A Survey of Intelligent Agro-climate Decision Support Tool for Small-Scale Farmers: An Integration of Indigenous Knowledge, Mobile Phone Technology and Smart Sensors

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Abstract Food security in Africa and the rest of the globe has come under tremendous threat, meaning that agriculture which is the driving force behind many economies is under threat. Seventy per cent of the food produced in sub-Saharan Africa is produced in the rainfed small-holder agriculture, which in turn is the most devastated by any disasters experienced in the agricultural sector. Although the indigenous knowledge system has been used by many small-scale farmers as the basis for their day-to-day agricultural decision support, climate change and global warming have rendered this knowledge unreliable. Documented limitations on the isolated use of indigenous knowledge and modern scientific systems are the basis of this study. We investigate the effectiveness of the integration of indigenous knowledge interpreted through fuzzy inference systems, mobile phone and smart sensor technology with intelligence, on farmers decision support systems.

Keywords Fuzzy inference systems (FIS) · Indigenous knowledge · Decision support systems (DSS) · Cropping decisions · Small-scale farmers · Sensor technology

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S. Fong et al. (eds.), *ICT Analysis and Applications*, Lecture Notes in Networks and Systems 154, https://doi.org/10.1007/978-981-15-8354-4_71

1 Introduction

Information and Communication Technologies (ICT) in agriculture may generally include technologies such as Global Positioning System (GPS), robotic systems, sensor technology and Geographic Information Systems (GIS). There is a plethora of these kinds of technologies already developed and put to a test in an effort to support agricultural practices and operations in order to improve production [1]. It should not come as a surprise therefore that so much research effort and resources have been put behind agricultural innovation. Agriculture is a mammoth economic driver in most countries and has the highest impact on the world's food security. Of all the food produced in sub-Saharan Africa, 80% is produced in the informal rainfed smallholder farms. Besides, out of 235 droughts reported worldwide between 2006 and 2015, 50% occurred in Africa. It is evident therefore that Africa is leading in terms of global droughts in comparison with the rest of the world [2]. What is more striking about these statistics is that these droughts have been reported to have been the cause of about 99% of deaths that occurred in Africa. Evidently, Africa is the worst affected by droughts, and small-scale farmers are the most tremendously affected by the most unpropitious disasters such as these, due to the absence of timeous warnings and relevant information [3].

It is important to differentiate small-scale farmers from the rest of the agricultural sector. According to [4], "A small-scale farmer is one whose scale of operation is too small to attract the provision of services he/she needs to be able to significantly increase his/her productivity". These farmers do not have access to equipment and machinery that can make their work easier. In fact, their work is labour intensive, and they rely on their human strength. They also have no access to any kind of ICT assistive tools due to the high costs related to such. Access to information such as weather forecast is another limitation for the small-scale farmer. Small-scale farmers mostly rely on their indigenous knowledge as a form of forecast and the basis for their daily decision support operation [5].

Why integrate indigenous knowledge into mobile technology, you may ask. Mobile phone technology is playing a colossal role in bridging the digital divide in Africa [6], i.e. the gap that exists between the demographic regions that have no access to modern ICT and Internet and those that don't. The mobile technology in comparison with other ICT technologies that is more affordable, user-friendly and less complicated in a sense that it has less infrastructure requirements. The mobile technology footprint in Africa stands at higher than 63% [7]. In Africa, mobile phone technology overtooks the use of landlines [6] to become the preferred mode of communication. In comparison with other available technologies in terms of performance and preference, mobile phone technology has become the technology of choice because of portability, high computing speed and power [8].

ICT in agriculture most often includes collaboration of two or more technologies. Agro-climate is a term used to refer to decision support tools in agriculture that incorporates climate information in crop management. Research has already shown that there is great potential in combining different ICT for agriculture to provide smart technology in an effort to improve small-scale farmers' production [3]. In pursuit of such kind of smart technology, artificial intelligence (AI) and the creation of intelligent systems have become the new and most popular topic in technology.

This paper is aimed at developing a study that seeks to review and evaluate provision of the small-scale farmer with a portable, cost-effective, accessible and sustainable decision support tool. This would be done to enhance the small-scale farmers capability to make informed cropping decisions. The idea is to exploit technologies that have already been severally employed but never together. Incorporation of indigenous knowledge and to build this intelligent system will be evaluated to determine intensity of precision. Figures adapted from other papers shall be cited in the text and in the figures and tables section.

2 Mobile Phone Technology in Agriculture

2.1 Mobile Phone Technology Background

In 1947, when the transmitter was invented, an engineer at the Bell Labs sketched out the rough design for a standard cellular phone network, his name was Douglas H Ring. It would take 40 years for technology to catch up with that vision. Although Martin Cooper of Motorola is considered the inventor of the hand-held cellular telephone, he used technology developed by Bell Labs engineers. Since the very first invention, mobile phone technology evolved five generations and transformed the way we live. The first generation of mobile phone technology basically used analog radio signals. It was gradually replaced by the second generation which incorporated digital networks, and the first introduction of short message service (SMS) and multimedia messaging service (MMS). The third generation introduced multimedia application and Internet application with high connectivity speed. The fourth generation improved on the Internet connection speed, and the fifth generation is expected to solve most major smart phone issues and the security over the Internet.

2.2 Mobile Technology Is Sub-Saharan Africa

In terms of ICT indicators, though African has made a significant improvement in terms of Internet use, it is still far behind other counterparts from other regions [5]. In Africa, where the footprint of mobile phone stands higher than 63% [7], idiosyncrasies are towards mobile broadband as an Internet connectivity of choice because the cost of mobile broadband is fifty per cent lower than that of fixed broadband. According to [7], "Advancement in mobile phone technology has resulted in phones that can ably compete with personal computers of less than a decade ago; the devices (especially smart phones) are no longer used as mere phones for making/receiving calls". The mobile phone added advantage is that it can act as both input and output device, owing to its highly technologically developed user interface.

The mobile phone technology has become a gigantic form of communication worldwide, and mobile phone networks have gained an explosive growth in the more recent past [6]. According to [6], mobile phone technology in sub-Saharan Africa has enhanced dissemination and retrieval of information for people, particularly in the rural communities. The author discovered that in Africa, mobile phones overtook the number of landlines. According to [9], "since the 2000s, mobile phone ownership has grown faster in Africa than anywhere else in the world". The author points to the fact that 83% of the population in Africa currently has mobile subscription. Mobile phones technology has also had an impact on the decrease of certain costs, resulting in improved functioning of certain sectors including agriculture, and there has been great improvement in the way business is conducted. Sub-Saharan Africa continues to lead the whole world in adoption of mobile money services [6, 10], and in sub-Saharan Africa, mobile industry continues to experience exponential growth reaching 367 million subscribers in 2015. Mobile phones are the most easily accessible and cost-effective technology available in South Africa. According to [11], "Africa has achieved a mobile phone penetration level much higher than that of computers". It is apparent therefore that it would be easy for any small-scale farmer operating anywhere to acquire one.

Mobile communication technology has become the most quotidian manner of transmitting data and services in a world that is constantly evolving. This drastic change gave rise to mobile applications [10]. The author suggests that mobile applications for agricultural and rural development possess potential for the advancement of rural development and can provide an affordable medium of information access to numerous people who were previously disadvantaged. Mobile phone technology seems to be bridging the gap in Africa between the rural demographic group with restricted access and the more urban demographic group with access to the latest ICT [6], owing to the fact that in comparison to other ICT mobile phone technology is much more affordable. Studies have also proved that if mobile phones were exploited properly they could improve the influence of sub-Saharan African farmers in the value chain [6].

According to [12], it is of the most utmost importance to explore intentions of small-scale farmers to adopt technological inventions that affect them. The study showed that expectancy of performance and effort, price value and trust proved critical to the adoption of such. In [6, 13], the author eluded to the fact that the farmers would have to be educated to realize the full potential of the mobile phone technology that is being offered in order to gain their buy in for the purpose of the adoption or acceptance of the ICT in their space. According to [6], studies have shown how technology and digitization impact on rural communities and that it can aid curb hinderances such as information access challenges for small-scale farmers.

2.3 Mobile Technology in Agriculture

According to [6], one of the most neglected global challenges that Africa faces is digital divide. However, the author eludes to the fact that this colossal challenge is being restrained by the adoption of mobile phones. In agriculture, technology-based decision support tools are typically software applications that commonly based on models that describe different processes in farming [10, 14]. "Mobile phone technology holds significant potential for advancing development" [10], but many technologies in agriculture, including those that are climate-smart are not being maximized because of low rate of adoption by small-scale farmers [1, 6]. Users for mobile technology in agriculture are also diverse and include several stakeholders. Mobile phone technology applications generally provide crucial information for rural small-scale farmers. DrumNet is one of the mobile applications used by Kenyan farmers, which has been instrumental in increasing their income by a third.

3 Integration of Indigenous Knowledge and ICTs in Small-Scale Farming in Africa

3.1 Indigenous Knowledge

The indigenous knowledge, which seems to be challenged currently by the ever-changing climate, is the local based (undocumented) knowledge that the small-scale farmers have employed for many years as a prediction tool and decision support management tool. It is somehow a legacy for the community and passed down from generation to generation [11]. Indigenous knowledge is normally based on the cultural ties to the natural environment, and the interpretation of the behaviour of nature around, including insects, animals and birds for example. This can include predictions such as rain or drought forecast, ploughing and planting season, harvest success and is based on environmental circumstances and events. These events can include, as an example, the yellowing of leaves on a crop, which will have a meaning attached to depending on the community. This has been the basis of the decision supporting tool used by small-scale farmers. The idea is not to confiscate the indigenous knowledge they are already familiar with, but to turn it into an enhanced decision supporting tool that is collaborated with modern science and technology.

3.2 ICTs in Small-Scale Agriculture

Information and Communication Technologies (ICT) in agriculture encompasses a plethora of technologies already in services [15], such as Global Positioning System (GPS), Geographic Information Systems (GIS), robotic systems and many more. In

South Africa, the agricultural industry is fractionated in two sectors. These include the large-scale commercial farmers and the small-scale rural farmers. The differentiation between the two was defined by the Department of Agriculture. According to [4], the Department of Agriculture states in their policy, "a small-scale farmer is one whose scale of operation is too small to attract the provision of services he/she needs to be able to significantly increase his/her productivity". The technology, mechanization and machinery available to support daily operations are in fact what separates the two, and the size has nothing to do with establishment of the difference. While state-of-the-art technology and sophisticated machinery is at the disposal of the commercial farmer for the support of daily running, the small-scale rural farmer will support his daily operations through intense labour, relying on their own strength and working with their hands. Hiring equipment is a luxury for the small-scale farmer.

3.3 Integration of Indigenous Knowledge in ICTs

Potential in collaboration of ICT to provide smart innovation for agriculture was uncovered in a study by [3]. The study proved that "the greatest impact of ICT can be expected in areas where farmers' actions are currently the primary limitation to their production". The author emphasizes that advancement in a single aspect of agricultural crop farming without taking into consideration all other relevant aspects such as soil tillage, geographic location, tolerance of environmental stress, soil type, rainfall, soil fertigation, pests and disease control and nutrition can be economically inefficient. The study concluded that it was critical to scale up on agricultural ICT services for small-scale farmers, but also that these services should be delivered at tailored local scale to for them to be relevant and to support the small-scale farmers' decision management.

A study reported in [16] highlighted the need for integration of indigenous knowledge in agricultural ICT development. According to the author, "farmers greatly value local experiential knowledge as they see it as having practical, personal and local relevance". It is therefore important to deliver information to small-scale farmers in a customized format that is relevant to them. In actual fact, studies have uncovered that more than 80% of farmers in countries such as Kenya, Zambia and Zimbabwe in the African continent are still dependent on their indigenous knowledge as a form of forecast on which their daily agricultural management decisions are based [2]. In the study by [17] the author quotes, "the effectiveness of the forecast information depends strongly on the systems that distribute the information, the channels of distribution, the recipients' models of understanding and judgement about the information sources, and the way in which the information is presented".

There is a strong relationship that exists between Indigenous knowledge and the decision support systems (DSS) that are based on scientific models. This relationship between the two areas of expertise in question has been accepted as rather complementary and not antagonistic. This manifested the basis of countless relevant and appropriate technologies that have been inaugurated to date [11]. Researchers are also in one accord to the certitude that the integration between the two "can improve livelihoods", that means making a valuable difference in the lives of many. According to the author, "in order to build sustainable strategies, it is therefore important to take into account of, and learn from what the local people already know and do". As much as Indigenous knowledge and scientific models may harmonize, they are luminously contrasting expertise. Considering that Indigenous knowledge indicators have come under threat owing to the change in climate and global warming, it can be argued that science is needed to support the fading discipline.

Meteorological organizations in Africa have a colossal task with seasonal weather forecast generation. They are equipped with currently very few weather stations scattered over a vast area. This is an opportunity to introduce technologies that will help to bridge the gap and the indigenous knowledge of the local communities can contribute to the solution, giving them a sense of ownership of a system that is delivered. There is an opportunity that can be exploited in thorough unclouded comprehension of indigenous knowledge and appropriate integration with science, particularly in the distribution of weather forecasts to farmers in rural settlements.

In pursuit of the solution to the question, "does incorporating indigenous knowledge into the drought prediction tool improve the resilience and relevance to the countries in Sub-Saharan Africa", in a study by [17] a framework was developed for integration of mobile technology and indigenous knowledge for Africa. The idea is to enhance what the small-scale farmer also has, rather than replace it completely to curb resistance in adoption of the deliverable system. According to the study done by [6], the conclusion was that "perceived advantage and perceived usefulness influences mobile phone adoption negatively". This was attributed to the fact that most small-scale farmers only used their mobile phones for normal communication and not as an assistive tool for their agricultural activities. Incorporating what they already know, that their indigenous knowledge, could play a role in encouraging adoption of the deliverable system. This also encourages multi-purpose of their mobile phones.

4 Decision Support Systems for Small-Scale Farmers

"Agricultural decision support tools are typically software applications, commonly based on models describing various biophysical processes in farming systems and the response to varying management practices" [14]. Agricultural practices and operations are governed by decision management, which is in turn dependent upon or is supported by access to information such as climate forecast, soil fertigation, soil type and humidity. Crop farmers always need to be cognizant of all these factors to be able to make the right decision. According to [18], while either sparse or excess rain may kill crops, the adequate amount of rain spawns an ideal yield of crop. Hence small-scale farmers need timeous forecast on weather and climate. In sub-Saharan Africa, it is a gargantuan task for the rural small-scale farmers to just acquire seasonal climate forecasts even though it is constantly and regularly provided by meteorological institutions, because of the manner in which the information is distributed [17].

A plethora of variable models and tools have been investigated to forecast various features of crop agriculture [15, 18–21]. It is lucid therefore, that predicting crops are complex enough to require a synthesis of various considerations to deduce the best agricultural practices that maximize productivity. The proposed system solicits a solution that merges and brings assorted aspects of crop agricultural decision support tools into convergence and disentangles small-scale farmer's decision support management.

Niche market would be a luxury for the small-scale farmer, and therefore because they do not specialize, they often plant an assortment of crops planted in the same field. Studies were conducted to determine how to deal with the challenge of water tolerance in intercropping [22] and to determine what crops would thrive if paired in intercropping process [23]. According to [24], enhanced productivity can become a consequence of intercropping that is balanced and well-managed. Successful intercropping happens when paired crops profit from one another in a positive exchange of nutrients or water source. Though small-scale farmers make use of intercropping, it is done from an illiterate and ill-informed place. The lack of information is the reason why it has not been exploited to full extent. According to [24], "farmers need an efficient, relevant and accurate way to evaluate data for specific management decision". This presents incorporation opportunity for a solution that can be incorporated into the proposed system.

According to [25], one of the challenges that are faced by small-scale farmers in developing countries is undiagnosed crop diseases or inefficiency in the diagnosis of crop diseases. This study also found that some of the drawbacks in existing systems in agriculture generally includes insufficient knowledge about the diseases and the farmers' lack of education. According to [14], a well-designed agricultural decision support system equips farmers with a facile and rapid way of comparing multiple scenarios for the management of crop production decisions. One example of such tools is CropARM, which assists farmers with management decision actions such as planting, by establishing risks taking into taking climate into consideration [14] have been designed.

5 Application of Fuzzy Inference Systems in Cropping Decision Support

5.1 Fuzzy Inference System

Since the introduction of the Internet of things (IoT), the need for intelligent systems has grown in popularity. Artificial intelligence is the ability that is built into a computer system to be able to apply the intricate function that a human brain uses to learn and make decisions. Machine-learning and fuzzy logic have become the more widely used technological applications in the effort to produce intelligent systems. Fuzzy logic is a mathematical model in which logic depends on the degree of truth rather than a binary for where logic is either true or false. This kind of modelling is used in artificial intelligence, robotics, and business decision support systems. According to [25], fuzzy logic can be applied for decision-making for two reasons, “the rules are derived from expert knowledge that is described in natural language”, and “it handles the vagueness and uncertainly inherent in the problem”.

Fuzzy inference system can be used in this regard because it would take as input the information entered by the small-scale farmers as described according to their understanding. The information the farmer enters may be “fuzzy” or vague. Fuzzy logic is a multi-valued mathematical model that works on the degree of truth rather than either true or false. Fuzzy logic may be employed in image processing, decision-making and other artificial intelligence kinds of systems. Fuzzy logic magic may also be used over Android mobile. An intelligent framework was developed in the study by [25] for diagnosis of crop diseases. A fuzzy inference system (FIS), which is a rule-based system that makes use of fuzzy logic instead of normal Boolean logic, is exploited in this study. FIS provides an intelligent engine for synthesizing vague and uncertain information provided as part of the decision-making process.

The FIS process has three different stages as explained in [25], as shown in Fig. 1. First there is an input from the environment that must be fuzzified. This input passes through the inference engine where the fuzzy rules are applied using the fuzzy logic. A mapping according to the degree of truth is used to get a fuzzy value. This value is used in one of two methods of defuzzification, centroid or middle of maximum (mom). The following formulas apply:

$$\text{Centroid } z^* = \int \mu(x)x\,\mathrm{d}x/\mu(x)\,\mathrm{d}x$$

$$\text{Mom } z^* = a + b/2$$

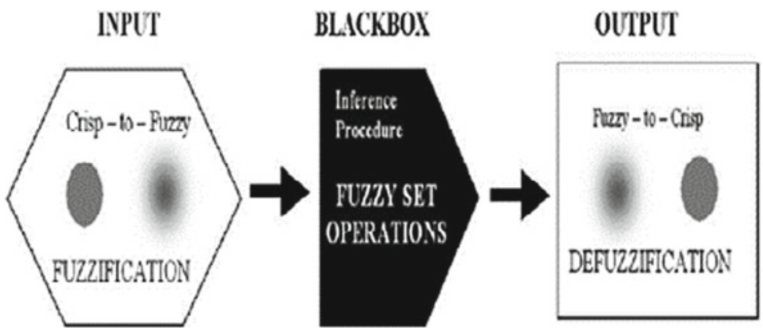

Fig. 1 Defuzzification through fuzzy inference engine

5.2 Cropping Decision Support for Farmers

According to [26], “agricultural statistics reveal interannual variations in the proportions of crops”. This can be attributed to climate change and global warming. The variation in the climatic change becomes difficult to keep track of if it is not properly documented and causes environmental uncertainties. It is very important to understand these climatic variations since it affects the agricultural decision the farmers have to make regarding their crop that directly affects the quality and quantity of the harvest [26]. Agricultural farming is also impacted by economic circumstances, access to credit and markets [26]. With such a multitude of external factors affecting operations in farming, small-scale farmers find themselves having a mammoth task of having to make strategic, operational, tactical, long-term and short-term decisions [26]. Without relevant information, it becomes a daunting task for small-scale farmers to make informed decisions.

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5.3 Applying the Fuzzy Inference System to Cropping Decisions

In the study by [25], a diagnostic expert system with artificial intelligence to diagnose crop diseases. The architecture for this system used fuzzy logic as a backend decision engine and was designed to work with Android mobile technology employing jFuzzylite library. Figure 2 depicts the architecture of the mobile application developed in the study [25]. According to the author, fuzzy logic was used for decision support in this frame for two main reasons. The one reason is that the rules are acquired from expert knowledge articulated in simple language and fuzzy logic does a powerful representation for linguistic knowledge. The other reason is that it can handle uncertainty of the input thereby providing the farmer with the opportunity to be as intuitive as possible in their input guesses. This also explains why fuzzy logic was employed in the study [17] in the development of the ITIKI framework shown in Fig. 2.

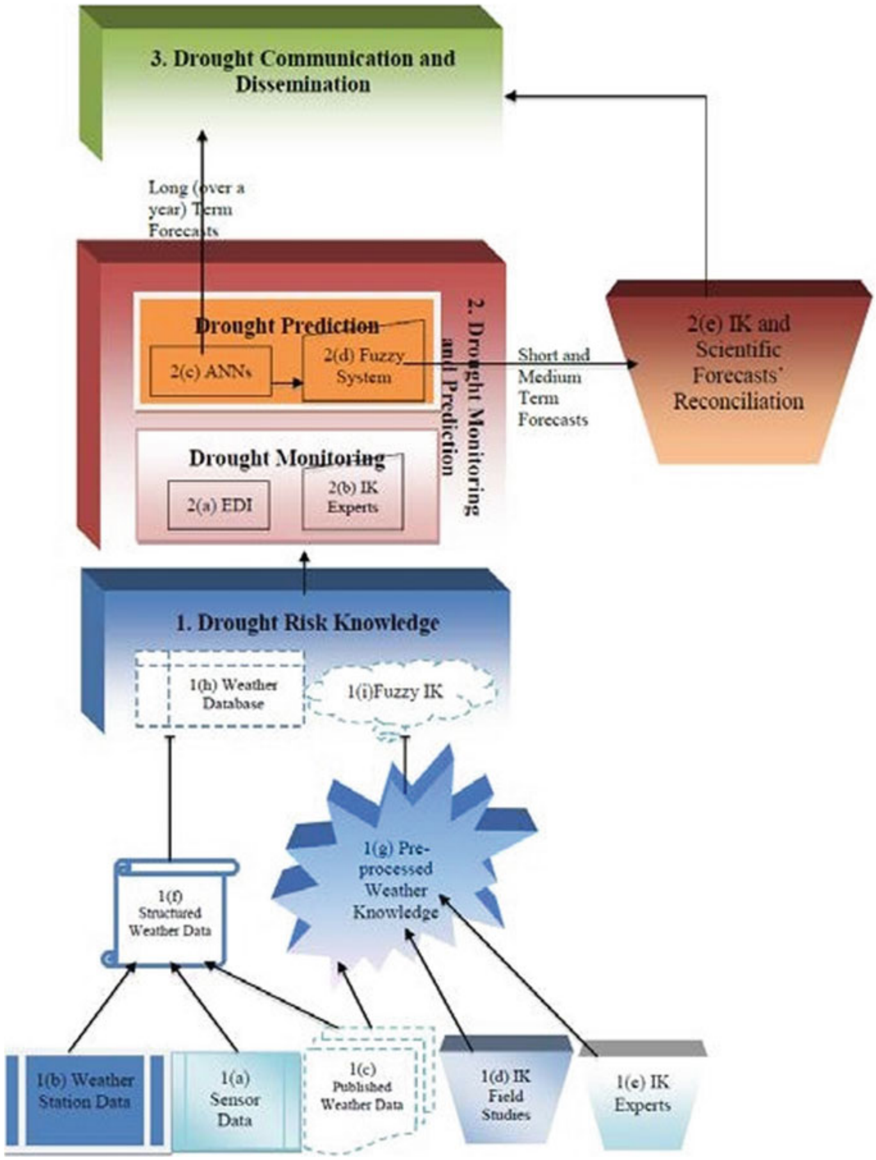

Fig. 2 ITIKI: Integrated Drought Early Warning System Framework

6 Comparison and Discussion

The ITIKI system did well in incorporating the indigenous knowledge, Artificial neural networks and the sensor technology to assist small-scale farmers with drought prediction [17]. This is a crucial solution considering that small-scale farmers operate in rainfed agriculture. Rainfall is but only one part involved in agricultural decision-making. This prediction tool has been instrumental in the improvement of the farming decisions in sub-Saharan Africa. The challenge that the system has is that it does not provide the farmers with holistic agricultural information required to make strategic, tactical and operational management, such as decisions on fertilizer options, choice of crop for different conditions provided, agricultural drought, and the intercropping potential to exploit water resilient crops for maximum benefit.

The advantage of the ICT solution in the Intelligent mobile application system applied in the study by [27] is that it allows for uncertainty of input to go through a fuzzy inference engine to provide a prediction on crop diseases. The system also employs the use of mobile phone technology, which is a kind of technology that is more accessible to the small-scale farming technology in sub-Saharan Africa. The challenge the system has is that it does not allow for expert authentication of the output at runtime. The system does not cater for a more encompassing solution towards agricultural challenges that the rural small-scale farmers encounter, making it a single target problem-solving solution.

While SIMAGRI, also an agro-climate system was aimed at assisting strategic and tactical decision in the production of crops, it uses historical weather to predict climate crop yield by running a simulation of "what if" scenarios [28]. Advantage of the system is that it takes a lot more management disciplines into consideration, such as planting dates, fertilizer type and environmental conditions, but on top of that it takes user input. The disadvantage is that the system simulates yield predictions in a graphical manner which is not what small-scale farmers sub-Saharan Africa need.

CropARM is one other tool that was developed in the study by [14] in order to assist users to establish a framework of risk. It used the APSIM model to simulate scenarios using climate conditions and management actions. Though this system is available online and assists in management decisions that generated very close to predicted yields, it is not accessible to small-scale farmers in rural areas. In the study by [26], one of the limitations was determining the influential factors to cropping plans, meaning that there was no clear indication of the reasoning behind tactical decision. The author eluded to the fact that the small community based their choices on what the society in general was doing. This clearly shows that without enough resources and information, small-scale farmers agricultural decisions could clearly be hampered.

Table 1 highlights advantages and disadvantages of four agricultural solutions that already exist. All the solutions discussed had very successful results in their respective investigations, but this paper set one's sight on the emphasis of the target users of the envisaged system under scrutiny. The disadvantages are therefore highlighted in the comparison table. SIMAGRI is a highly specialized system that supports multiple disciplines of agricultural management using historic data, making it a daunting task to enable the use for decision management for small-scale rural farmers. Though CropARM establishes a framework of risk in agriculture by merging climate scenarios with agricultural management actions, it provides a complicated interface for output or results which would make it not user-friendly for the rural small-scale farmer. This makes both solutions highly inaccessible to small-scale farmers due to

Table 1 Technology comparison

ICT solution	Technology used	Advantages	Disadvantages
SIMAGRI	DSSAT	• Supports multiple strategic and tactical agricultural decisions • Uses tercile seasonal climate and climatology for risk analysis	• Can be exigent for non-experts to apply for the purpose of agricultural decision-making
CropARM	APSIM	• Help establish a framework of risk by incorporating climate scenarios and management actions • Regular updated climatic streams	• Inaccessible to small-scale rural farmers • Output method is not user-friendly for the small-scale farmers
Intelligent Mobile App	Fuzzy logic Mobile phone technologies	• Able to interpret vague inputs • Uses mobile phones technology and android OS • Incorporates local language for the for the farmers	• For diagnosis of crop diseases only • Does not take many other agricultural management components into account
ITIKI	Fuzzy logic Mobile phone technologies ANN	• Early warning prediction for droughts • Able to interpret vague inputs • Incorporates Indigenous knowledge and is user friendly for small-scale farmers • Built to be user-friendly for small-scale farmers	• Does not take many agricultural management components into account, it is only a drought prediction tool

the lack of education in rural areas. It is apparent therefore that these solutions are not suited for target user in this case.

The intelligent mobile application for diagnosis of crop diseases is only utilitarian in a case where crop health is in question, which is passable given the disaster that small-scale farmers experience when crop diseases go undiagnosed. This brings us to the question, ‘what about cases where there is no crop health scare’. How will this tool be of any use to a small-scale farmer? The answer is then that it would be impractical. This disqualifies the solution for small-scale farmers because it is inaccessible to them. The ITIKI seems at this stage to be the only solution that is focused mainly on assisting small-scale farmers. It incorporates the small-scale farmer’s indigenous knowledge in a drought prediction tool, allows for vague user input and was developed for small-scale farmers, making it a more user-friendly tool. Though this is only a drought prediction tool which is a bit of a disadvantage, it provides a foundation for a decision support tool that is more encompassing of agricultural management and management actions. With the prescription of the foundation, therefore an intelligent agro-climate decision support tool can be instituted.

7 Conclusion

In the various research experiments that have been performed, it has been substantiated through research that certain limitations can be attributed to scientific models that certain decision support systems are based on [29], even though they can also be very crucial in agronomics. This furnishes opportunity in exploring innovation in technology that integrates scientific models, agro-climate, mobile phone technology, indigenous knowledge and artificial intelligence into a decision support system that supports an intelligent crop prediction tool. Research has also shown that the sub-Saharan African small-scale farmer is in desperate need of a sustainable, accessible and cost-effective, comprehensive decision support tool to support daily operation, for short term and long term, that takes into consideration the knowledge that they possess and can bring to the table [5, 7, 11, 30]. This decision support tool must also be acceptable by the small-scale farmer more than just imposed on them, that there may be a level of ownership they can take some pride in. The proposed solution seeks to amalgamate and merge divergent ICT to provide a solution more fitting for the sub-Saharan small-scale farmer using the ITIKI framework (ITIKI Plus) [30].

Acknowledgements This research was supported by the Council for Scientific and Industrial Research, Pretoria, South Africa, through the Smart Networks collaboration initiative and IoT-Factory Program (Funded by the Department of Science and Innovation (DSI), South Africa). The authors also would like to appreciate the support of the Department of Electrical, Electronics and Computer Engineering and the Department of Information Technology at the Central University of Technology.

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