity has a trade-impeding effect.

Bahn et al. [21] and Klerkx et al. [22] did extensive reviews of the literature on the potential of digital technologies to address major social challenges related to agriculture and food systems. Bahn et al. reviewed the role of digital solutions in improving sustainability in the Middle East and North Africa. They found out that at the time of their research the adoption of digital agriculture is led by high-value agricultural products targeting the domestic and export markets to nearby countries. The general rate of adoption of digital agriculture was found to be at an early stage. Clearly, the main drivers for the adoption of digital technologies turned out to be economic sustainability. The authors proposed that policy makers need to foster the adoption of those technologies that support social environmental sustainability.

Klerkx et al. reviewed several social science scientific articles to study the effect of the latest ICT technologies, such as big data, the internet of things, augmented reality, robotics, AI, and blockchain on social, economic, and institutional dynamics in the agriculture sector. They identified grouped the literature on the adoption of digital technologies in agriculture around the following

thematic clusters: use and adaptation, farmer identity and skills, power and ethics, knowledge, and economics and management. They identified four thematic areas that they consider as poorly which include the conceptualization of digital agriculture from broader social, cyber-physical and ecological systems, and policy processes of the digitalization of agriculture.

The results of these studies indicate that more detailed research is needed that target the various aspects of the adoption of ICT innovations in the agricultural sectors of Africa.

## Materials and methods

The review protocol proposed by Kitchenham and Charters [23] was followed in this study as shown in Fig. 1. The remainder of this section discusses our methodology in more detail.

### Research questions

In this paper, we are interested in investigating empirical studies on the current state of adoption of ICT innovations within the agriculture sector in Africa. We reviewed the existing literature per specific aspects such as where the ICT innovations were applied, the agricultural domains for which the ICT innovations were used, and what challenges were encountered, and thereby address the current gap in the existing reviews of the literature. To achieve this objective, the following research questions were defined:

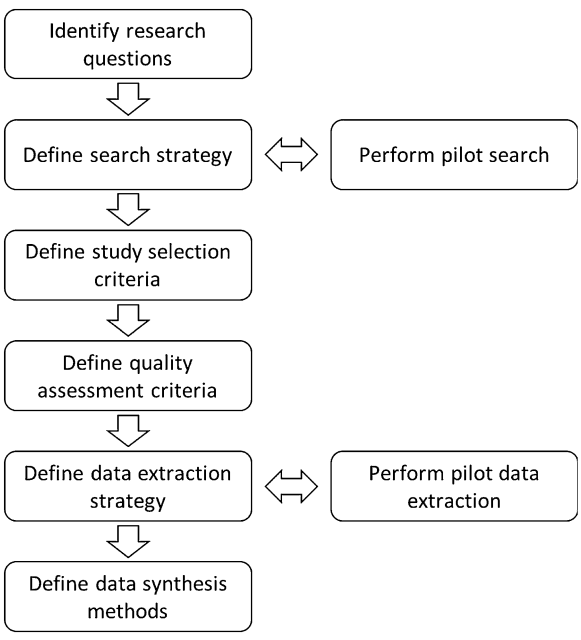


**Fig. 1** Review protocol used in our study ( Adapted from Kitchenham and Charters [23])

RQ1. What are the main ICT technologies used within the agriculture domain?

RQ2. Who were the agriculture stakeholders identified in the studies?

RQ3. Which African countries have applied ICT technologies?

RQ4. What are the agricultural domains considered for ICT innovation?

RQ5. What are the frameworks used in the studies?

RQ6. What are the challenges in ICT adoption?

### Search strategy

The search strategy was defined by explaining the search scope, search method, and search string. The search scope constitutes the year of publication and the venue of publication. In terms of publication year, the search focused on papers published from 2010 up to the time the research was conducted, which is February 2019; however, this scope was applied at the study selection criteria stage. In terms of the venue of publication, the following well-known databases were used to search for the targeted research papers: Scopus, ScienceDirect, IBI/Inform, and Wiley online. We searched for literature using both automated and manual methods. The automated search was conducted by searching in the selected databases using a pre-defined search string. The search string was constructed using keywords from the research questions and the synonyms of the keywords. The search string was then improved by conducting a pilot search. The resulting search string is as follows: *(ICT OR digitalization OR digitalisation) AND (Africa OR "Sub-Saharan Africa") AND (agriculture OR "agri-food") AND ("innovation model" OR "innovation framework")*. Since Wiley online and ABI/INFORM provided limited results, we adapted the search string slightly by adding *farming* in the third group of keywords to retrieve potentially relevant papers. The manual search was performed using the snowball method. We looked at papers referenced by and papers that refer to the primary studies selected through the automated search.

The result of the overall search process after applying the search queries is given in Table 1.

### Study selection criteria

We detailed our study selection criteria to serve as a way of reducing the number of studies while retaining relevant studies of interest. A set of criteria (exclusion criteria) was applied to the identified papers to exclude the papers that do not correspond to the purpose of the study. The exclusion criteria used in the study are presented in Table 2. The exclusion criteria were applied to the 779 papers obtained from the automatic and manual search. This was done by first reading the title and

**Table 1** Overview of literature search results

| Source | Retrieved[a] | Included[b] | Selected[c] | Method |
|---|---|---|---|---|
| Scopus | 106 | 12 | 7 | Automatic |
| ScienceDirect | 132 | 5 | 4 | Automatic |
| Wiley Online | 206 | 5 | 5 | Automatic |
| ABI/INFORM | 322 | 4 | 4 | Automatic |
| Other channels | 13 | 3 | 3 | Manual |
| Total | 779 | 28 | 23 | |

[a] Papers retrieved through automated and manual search

[b] Papers remaining after applying the exclusion criteria

[c] Papers remaining after applying both the exclusion and the quality assessment criteria

**Table 2** Exclusion criteria

| No. | Criteria |
|---|---|
| SC1 | Paper is published before 2010 |
| SC2 | Paper is not written in English |
| SC3 | The full text of the paper is not available |
| SC4 | Paper does not relate to the agriculture domain |
| SC5 | The abstract does not discuss any ICT innovations and/framework |
| SC6 | Duplicate publication from multiple sources |

**Table 3** Quality assessment criteria for identified primary studies

| No. | Question |
|---|---|
| Q1 | Is the aim of the study clearly stated? |
| Q2 | Is the scope and context of the research clear? |
| Q3 | Is the reporting clear and coherent? |
| Q4 | Are the theories used clear? |
| Q5 | Is the research methodology well presented? |
| Q6 | Are all study questions answered? |
| Q7 | Is the research process adequately documented? |
| Q8 | Is there a comprehensive description of ICT innovation and/frameworks? |
| Q9 | Does the conclusion relate to the aim of the study? |
| Q10 | Are the limitations of the research clearly stated? |

abstract of papers and second going through the entire paper. After applying the criteria, 28 papers were kept for further assessment.

#### Quality assessment criteria

The 28 papers remaining after applying the exclusion criteria were further assessed according to a well-defined quality checklist presented in Table 3. This was done to provide a more detailed exclusion criterion. The quality assessment instruments used in the studies were based on [23] criteria. This criterion was divided into four main categories based on the factors that could bias the results, namely: reporting, relevance, rigor, and credibility. First, the quality of the reporting was analysed based on the aim, clarity, and coherence of the studies. Then, the issue of rigor was judged based on the extent to which the studies provide value for research and practice. The relevance of the studies was also assessed according to how thorough and complete all the aspects that the paper promised to answer were answered. Finally, credibility is assessed according to the extent to which the findings and the conclusions of the studies are meaningful and logical. The answers to the quality checklist questions were deployed on a numerical scale numbered with 0 for "no", 0.5 for "somewhat" and 1 for "yes" with regards to how well the paper answers the questions asked. After reading the full text of the 28 papers and applying the quality checklist, 23 papers were extracted based on their good quality scores. The detailed scores of the quality checklist are presented in Appendix A.

#### Data extraction

The selected primary studies that we reviewed are listed in Table 4. At this stage, a data extraction form was developed to accurately extract data from the primary studies. Pilot data extraction was performed and all the fields relevant for addressing our research questions were agreed upon. The data extraction form is available in B. This form contains 15 elements, which include standard information such as authors, title, publication year, document type, and data repository. It also contains elements needed for answering the research questions like the considered ICT domain, the considered agriculture domain, and the challenges in ICT adoption. A record of the extracted information was kept in a table (see Appendix C) to support the process of synthesizing the extracted data.

#### Data synthesis

The purpose of the data synthesis is to summarize and present the findings of the primary studies in a manner suitable for answering our research questions. Based on the research objective and findings from the primary studies that were selected, this paper fits in a qualitative study, and hence a descriptive synthesis of the extracted data was performed. We analysed the individual studies and the set of studies as a whole. Studies with a similar or same meaning were identified and grouped under one concept. For instance, the challenges in the adoption of ICT's, we analysed and grouped them into four main concepts.

**Table 4** List of primary studies selected for review

| Study | Authors | Title | Year | Method |
|---|---|---|---|---|
| [24] | Owusu A.B., et al. | Smallholder farmers' knowledge of mobile telephone use: Gender perspectives and implications for agricultural market development | 2017 | Survey |
| [25] | Hudson H.E., et al. | Using radio and interactive ICTs to improve food security among smallholder farmers in Sub-Saharan Africa | 2017 | Survey |
| [26] | Kante M., et al. | Influence of perception and quality of ICT-based agricultural input information on use of ICTs by farmers in developing countries: Case of Sikasso in Mali | 2017 | Survey |
| [27] | Barakabitze A.A., et al. | The use of participatory approaches in developing ICT-based systems for disseminating agricultural knowledge and information for farmers in developing countries: The case of Tanzania | 2017 | Survey |
| [28] | Mugwisi T., et al. | Access to and Utilization of Information and Communication Technologies by Agricultural Researchers and Extension Workers in Zimbabwe | 2015 | Survey |
| [29] | Mwombe S.O.L., et al. | Evaluation of Information and Communication Technology Utilization by Small Holder Banana Farmers in Gatanga District, Kenya | 2014 | Survey |
| [11] | Aleke B., et al. | ICT adoption in developing countries: Perspectives from small-scale agribusinesses | 2011 | Survey |
| [30] | Misaki E., et al. | Technology for small scale farmers in Tanzania: A design science research approach | 2016 | Survey |
| [31] | Barakabitze A.A., et al. | New technologies for disseminating and communicating agriculture knowledge and information: Challenges for agricultural research institutes in Tanzania | 2015 | Survey |
| [32] | Kabbiri, R., et al. | Mobile phone adoption in agri-food sector: Are farmers in Sub-Saharan African connected? | 2018 | Survey |
| [33] | Jere N.J., et al. | Evaluating the influence of information and communications technology on food security | 2017 | Survey |
| [34] | Beza, E., et al | Exploring farmers' intentions to adopt mobile Short Message Service (SMS) for citizen science in agriculture | 2018 | Experiment |
| [35] | Wyche, S., et al. | Why Don't Farmers Use Cell Phones to Access Market Prices? Technology Affordances and Barriers to Market Information Services Adoption in Rural Kenya | 2015 | Case study |
| [36] | Kante M., et al. | An ICT model for increased adoption of farm input information in developing countries: A case in Sikasso, Mali | 2018 | Case study |
| [37] | Mtega, W. P., et al. | Using Information and Communication Technologies for Enhancing the Accessibility of Agricultural Information for Improved Agricultural Production in Tanzania | 2013 | Case study |
| [27] | Kiambi, D | The use of Information Communication and Technology in advancement of African agriculture | 2018 | Case study |
| [39] | Meijer, S.S., et al. | The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa | 2015 | Case study |
| [40] | Maredia, M.K., et al. | Can mobile phone-based animated videos induce learning and technology adoption among lowliterate farmers? A field experiment in Burkina Faso | 2017 | Experiment |
| [30] | Freeman, K. et al. | ICT use by smallholder farmers in rural Mozambique: a case study of two villages in central Mozambique | 2017 | Case study |
| [42] | Aleke, B., et al. | Social networks among small agribusiness in Nigeria | 2011 | Case study |
| [43] | Otene, V.A., et al | Assessment of Mobile Phone Usage Among Farmers in Keana Local Government Area of Nasarawa State, Nigeria | 2018 | Survey |
| [44] | Magesa, M.M., et al. | Towards a framework for accessing agricultural market information | 2015 | Survey |
| [45] | Awuor, F., et al. | Building E-Agriculture Framework in Kenya | 2016 | Survey |

## Results

### Overview of selected studies

As previously stated, the review spelled out the time boundary of the search to include papers from 2010 until the literature review was conducted in 2019. The yearwise distribution of the primary studies selected is shown in Fig. 2.

The selected primary studies were published in diverse journals. While some journals were broad in terms of the country scope, others were context specific. The "Electronic Journal of Information Systems in Developing Countries" is an example of a context-specific journal that looks for publication only in developing economies.

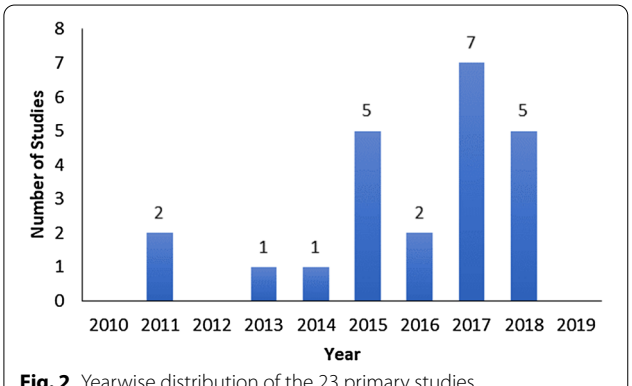


**Fig. 2** Yearwise distribution of the 23 primary studies

In addition, the highest number of primary studies (6) were retrieved from this journal. The second most popular publication channel was "Information Technology for Development" with 3 primary studies (see Table 5).

### Methodological quality

The overall methodological quality scores of the selected 23 primary studies are summarized in Fig. 3. All the four criteria (reporting, relevance, rigor, and credibility) were taken into account, and 13 of the studies (57%) have scores greater than or equal to 8 which can be said to be of good quality while 10 (43%) of the remaining primary studies with scores less than 8 is of medium quality.

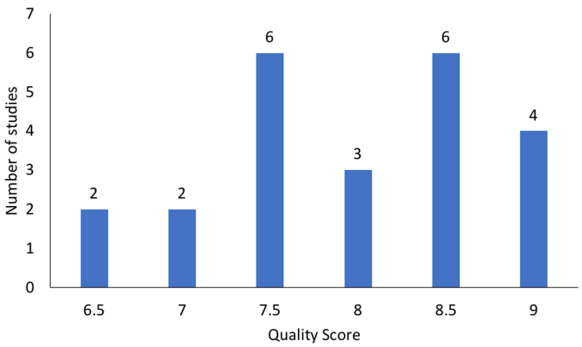


**Fig. 3** Overall quality of the 23 selected studies

### What are the main ICT technologies used within the agriculture domain? (RQ1)

The main ICT technologies reported in the primary studies are shown in Table 6. Most of the studies identified mobile phones as being the widely used ICT tool within the agriculture sector. According to most of the studies reviewed [11, 24–45], the proliferation of mobile phones within the African continent has led to the development of mobile-based applications and services within the sector. These services and applications are mostly targeted at farmers and provide a range of agricultural information such as market prices of farm produce, weather, agriculture input, and improved agriculture techniques. For instance, Ken Call is a farmer's helpline service in Kenya that provides agricultural advice and information to support smallholder farmers. Farmers are provided with information on improved agricultural production, inputs, processing, climate, and market information through the medium of a mobile phone [35].

Studies [25, 27, 29, 30, 37, 38, 41, 44] also highlighted the importance of radio in disseminating agriculture information to rural farmers. According to one study [25], the radio remains the most widely used medium in rural areas in four African countries. The study cited an example of an interactive radio project that was designed to help small-scale farmers to increase their production in Tanzania, Uganda, Malawi, and Ethiopia. The radio programme included regular radio broadcasts on agricultural information to farmers. The programme allowed farmers to ask questions through SMS or by calling and the responses are disseminated via the radio. Studies [25, 27, 29] explained that the use of radio by most farmers is because the programmes are broadcasted on community radios in the local language of the farmers allowing them to understand the content of the information better.

According to studies [11, 28, 31, 37] computers are mostly used by researchers and agribusiness experts within the agriculture sector. Furthermore, remote sensing technologies were also recognized by [31, 38, 45] as being accessible by researchers and agribusinesses. These technologies were identified to be inaccessible to farmers due to a lack of technical know-how and financial constraints.

**Table 5** Publication channel and the number of occurrences of the selected studies

| Publication channel | # |
|---|---|
| Progress in Development Studies | 1 |
| Telecommunications Policy | 1 |
| Electronic Journal of Information Systems in Developing Countries | 6 |
| Information Technology for Development | 3 |
| Journal of Agricultural Education and Extension | 1 |
| Journal of Enterprise Information Management | 1 |
| Technological Forecasting & Social Change | 1 |
| South African Journal of Information Management | 1 |
| Computers and Electronics in Agriculture | 1 |
| Information Processing in Agriculture | 1 |
| African Journal of Agricultural Research | 1 |
| International Journal of Agricultural Sustainability | 1 |
| Journal of Rural Social Sciences | 1 |
| Society and Business Review | 1 |
| Journal of Agricultural & Food Information | 1 |
| Journal of Agricultural Informatics | 1 |

**Table 6** ICT technologies identified from primary studies

| ICT tools | Studies |
|---|---|
| Mobile phone | [24–30, 32, 34–41, 43–45] |
| Radio | [25, 27, 29, 30, 37, 38, 41, 44] |
| Television | [29, 37, 38, 41, 44] |
| Computer | [11, 28, 31, 37] |

### Whom were the agriculture stakeholders identified in the studies? (RQ2)

This research question aims to identify the stakeholders under investigation in the selected primary studies and the resulting outputs are summarized in Table 7. A considerable proportion of the studies investigated the use of ICT tools among farmers. According to the studies, farmers use ICT tools such as mobile phones for contacting extension workers, and accessing prices of agriculture inputs and commodities. Studies [11, 28, 31, 42] discuss the use of ICT by researchers, extension workers, and agribusinesses. Here the focus is on the use of ICT in agriculture research. One study [28] examines the access and utilization of ICT among researchers and extension workers. Studies [11, 42] discuss social factors that contribute to the adoption of ICT among agribusinesses operating in rural areas. In one study [31], socio-technical factors that limit the usage of ICT by agriculture researchers are discussed.

**Table 7** Identified agriculture stakeholders

| Study | Farmers | Researchers | Extension workers | Agri-businesses | Country |
|---|---|---|---|---|---|
| [24] | X | | | | Ghana |
| [25] | X | | | | Ethiopia, Malawi, Tanzania, Uganda |
| [26] | X | | | | Mali |
| [27] | X | X | | | Tanzania |
| [28] | | X | X | | Zimbabwe |
| [29] | X | | | | Kenya |
| [11] | | | | X | Nigeria |
| [30] | X | | | | Tanzania |
| [31] | | X | | | Tanzania |
| [32] | X | | | | Uganda |
| [33] | X | | | | South Africa |
| [34] | X | | | | Ethiopia |
| [35] | X | | | | Kenya |
| [36] | X | | | | Mali |
| [37] | X | X | X | | Tanzania |
| [38] | X | | | | Kenya |
| [39] | X | | | | |
| [40] | X | | | | Burkina Faso |
| [41] | X | | | | Mozambique |
| [42] | | | | X | Nigeria |
| [43] | X | | | | Nigeria |
| [44] | X | | | | Tanzania |
| [45] | X | | | | Kenya |

## Which African countries have applied the ICT technologies? (RQ3)

Classifying the primary studies based on geographical location within which the studies were conducted, it was evident that the research was undertaken in 12 different countries, namely: Ghana, Ethiopia, Mali, Tanzania, Zimbabwe, Kenya, Nigeria, Uganda, South Africa, Malawi, Mozambique, and Burkina Faso (see Fig. 4). As shown in Table 7, Tanzania is mentioned most (in 6 studies), followed by Kenya (in 4 studies) and Nigeria (in 3 studies); the remaining countries are mentioned in either two studies or only one study.

### What are the agricultural domains considered for ICT innovation? (RQ4)

The agricultural domains encountered in the 23 selected primary studies are summarized in Fig. 5. Most of the primary studies (52%) emphasized the agriculture sector in general in studying the ICT innovations; 39% of the studies emphasized on crop cultivation; the focus on the livestock and agroforestry sub-domain constituted only 4% and 5% of the primary studies, respectively. Though the results of the generic studies may apply for the livestock and agroforestry sectors, the low number for these sectors indicates the low level of attention these sectors received from the scientific community studying ICT innovations in rural Africa.

### What are the frameworks used in the studies? (RQ5)

This research question aimed to identify the various frameworks used in the studies. The study identified four main theoretical frameworks from the primary studies as presented in Table 8.

As shown in Table 8, we identified four theoretical frameworks. These are the Technology Acceptance Model (TAM), the Diffusion of Innovation Theory (DOI), the Social Network Theory (SNT), and the Unified Theory of Acceptance and Use of Technology (UTAUT).

The DOI and TAM theories were the dominant theories used in the selected studies. For instance, studies [33, 39] used the DOI and TAM in providing a conceptual foundation for their studies. Study [32] applied the TAM to investigate the factors that determine the adoption of mobile phones among Uganda farmers. Similarly, study [33] used TAM and DOI to explore the adoption of ICT innovations by small-holder farmers.

The TAM postulate that perceived usefulness (PU) and perceived ease of use (PEOU) are the predictors of the intention of a user to use technology. PU denotes the extent of an individual's belief that using technology would enhance his or her performance while PEOU is the measure of the extent to which an individual believes that using technology would require less effort.

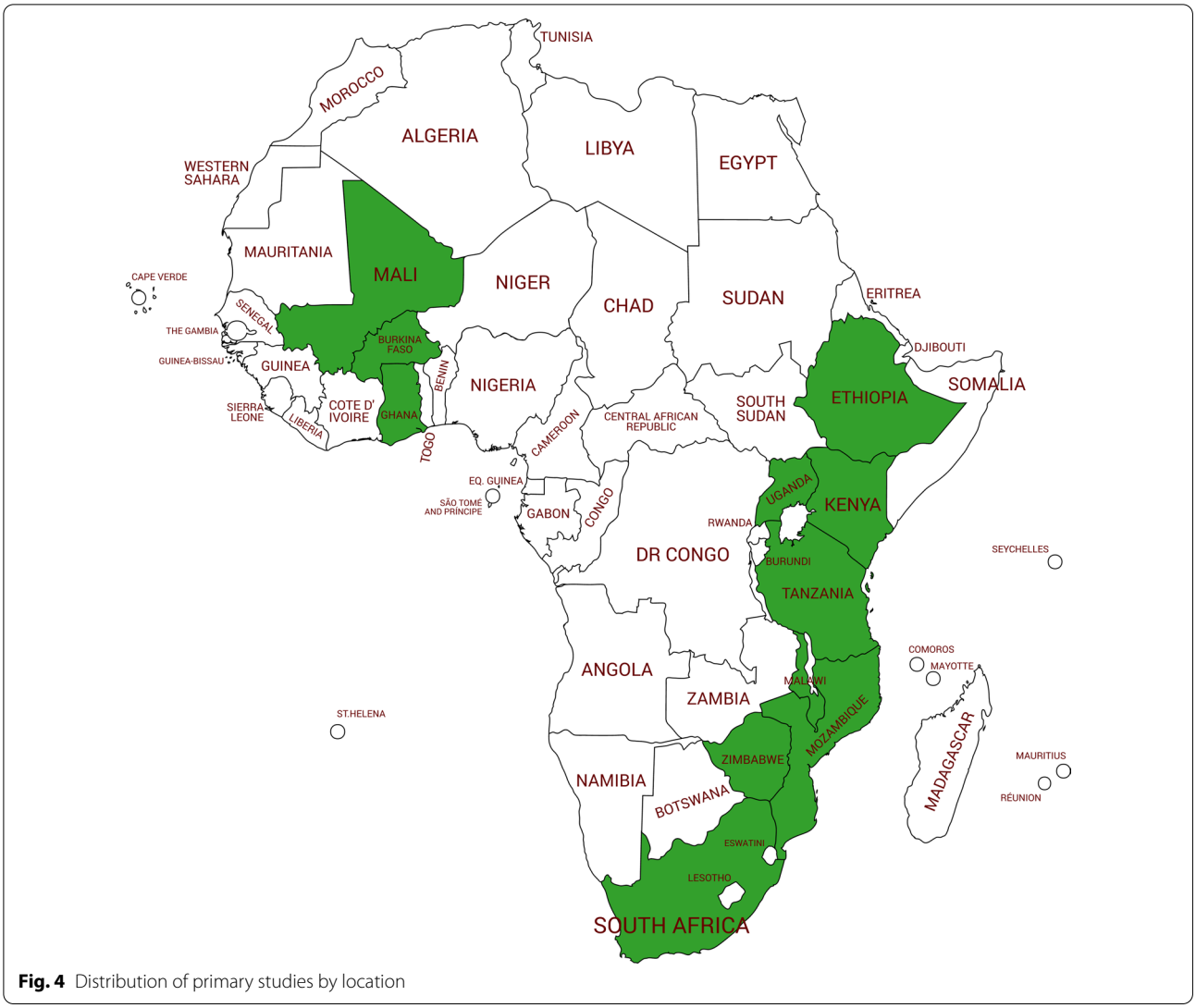


**Fig. 4** Distribution of primary studies by location

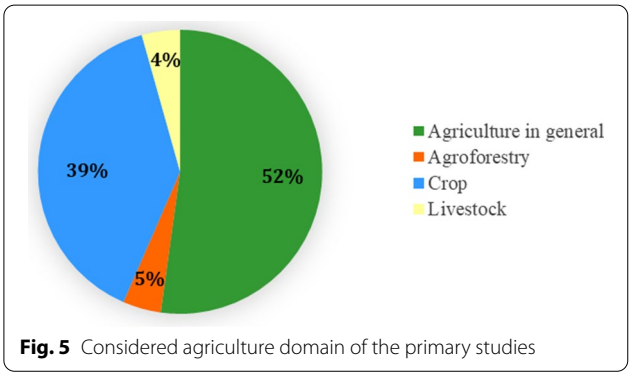


**Fig. 5** Considered agriculture domain of the primary studies

The DOI postulates five main characteristics of innovation that determine the rate of adoption, namely: relative advantage, compatibility, simplicity, observability, and trialability. Relative advantage is the degree to which an innovation is perceived as being useful. Compatibility talks about the degree to which an innovation is perceived as consistent with the existing values and needs of potential users. Simplicity is the degree to which an innovation is perceived as relatively less complex and easy to understand and use. Observability on the other hand is the degree to which the results of an innovation are visible to others. Trialability describes how easily the innovation can be explored.

Studies [11, 42] used the SNT theory to identify the social imperatives that impact the adoption of ICT by agribusinesses. The SNT refers to the social structure of relationships and links between individuals, and organizations within a particular context that can influence ICT adoption behaviour. According to the studies,

**Table 8** Theoretical frameworks identified from SLR

| Type of theory | Construct | Studies |
|---|---|---|
| Technology acceptance model (TAM) | Perceived usefulness<br>Perceived ease of use | [11, 32, 33, 39, 42] |
| Diffusion of innovation theory (DOI) | Relative advantage<br>Compatibility<br>Simplicity<br>Observability<br>Trialability | [11, 26, 28, 29, 33, 34, 36, 39, 42] |
| Social network theory (SNT) | Social influence<br>Network externalities | [11, 42] |
| The unified theory of acceptance and use of technology (UTAUT) | Performance expectancy<br>Effort expectancy<br>Facilitating conditions<br>Social influence | [34] |

communication, networking, and active participation among agribusinesses influence the awareness and diffusion of ICT innovation among agribusinesses.

Study [34] adopted the UTAUT theory in identifying the drivers of mobile SMS adoption by farmers. The UTAUT incorporates social influence in determining behavioural intention. The UTAUT postulates that behavioural intentions are determined by four key constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions. Performance expectancy is the degree to which using technology will provide benefits to users in performing certain activities. Effort expectancy is the degree of ease associated with farmers' use of technology. The underlying concept of social influence is that individuals can be influenced by the perceived social pressure of important others. Facilitating conditions are also perceived enablers or barriers in the environment that influence a person's perception of ease or difficulty of performing or using an ICT technology.

#### What are the challenges in ICT adoption (RQ6)?

The identified challenges are summarized in Table 9. The challenges are classified into four categories: poor infrastructure, low capacity of the intended users of ICT innovations, poor ICT policies, and inefficiencies in agriculture institutions. Each of these challenges is further discussed in detail.

##### *Poor infrastructure*

Study [27, 28, 31, 38, 43–45] discuss poor infrastructure as a challenge to the adoption of ICT. According to the studies, infrastructure development is still in its infancy in most African countries. This is, however, prevalent in most rural communities. Most rural communities in Africa are characterized by poor road network, no access to electricity, and poor network connectivity. As most of the farming population live in rural communities, the absence of these technological infrastructures poses a barrier to ICT adoption.

**Table 9** Identified challenges from primary studies

| Challenges | Description of challenges | Studies |
|---|---|---|
| Poor infrastructure | Unreliable electricity supply<br>Network connectivity problem | [27, 28, 31, 38, 43–45] |
| Low capacity | Low illiteracy rate<br>Lack of ICT knowhow<br>Poverty | [27, 28, 31, 38, 43–45] |
| Poor ICT policies | Lack of appropriate ICT policies<br>Poor monitoring of ICT projects<br>Poor funding of ICT initiatives | [27, 28, 31, 38, 43–45] |
| Inefficiencies in agriculture institutions | Weak network between agriculture institutions<br>Poor incentives to motivate stakeholders | [31, 45] |

##### *Low capacity*

The adoption of ICT is constrained by poverty, lack of ICT know-how, and illiteracy as discussed in studies [27, 28, 31, 38, 43–45]. One important aspect identified in the studies is the illiteracy rate among farmers. According to the studies, the illiteracy rate is very high amongst smallholder farmers which affects their ability to effectively understand and manage the use of ICT tools. In addition, farmers are unable to afford the cost of servicing mobile phones and paying for extension advisory services rendered by ICT innovators because of their low standard of living. Furthermore, studies [28] and [34] highlights the role of gender in ICT adoption. According to the studies, women are not equally able to access and use ICT due to their unequal access to opportunities such as income and education.

#### *Poor ICT policies*

Furthermore, poor ICT policies is discussed in studies [27, 28, 31, 38, 43–45]. Agriculture development in most African countries has been undermined by poor policies that constrain market entry and the effective allocation of resources. According to the studies, poor prioritization of ICT initiatives, weak monitoring, and poor implementation and integration of ICT within the sector are due to poor ICT policies. This affects the adoption of ICT in agriculture, especially those targeting rural communities and rural development. In addition, the adoption of ICT is constrained by uncoordinated and scattered ICT initiatives as discussed in the studies.

#### *Inefficiencies in agriculture institutions*

According to studies [31, 45], ICT adoption is hindered by inefficiency in agricultural research institutions in Africa. Diversity among agriculture stakeholders, lack of commitment and accountability of policymakers and agriculture experts, and lack of incentives to undertake ground-breaking ICT research affect the effective adoption of ICT. In addition, weak institutions, lack of information sharing, and lack of awareness of existing ICT facilities and resources affect ICT adoption is discussed.

## Discussion

This systematic review presented the findings of the 23 selected primary studies on the adoption of ICT within the agriculture domain in Africa. We identified that high-quality papers have been published on the topic over the past years. In this study, we summarized the findings of the selected primary studies using a qualitative research approach. The analysis of the primary studies showed the proliferation of technological innovations such as television, radio, computer, and mobile phone in the agriculture sector. ICT innovations, particularly mobile phones, were identified as the predominant innovative tools used within the sector, which is in line with the findings of [9]. Apps and services on mobile phones which are mostly targeted at farmers allow farmers to access financial and extension-advisory services such as weather, market, and agriculture advice. The use of remote sensing technology which is one of the enabling ICT technologies is also available within the sector but mostly accessible to researchers and agribusinesses only for research-related purposes. Despite the proliferation of ICT technologies, usage and accessibility are still constrained by poor infrastructure, poor policy environment, and low ICT skills and competencies of farmers.

The study also identified various theories underpinning the primary studies. The theoretical approaches tend to be narrowly focussed, identifying specific constructs that affect the adoption of technology and then using empirical evidence to demonstrate the robustness of the identified constructs. Several gaps were identified in the various theories. The TAM model for instance focuses on attributes such as ease of use and perceived usefulness in determining factors that affect the adoption of technology. This theory tends to focus on the technical feasibility of the technology without taking into consideration other socio-economic factors that might impact adoption. Similarly, the DOI also falls in line with the proposed construct in TAM and thereby lacks a social–cultural context. The SNT, however, discusses only social dimensions that affect adoption. These individual theories do not fully explain the factors that affect ICT adoption or usage. This confirms the findings of Zewge and Dittrich [9]. According to the authors, an appropriate design solution that takes social, as well as technical issues into account, is lacking in most literature. To prevent a mismatch between deployed technologies and the ecosystem of the local community, it is important to understand all the possible factors including usage-context factors that might impact adoption. The UTAUT model addresses the shortcoming by combining the TAM and seven other models into a unified user adoption model. This model is developed for the specific goal of exploring the willingness to adopt mobile SMS technology by smallholder farmers. It was also evident that literature on generic frameworks for guiding the development of new ICT solutions is lacking as most of these theories focus on assessing the feasibility of already existing ICT solutions.

Regarding threats to the validity of our study, a review protocol was adapted in the study which helped in ensuring a rigorous review. In ensuring that an adequate number of relevant studies are retrieved, different databases were searched and both automatic and manual search approach was employed. We were, however, unable to exhaust all available databases. Moreover, our review was restricted to English language publications, making it a possibility that some relevant studies were missed. Furthermore, our study mainly focussed on published scientific literature. Grey literature, such as reports and non-scientific journals were not included in the study. This exclusion may have excluded relevant information.

To ensure that the keywords used were related to the research topic, pilot searches on search engines of selected electronic databases were conducted before constructing the keyword list. Data extraction form was also developed and the necessary fields that answer the research questions were outlined in consultation with fellow authors which helped in ensuring a detailed data extraction. In ensuring that bias at the reporting phase is reduced, evaluation by fellow authors was highly valued. The findings and conclusions were evaluated by

individual authors and areas for improvements were identified and improved.

## Conclusions

In this study, we have provided a systematic review of the state of the art of ICT innovations within the agriculture sector in Africa. The results of the study will contribute to the scant literature on the state of the art of ICT innovation in Africa. In addition, this study uses theoretical insights to make recommendations and policy suggestions.

The review followed a detailed protocol and included primary studies from 2010 to 2019. We identified 779 papers after applying our search string and selected 23 primary studies that are relevant for addressing our research questions. The analysis of the primary studies revealed mobile-based services and platforms as the predominant ICT innovations within the agriculture sector in Africa. Applications and services on mobile phones allow farmers to access extension advisory services such as weather and market price information. Radios are still widely used in disseminating agriculture information to rural farmers.

Several challenges that were found to impede the adoption of ICT include poor policy environment, low capacity, and poor technological infrastructure within the continent. The study thus recommends the training and empowerment of smallholder farmers to enhance their ability to interact with new agriculture technologies. There is also the need for the development of a favourable policy and business environment that favours the use of ICT's and other digital technologies. Strong commitment, trust, and collaborations are also needed among the different actors in the agriculture value chain.

The theoretical frameworks identified from the primary studies tend to be predominantly focused on assessing the technical feasibility of the ICT tools that can impact adoption. We were unable to find a generic framework that took into account the social and cultural dimensions of the local context. In addition, while the challenges in adopting ICT innovations have attracted the focus of researchers, the advantages and disadvantages of adopting the technologies are important areas of study that need to be explored. This study, therefore, recommends a more holistic framework for guiding the development of ICT initiatives. The limited number of primary studies found indicates that the number of publications available on the topic is not extensive. There could be a larger number of publications available as reports and non-scientific publications that could be included in such analysis. Future studies could expand the scope of the research to include publications both on scientific and grey literature to provide further insight.

## Appendix

### A. Quality assessment checklist

| Study | Quality of Reporting | | | Rigour | | | Relevance | | Credibility | | Quality of reporting | Rigour | Relevance | Credibility | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | | | | | |
| [24] | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0.5 | 1 | 0 | 3 | 2 | 1.5 | 1 | 7.5 |
| [25] | 1 | 1 | 0.5 | 0 | 0.5 | 1 | 1 | 1 | 1 | 0 | 2.5 | 1.5 | 2 | 1 | 7 |
| [26] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.5 | 1 | 0.5 | 3 | 3 | 1.5 | 1.5 | 9 |
| [27] | 1 | 1 | 1 | 0.5 | 1 | 1 | 1 | 1 | 1 | 0.5 | 3 | 2.5 | 2 | 1.5 | 9 |
| [28] | 1 | 0.5 | 1 | 1 | 0.5 | 1 | 0.5 | 0.5 | 1 | 0 | 2.5 | 2.5 | 1 | 1 | 7 |
| [29] | 1 | 1 | 1 | 1 | 1 | 1 | 0.5 | 1 | 1 | 0 | 3 | 3 | 1.5 | 1 | 8.5 |
| [30] | 1 | 1 | 1 | 0 | 1 | 1 | 0.5 | 0.5 | 1 | 0.5 | 3 | 2 | 1 | 1.5 | 7.5 |
| [32] | 1 | 1 | 0.5 | 1 | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 2.5 | 2 | 1.5 | 2 | 8 |
| [34] | 1 | 1 | 1 | 1 | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 3 | 2 | 1.5 | 2 | 8.5 |
| [35] | 0.5 | 1 | 1 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 | 2.5 | 2.5 | 2 | 2 | 9 |
| [36] | 1 | 0.5 | 1 | 1 | 0.5 | 1 | 1 | 1 | 1 | 0.5 | 2.5 | 2.5 | 2 | 1.5 | 8.5 |
| [37] | 0.5 | 1 | 1 | 0.5 | 1 | 1 | 0.5 | 1 | 1 | 0 | 2.5 | 2.5 | 1.5 | 1 | 7.5 |
| [38] | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 0.5 | 1 | 0 | 2.5 | 2.5 | 1.5 | 1 | 7.5 |
| [40] | 1 | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 1 | 0.5 | 3 | 2 | 2 | 1.5 | 8.5 |
| [41] | 1 | 1 | 1 | 0.5 | 1 | 1 | 1 | 0.5 | 1 | 0 | 3 | 2.5 | 1.5 | 1 | 8 |
| [43] | 1 | 1 | 0.5 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 2.5 | 2 | 2 | 1 | 7.5 |

| Study | Quality of Reporting | | | Rigour | | | Relevance | | Credibility | | Quality of reporting | Rigour | Relevance | Credibility | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | | | | | |
| [44] | 1 | 0.5 | 1 | 0.5 | 0 | 1 | 0.5 | 0.5 | 1 | 0.5 | 2.5 | 1.5 | 1 | 1.5 | 6.5 |
| [45] | 1 | 1 | 0.5 | 0.5 | 0.5 | 1 | 0.5 | 0.5 | 1 | 0 | 2.5 | 2 | 1 | 1 | 6.5 |
| [11] | 1 | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 3 | 2 | 1.5 | 2 | 8.5 |
| [31] | 1 | 1 | 1 | 0.5 | 1 | 1 | 1 | 0.5 | 1 | 1 | 3 | 2.5 | 1.5 | 2 | 9 |
| [33] | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 0.5 | 1 | 0.5 | 2.5 | 2.5 | 1 | 1.5 | 7.5 |
| [39] | 1 | 1 | 1 | 1 | 0.5 | 1 | 1 | 0.5 | 1 | 0 | 3 | 2.5 | 1.5 | 1 | 8 |
| [42] | 1 | 1 | 0.5 | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 2.5 | 2.5 | 1.5 | 2 | 8.5 |

## B. Data extraction form

| Extracted element | Contents |
|---|---|
| General information | |
| ID | Unique ID for the study |
| Authors | |
| Title | Full title of the paper |
| Year | The publication year |
| Source Title | The Publication channel |
| Document Type | + Journal + Article |
| Repository | Scopus,<br>ScienceDirect,<br>Wiley Online,<br>Abi/Inform,<br>Taylor and Francis |
| Study description | |
| Study design | + Survey + Case study + Experiment |
| Considered ICT domain | |
| Unit of analysis | Targeted agriculture stakeholders |
| Country scope | |
| Considered agriculture domain | |
| Identified theoretical framework | + Yes + No |
| Identified challenges | + Yes + No |
| Evaluation | |
| Quality assessment | Quality, Rigour, Relevance, Credibility |

## C. Data extraction table

| Ref | Authors | Year | Study design | RQ1 | RQ2 | RQ3 | RQ4 | RQ5 | RQ6 | RQ7 |
|---|---|---|---|---|---|---|---|---|---|---|
| [24] | Owusu A.B., et al | 2017 | Survey | Mobile phone | Farmers | Ghana | Crop | Access agriculture market information | Not specified | |
| [25] | Hudson H.E., et al | 2017 | Survey | Radio and mobile phone | Farmers | Ethiopia, Malawi, Tanzani, Uganda | Crop | Increase adoption of proper farm practices | Not specified | |
| [26] | Kante M., et al | 2017 | Survey | Mobile phone | Farmers | Mali | Crop | Access agriculture market information | Diffusion of innovation theory ( DOI) | |

| Ref | Authors | Year | Study design | RQ1 | RQ2 | RQ3 | RQ4 | RQ5 | RQ6 | RQ7 |
|---|---|---|---|---|---|---|---|---|---|---|
| [27] | Barakabitze A.A., et al | 2017 | Survey | Mobile phone and radio | Researchers and farmers | Tanzania | Crop | Improve business operations | Not specified | Yes |
| [28] | Mugwisi T., et al | 2015 | Survey | Computers,telephone and mobile phone | Researchers and extension | Zimbabwe | Generic | Improve business operations | DOI | |
| [29] | Mwombe S.O.L., et al | 2014 | Survey | Radio, television, mobile phone | Farmers | Kenya | Crop | Access agriculture market information | DOI | |
| [11] | Aleke B., et al | 2011 | Survey | Computer | Agribusinness | Nigeria | Agriculture in general | Enhance business operations | TAM, DOI, SNT | |
| [30] | Misaki E., et al | 2016 | Survey | Radio and mobile phone | Farmers | Tanzania | Agriculture in general | Access agriculture market information | Not specified | Yes |
| [31] | Barakabitze A.A., et al | 2015 | Survey | Computer, Video recorder, remote sensing, GIS | Researchers | Tanzania | Agriculture in general | Improve business operations | Not specified | Yes |
| [32] | Kabbiri, R., et al | 2018 | Survey | Mobile phone | Farmers | Uganda | Livestock ( dairy) | Access agriculture information | Technology acceptance model | |
| [33] | Jere N.J., et al | 2017 | Survey | ICT in general | Farmers | South Africa | Agriculture in general | Improve production | Technology acceptance model | |
| [34] | Beza, E., et al | 2018 | Experiment | Mobile phone | Farmers | Ethiopia | Crop | Access agriculture information | UTAUT | |
| [35] | Wyche, S., et al | 2015 | Case study | Mobile phone | Farmers | Kenya | Agriculture in general | Access market price | Not specified | |
| [36] | Kante M., et al | 2018 | Case study | Mobile phone | Farmers | Mali | Crop | Access agricultural information | DOI | |
| [37] | Mtega, W. P., et al | 2013 | Case study | Mobile phone, radio, television, computers and internet | Farmers, extension, researches | Tanzania | Agriculture in general | Access agriculture information | Not specified | |
| [38] | Kiambi, D | 2018 | Case study | Radio, television, mobile phone, GIS, web portal | Farmers | Kenya | Agriculture in general | Access agriculture information | Not specified | Yes |
| [39] | Meijer, S.S., et al | 2015 | Case study | ICT in general | Farmers | Generic | Agroforestry | Access agricultural information | TAM, DOI | |
| [40] | Maredia, M.K., et al | 2017 | Experiment | Mobile phone | Farmers | Burkina Faso | Crop | Access agricultural information | Not specified | |
| [41] | Freeman, K. et al | 2017 | Case study | Mobile phone, radio,television | Farmers | Mozambique | Crop | Access agricultural information | DOI | |
| [42] | Aleke, B., et al | 2011 | Case study | e-commerce | agri-businesses | Nigeria | Agriculture in general | To improve business operations | Social network theory | |
| [43] | Otene, V.A., et al | 2018 | Survey | Mobile phone | Farmers | Nigeria | Agriculture in general | Access agriculture information | Not specified | |

| Ref | Authors | Year | Study design | RQ1 | RQ2 | RQ3 | RQ4 | RQ5 | RQ6 | RQ7 |
|---|---|---|---|---|---|---|---|---|---|---|
| [44] | Magesa, M.M., et al | 2015 | Survey | Radio, mobile,TV | Farmers | Tanzania | Agriculture in general | Access agriculture market information | Not specified | Yes |
| [45] | Awuor, F., et al | 2016 | Survey | Mobile, sensors | Farmers | Kenya | Agriculture in general | Access agriculture market information | Not specified | Yes |

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**Ethics approval and consent to participate**
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**Consent for publication**
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**Competing interests**
All authors declare that they have no conflict of interest.

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