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A Cloud Computing Model for Augmenting Agricultural Activities in Marginalized Rural Areas in Developing Countries

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Abstract: Marginalised Rural Areas (MRAs) practice farming as their main source of food, employment and income yet in most cases they lack basic resources and skills to improve yields. In developing countries that are often challenged by rapidly growing urban populations, crime and unemployment, farming could have offered solutions to improve food security and employment opportunities though this is not the case. In this study, we proposed the development of the cloud computing model that augments the use of ICT to improve agriculture in MRAs. In the preliminary exploratory survey conducted in Pongola in South Africa, we established that mobile devices are commonly used with 94% of farmers owning mobile devices. Of these, 59% of the mobile devices had access to the internet and could as well take pictures. Based on this understanding, this study has developed mobile-based application in Java using NetBeans and MySQL database. The developed model includes cloud architecture, used by farmers to share farming related information. We have evaluated the performance of the application by conducting usability testing and the results indicated that 90% of the participants found the application user friendly, 61% found it is easy to learn and 83% said is of the expected standard as they could share information easily.

Key words: Agriculture, cloud computing, information sharing, food security, mobile system, marginalised rural areas

INTRODUCTION

United Nations indicate that almost 50% of world population are living in rural areas, however, more than 70% of that population is from developing countries (Firdhous *et al*., 2013). Most of these people in MRAs live in poverty especially in Africa. Rural poverty is often a product of poor infrastructure that hinders development and mobility. Livelihoods of people in rural areas are based on agricultural production system that is characterised by small family farms. People in rural areas often lack information and sufficient roads that would increase access to agricultural inputs and markets.

Agriculture in MRAs is not effective due to lack of resources and support from government and established farmers that are successful and productive. Farming in MRAs includes crop and livestock farming which is suffering from low yields and dying of animals from diseases that impede the productivity of MRA farmers. The majority of people in MRAs carry out their farming activities in the old fashion ways and have numerous heterogeneous challenges that limit them from copying with modern methods that would have helped them to improve their yields (Simelane *et al*., 2015). Since, farming is their major source of food and income, many people in these areas have lately migrated to urban places in search for food and employment. Such migration not only cause urban growth but also deprives the MRAs of economic development.

In the last decade, it has been seen that there is improved access to current information regarding market trends and players in the agribusiness industry around the globe and such has led to the renaissance of agriculture. The increasing use of Information and Communication Technology (ICT) especially the internet has provided opportunities to farmers to gain more options for the seeds they plant, the fertilisers they use and the markets they sell their produce (Martin and Abbott, 2011). Prior to the 1990s, the infusion of ICT in agriculture in many developing countries was very minimal and farmers depended mostly on radios and TVs as their source of information. The advent of mobile phones has however led to a new paradigm shift where farmers can now share timely and relevant information anytime and anywhere that is tailored to their individual needs.

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This could imply that if agriculture is practiced based on latest technologies in developing countries challenges of famine, poverty, crime and rural to urban migration would be eradicated. More so, using mobile phones could enable MRAs farmers to gain quick contact for information, gain access to new markets and buyers and to obtain advice from distant experts. However, little has been done to guide farmers on the use of ICT to improve agricultural information sharing.

In this study, we developed cloud computing model and implemented a Mobile Information Sharing System (MISS) that could be leveraged to improve agriculture in MRAs. The MISS was implemented by developing a client application in JAVA programming language using NetBeans 8.0 and MySQL 5.0.27 standard database. Since, we were developing a mobile application, we used Java 2 Platform, Micro Edition (J2ME) designed for embedded systems such as mobile devices. We used MySQL 5.0.27 standard database since it's an open source and provides scalability and flexibility.

The MISS is intended to assist subsistence, small to large-scale farmers to share information about farming activities, crop and livestock diseases, epidemics and climate and weather changes.

The main contributions of this study are: We have developed the mobile based application called MISS that allows farmers to share agricultural information easily and affordable. We have managed to narrow the digital divide through the developed MISS application enhancing food security. Farmers from MRAs are now having enough harvesting which decreases the level of poverty and we have also curb people in migrating from rural to urban areas. Through, the developed cloud architecture farmers can upload and download information in form of text, videos and pictures about the farming techniques, diseases, markets, seeds and to monitor new farm produce on demand. Therefore, facilitating dissemination of this agricultural information to other farmers who might need such information.

Marginalised rural areas: Marginalisation is related to but different from inequality. There is no precise definition of MRAs since marginalisation on its own is relative and could vary from one situation to another. In the South African perspective, a large number of the populations is economically deprived, geographically isolated as well as culturally and socially marginalised (Ocholla, 2006). In some cases marginalisation may be explained by the nature of the rural area in a region or country.

Rural areas can be divided into two categories namely; modernised and marginalised rural areas. Modernised rural areas are those with high standards of living as compared to marginalised rural areas, they are located near towns and they have every basic needs and wants due to their active local municipalities. On the other hand, marginalised rural areas are those that lack or have insufficient access to the basic needs like water and sanitation, education facilities, food and also suffer from social exclusion. Additionally, these places have no development, resources are scarce and infrastructure is highly limited and they are geographically isolated. Other researchers have looked at MRAs as those areas that are without access to ordinary public services such as water and sanitation are without a formal local authority and have persistent low quality in education (Momba *et al*., 2006).

Communities or people can be marginalised in various ways. Ocholla (2006) categorizes marginalised communities into 5 groups. These include:

- The economically disadvantaged populations of the developing countries
- The rural people who are often geographically isolated by lack of communication and transportation systems
- Marginalised or disadvantaged by cultural and social poverty, especially the illiterate, the elderly, women and children
- Discriminated against by race, ethnicity, creed and religion and
- The physically disabled

Based on Ocholla (2006) and Momba *et al*. (2006) categorization of MRAs, this study used a case of Pongola area in South Africa that fits well with these characteristics of MRAs. This study developed and implemented a MISS for MRAs based on the model designed using a cloud computing architecture.

Cloud computing

Definition of cloud computing: Cloud computing can be defined as utilising the internet to provide technology enabled services to the people and organisations (Shaikh and Haider, 2011). It could also be looked at as a computing style that provides power referenced with Information Technology (IT) as a service (Zhang *et al*., 2010). Cloud computing allows access to information and computer resources anywhere so long as network connection is available. Most organisations and individuals have migrated their tasks, data and applications to the cloud. Such include but not limited to Amazon where we find Dropbox, Twitter, Instagram and Quora. Cloud computing has emerged over the past years as a common and helpful source of information between partners and people in the sharing of information.

Cloud computing classification and characteristics: Cloud computing could be classified into two major categories based on the location of the cloud and the type of service being offered. A cloud computing model is composed of five important characteristics, three service models and four deployment models (Mell and Grance, 2011). Five important characteristics being on-demand includes self-service, broad network access, resource pooling, rapid elasticity and measured service. The three service models are Software as a Service (SaaS), Platform as a Service (PaaS) and the Infrastructure as a Service (IaaS). On the other hand, there are four primary types of cloud computing models are: public cloud, private cloud, hybrid cloud and community cloud.

Types of cloud deployment models: The four primary types of cloud computing models are public, private, hybrid and community. These are explained as follows:

Public cloud: This is where the computing infrastructure is hosted by the cloud vendor at the vendor's premises. The customer has no visibility and control over where the computing infrastructure is hosted. The computing infrastructure is shared between many organisations.

Private cloud: This computing infrastructure is dedicated to a particular organisation and not shared with other organisations. Private clouds are more expensive and more secure when compared to public clouds.

Hybrid cloud: This combines both private and public clouds together. This ensures that a sudden increase in computing requirement is handled gracefully.

Community cloud: This involves sharing of computing infrastructure between organisations of the same community. For example in this study, all government organisations within Pongola may share computing infrastructure on the cloud to manage data related to citizens and services residing in the area. This deployment model of cloud was found to be relevant for this study and it was therefore chosen as the one to use.

Benefits of community cloud: Community cloud provide many benefits that include (Mell and Grance, 2011):

- Big storage capacity than private cloud
- Supports wide geographical area
- Having less threat exposure than public clouds
- Less costly than massive public clouds and
- Enabling easy content sharing and collaboration

Mobile cloud computing: Mobile cloud computing is an integration of cloud computing technology with mobile devices to make the later resourceful in terms of computational power, memory, storage, energy and context awareness (Othman *et al*., 2014). On the other hand, mobile cloud computing is a method or model in which mobile applications are built, ran and hosted using cloud computing technology (Fernando *et al*., 2013).

Mobile cloud applications move the computing power and data storage away from the mobile devices and into great and centralised computing platforms located in clouds which are then accessed wirelessly based on a thin native client. Mobile cloud computing offers mobile users with data storage and processing services in clouds, removing the need to have a powerful device configuration such as memory and central processing unit speed as all resources demand computing can take place in the cloud. The mobile computing architecture is as shown in Fig. 1.

The mobile cloud architecture illustrates that mobile devices simply connect to the servers through satellite, access points and bluetooth. In this setup, the mobile user's data requests and information are communicated to the central processors that are connected to the servers providing the network services. The subscriber's requests are delivered to the cloud. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services.

The web service is connected to the web application server which serves as the middle-man between the created web service and database. The middleware is responsible for transferring data from the database to the web service and then to the mobile devices.

Benefits of mobile cloud computing: Mobile cloud computing have several benefits including.

Extending battery lifetime: A mobile phone battery life is small and it cannot handle big simultaneous processes. However, with the introduction of the cloud, it is no longer the mobile devices responsibility to make these large processes but the servers in the cloud hence increasing the life span of the batteries that would have been depleted during the processes.

Improving data storage: Storage capacity of phones is limited and cannot handle huge information and files but with cloud, it ceases to be the mobile device's responsibility to store the large amount of data but servers in the cloud.

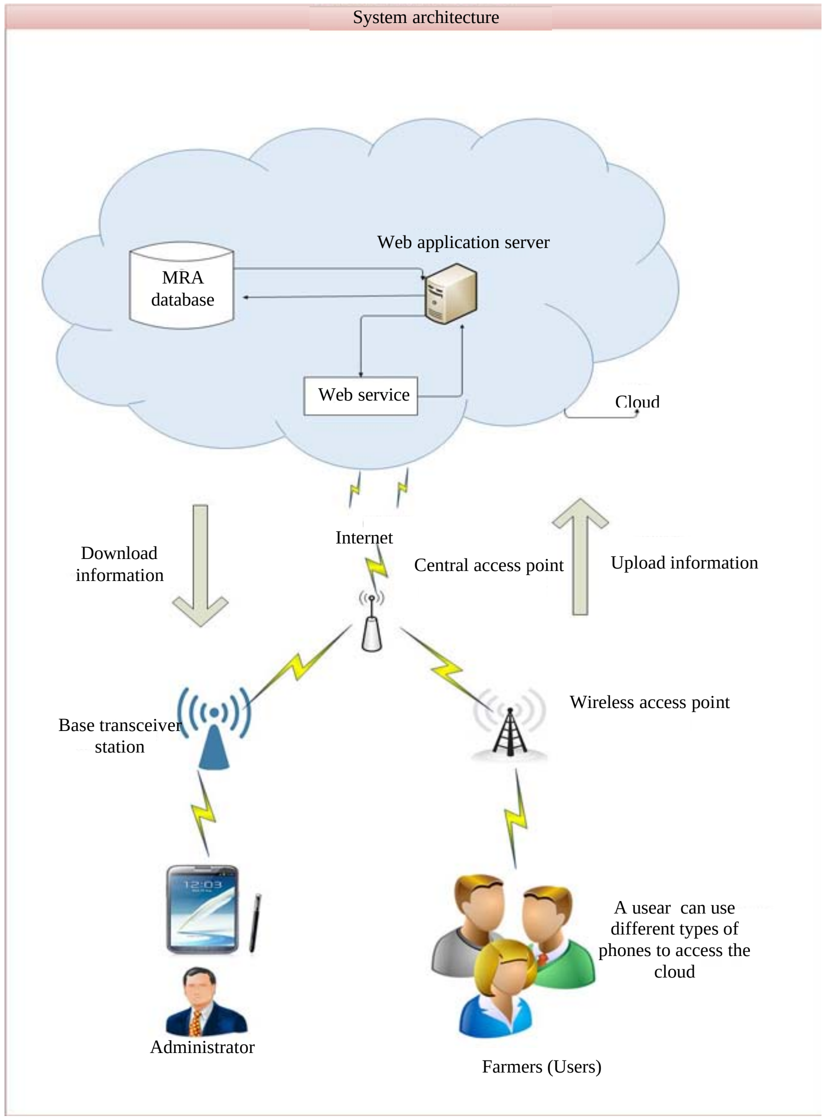

Fig. 1: Mobile cloud architecture Othman *et al*. (2014)

Processing power: Using the cloud helps to reduce the running cost for computation intensive applications that could have been handled by a single mobile device.

Limitations of mobile cloud computing: Mobile cloud computing suffers from some limitations including (Mannade and Bhande, 2013):

Security standards: When working mobile, one is dependent on public networks, requiring careful use of Virtual Private Network (VPN). Security is a major concern when it comes to mobile cloud computing. One can easily attack the VPN through a huge number of networks interconnected through the line.

Power consumption: When a power outlet or portable generator is not available, mobile computers must rely entirely on battery power. Combined with the compact size of many mobile devices, this often means unusually expensive batteries must be used to obtain the necessary battery life. Mobile computing should also look into greener IT in such a way that it saves the power or increases the battery life.

Storage limitation: Storage space on a portable computer is limited by physical size and power requirements. Traditionally, disks provide large amounts of non-volatile storage. In mobile computers, however, disk drives are a liability. They consume more power than memory chips, except when off line and they may not really be non-volatile when subject to the indelicate treatment a portable device receives. Hence, none of the PDA products have disk drives. Storage constraints can be solved using compression of files automatically, accessing remote storage over the network.

Bandwidth limitation: Mobile internet access is generally slower than direct cable connections using technologies such as General Packet Radio Service (GPRS), Enhanced Data rates for GSM Evolution (EDGE) and 3rd Generation (3G) and more recently, 4th Generation (4G) networks. These networks are usually available within range of commercial cell phone towers. Higher speed wireless Local Arear Networks (LANs) are inexpensive but have very limited range.

Agricultural activities in South Africa: Agriculture also termed as farming is the growing and maintaining of animals and plants for food to sustain and improve human life (Simelane *et al*., 2015). It is fundamental to the sustenance of life which on its own, constitute a bedrock of economic development of nations, especially in ensuring food security which is vital for human development and essential raw materials which is necessary for industrial production (Toluwase, 2010). There are three types of agriculture that are mostly practiced in South Africa. These are commercial, subsistence and organic farming.

Commercial agriculture is where the farmer produces goods (livestock, grains, fruits, vegetables, nuts or bio-fuels, etc.,) intending to sell them. These goods can be sold to wholesalers or retail outlets (Simelane *et al*., 2015). Subsistence agriculture is where the farmer only grows or produces enough products to feed his or her family. These products can be in form of crops or livestock. An example of this may be a family that have only one cow to give milk for their consumption and grows enough wheat to make bread for their food (Simelane *et al*., 2015). On the other hand, organic farming is a production system that sustains the health of soils, ecosystem and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.

South Africa (SA) is shifting from primary and secondary based economy to a tertiary economy and agriculture's contribution to Gross Domestic Product (GDP) which is declining at a current rate of 2.2% . The report further states that agriculture remains an important contributor to local economy, generating some R147.4 billion in income and R116.9 billion in expenditure. Nearly 20% of all households in SA (2.9 million) are agricultural household's. In addition, the census conducted in 2011 indicated that many of those involved are subsistence farmers with no income, their farming efforts provides their households with vital sustenance. Smallholder households fill the gap between subsistence and commercial farming where agricultural products are consumed by both the household and sold to market. Commercial farmers make up the smallest number of agricultural households in South Africa, yet contribute the majority of production.

South Africa's agriculture sector is at a significant crossroads, facing numerous challenges that need to be resolved concurrently. Increasing resource limitations include depleted soils and over-extracted and polluted water reserves. This sector is also most directly exposed to increasing risk and vulnerability due to climate change. Changing weather patterns will alter rainfall patterns and water availability, resulting in shifting, unpredictable growing seasons and crop yield variability. The current physical and economic energy insecurities, driven by a failing national power grid and volatile global oil prices, places further pressure on an already strained system.

Rising wealth, urbanisation and a fast-growing middle class have changed the country's consumption patterns, with more South Africans eating more processed and high-protein foods, especially meat, dairy products and empty calorie high sugar diets. These foods are more land and water-intensive than fruit, vegetable and grain crops and further stress existing resources.

Sustainable farming requires the use of farming methods that can strike a balance between the social and economic needs of an equitable and just society, whilst ensuring the security of the natural resource base and the protection of the long-term productivity of the land.

With South African economy under pressure, rural development can be of great help in stabilizing the economy. Marginalised rural areas practice subsistence farming and in most cases lack basic resources and skills to improve yields. This has led to famine, poverty, crime and rural to urban migration seeking for better life and resources. Agricultural activities when practiced very well can curb such challenges in the country.

Agriculture in Marginalised rural areas of South Africa: In South Africa, 50% of the general population live below the poverty line, the numbers are higher for South Africans particularly those on reserves (Simelane *et al*., 2015). Agriculture in MRAs which includes crop

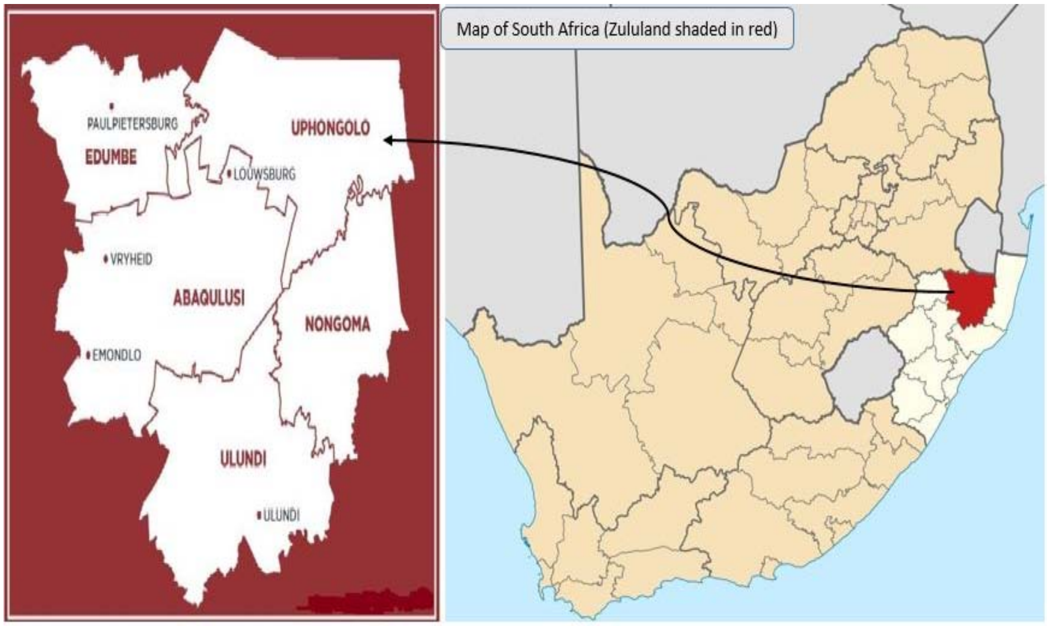

Fig. 2: South African map (Pongola)

farming, hay farming and livestock farming are suffering from low yields, dying of animals from diseases and which makes rural farmers not to be productive at all. MRAs carry out their farming activities in the old fashion way which makes them not to be productive enough. Agriculture is an important part of the livelihoods of many poor people and it is frequently argued that agricultural growth is a fundamental pre-requisite for widespread poverty reduction (Dorward *et al*., 2004). Lately, many people including rural farmers are migrating from rural areas to urban places due to lack of resources and support in marginalised rural places.

The above identified challenges could be tackled if agricultural sector develops and uses more sophisticated and better adapted knowledge and information on localised agro-ecological processes, market developments and risks (Leeuwis, 2008). More still, to eradicate challenges in MRAs, there is need to practice farming by leveraging the latest technologies that will enable the free exchange of knowledge and information among farmers as well as fundamental and applied research (Leeuwis, 2008). If farmers do share information freely using the various types of communication devices available to them, agriculture in MRAs could rapidly grow leading to eradication of poverty and hunger as well as to overall economic development of the country.

Pongola: Pongola also known as uPhongolo is a town place located in Northern KwaZulu-Natal, South Africa and 10 km away from the Swaziland border. UPhongolo Municipality area largely encompasses old-style buildings with its tribal land patterns and high density marginalised rural settlements. A large marginalised rural population depends on Pongola town for commercial and public services (e.g., health, home affairs, etc.) which places pressure on the primary node because of the lack of services and facilities within the rural areas. The economy of uPhongolo is largely based on agricultural activities mostly sugarcane and people in the area practice subsistence farming though they basically lack resources to improve their yields. The map of Pongola is shown in Fig. 2.

Literature review: ICT in agriculture has attracted a lot of attention and research globally due to its outstanding benefits compared to old ways of practicing farming. The introduction of IT into agriculture has been performed in areas where farmers have been more or less obliged to use it to comply with government and distribution industry rules such as filing tax returns and maintain traceability records (Hori *et al*., 2010). They alluded that IT has been less applied in actual agricultural production. These researchers came up with a model that can improve communication and information sharing. They used a projector to display the contents of a personal computer screen where one could deliver routine work reports and share information between experienced and inexperienced farm workers including specific information about harmful insects, growing conditions and offer expert advice. The developed model for this study offers similar benefits as our model which is to improve information sharing between small and large-scale farmers for better practice and yields. The biggest challenge is that their model is centralised and not mobile which we bring cloud computing to help all farmers to be able to access information from anywhere and at any time through their mobile devices.

IT and traditional business 2 business electronic-commerce had a decisive impact on the grocery industry, especially in improving the efficiency supply chain (Lu and Perreau, 2005). They further elaborated the important reason for this lack of success is the limited transfer of data between the grocery chains and food processing companies and their suppliers primarily farmers or growers in rural areas. Their study proposed and designed a mobile commerce application called SamCom which was intended to transmit food product data using mobile phones from both remote and rural areas to the next link in the supply chain supermarket, restaurant and export partners. They implemented the radio frequency identification in the grocery supply chain which enables faster inventory count and can significantly reduce point of sale cost.

ICT has been identified as a tool for bridging the development gap between the urban and rural communities (Firdhous *et al*., 2013). They noted that, ICT can be successfully leveraged to reduce the imbalance between the urban and rural communities by raising income, improving their quality of life, creating opportunities for access to better education, healthcare and other social benefit programs and creating better markets for their products and services by eliminating the middleware. Their study identified several factors affecting the success implementation in rural settings. These factors they identified as high cost of facilities, lack of human resources for managing facilities, lack of resources at tele-centres, users lack of English knowledge, lack of computer skills for users and lack of network capacity. They however recommended that these challenges could be overcome by co-locating services and facilities so as to reduce the cost of implementation and management of services. They indicated that this could be done by leveraging cloud computing and hence proposed a cloud powered rural ICT implementation framework where all processing is carried out at a centralised cloud data centre.

The current study is distinguished from these studies by the fact that much as many of them were implementing the SMS application to alert supply chain, this study is implementing a MISS that will help farmers in marginalised rural areas to acquire and share information of improving their agricultural yields.

The role of mobile phones in enhancing communication and information delivery support to agricultural development for improved rural livelihoods with reference to Rubaya Sub-county of Kabale District in Western Uganda. They distributed mobile phones to the rural communities in Kibuga, Karujanga, Rwanyena and Mugandu parishes. Their findings showed that there was a maximum usage of phones during planting and harvesting seasons. Most of the farmers used their mobile phones to call stockists, technocrats and traders due to the fact that crop husbandry is one of the most important livelihood activities in their study area.

They further elaborated that early in the season, the phones are used to ask about time of planting, source and availability of seeds and other inputs. During mid-season, most farmers used their mobile phone to inquire about availability of pesticides for pest and disease management. Later in the season during harvesting, the phones were used to inquire about prevailing market prices for agricultural commodities. They also found that usage of mobile phones was beneficial to farmers in different areas. Most conspicuous areas are productivity, market access, natural resource management and knowledge base. This increased cooperation among farmers within the village. According to this researcher, the presence and usage of the phones built self-confidence in the farmers that some managed to buy their own phones. These researchers were focusing more on analysing the impact mobile phones have when applied in agriculture.

The current study is significant and different from Masuki's because we develop mobile-based application that will facilitate communication and information sharing amongst farmers at large. The study also introduces the cloud as the agricultural information storage for these farmers which will assist them to be able to access information everywhere easily and at low cost.

MATERIALS AND METHODS

Proposed system architecture: The system was designed to be used by farmers at all levels to share information about the farming techniques, markets, seeds, etc. The designed system was based on the open source cloud computing platform as illustrated by Fig. 3, the architecture shows different locations where farmers reside separated by distance. Farmers in these different locations can either download or upload information using their different types of phones and other farmers access such information. Using the mobile phone, information is uploaded to the cloud through base transceiver station or wireless access points. The

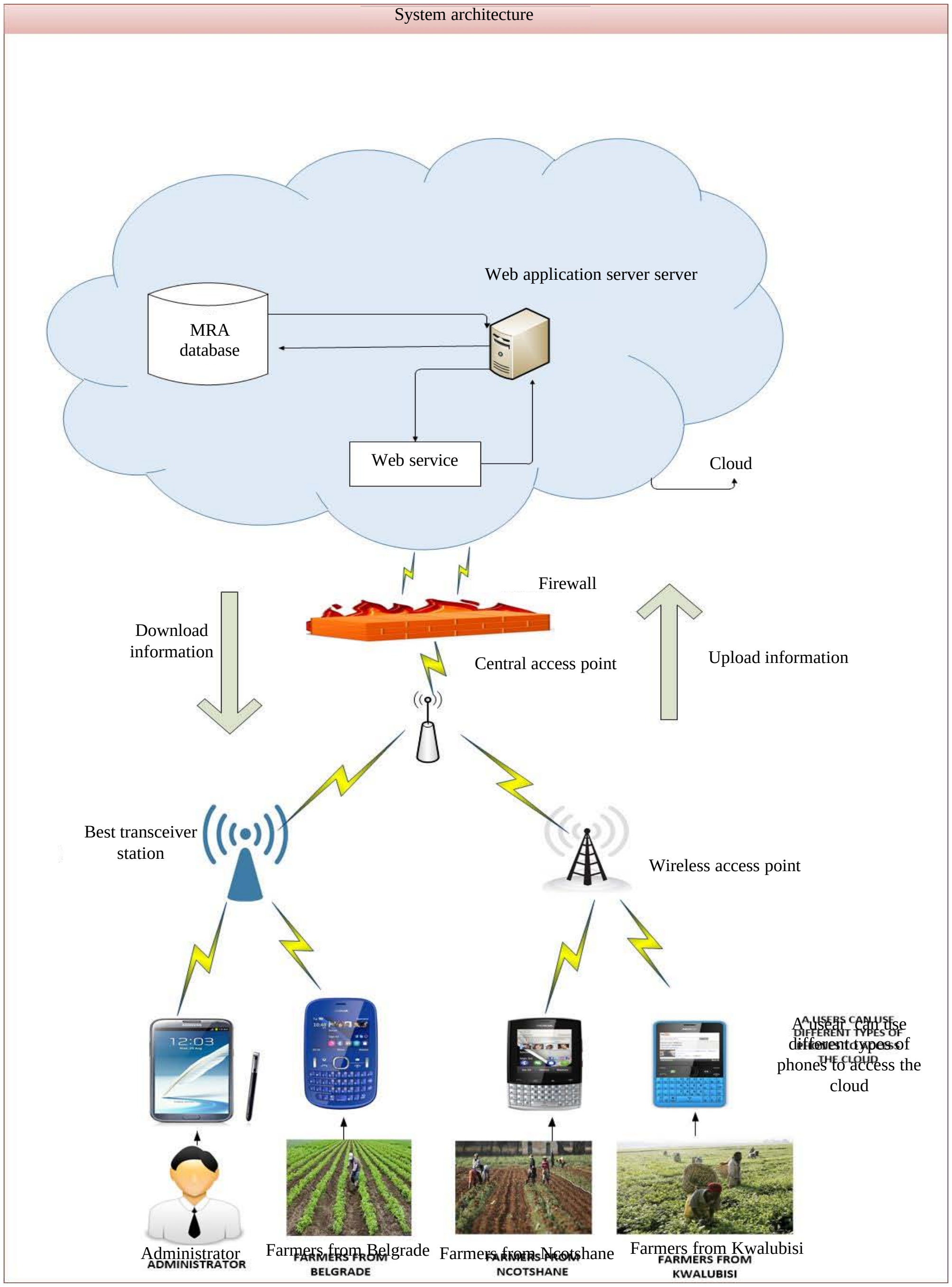

Fig. 3: Proposed mobile information sharing system architecture

information is then transmitted to the central processors that are connected to servers providing mobile network services. We have the cloud that contains web service, web application server and database. The web service is connected to the web application server which serves as the mediator between the web service and database. The web service provides us with data like weather forecasts and markets from other service providers. The mediator is responsible for transferring data from the database to the web service and then passes through firewall to the mobile devices.

MISS cloud architecture: We have permitted mobile devices used by farmers to get connected to the network

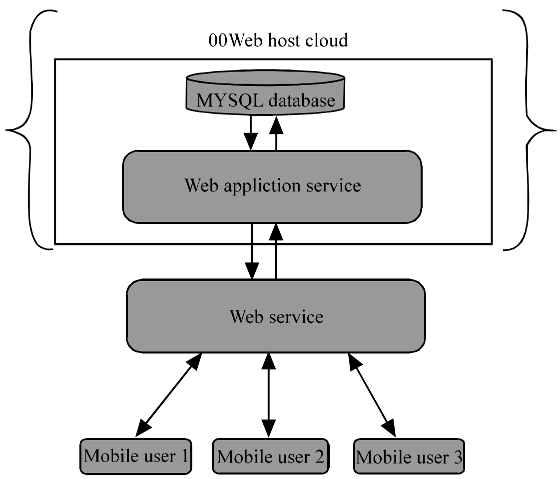

Fig. 4: MISS cloud architecture

via. web services which facilitate the communications between the users since they want to share information from database which is kept in the cloud. The web service is connected to the web application server which serves as the middleware between the created web service and database as shown in Fig. 4. The middleware is responsible for transferring data from the database to the web service and then to the mobile devices.

We have created the application database using My Structured Query Language (MySQL) which stores data including user profiles, posts, etc. Further, as farmers have to access the weather forecast and markets, we decided to access this information through an online free weather service known as Open Weather Map (OWM) to access the current weather forecast available. OWM weather service is based on the OWM platform for collecting, processing and distributing information about our planet through easy to use tools and Application Program Interface (API). On the other hand, OWM platform permits OWM to process and distribute billions of weather data points every second.

Finally, our database and web application server are stored in the cloud which is called 00 webhost. This was done primarily because it is a free source thus we have got rid of the costs involved in the creation of our own cloud storage.

Methodology: The proposed mobile information sharing system was implemented by developing a client application in JAVA programming language using NetBeans 8.0. Since, we were developing a mobile application, we used Java 2 platform Micro Edition (J2ME) designed for embedded systems such as mobile devices. J2ME is good for feature phones since the developed application looked to uplift people from marginalized rural areas which are mostly still using feature phones according to a case study we conducted in Pongola.

We chose J2ME because it doesn't need high cost configurations and so many phones support it. It also includes improved security and consistency of applications across platforms and devices, superior user interfaces with graphics, the ability to function off-line out of wireless coverage, peer-to-peer networking and no licensing expenses needed for the Software Development Kit (SDK) which means that anyone can create an application and market it.

We used MySQL 5.0.27 standard database since it's an open source and provides the ultimate scalability and flexibility. The application is called mobile information sharing system because it simply helps marginalized rural farmers to share information easily at very minimal cost.

RESULTS AND DISCUSSION

After implementing the system it was important to evaluate and to ensure that the system was doing what it was intended to do. To ensure this, we performed usability testing to get feedback and input from the farmers.

Profile of participants: Participants who were all farmers were selected randomly and we didn't require any experience. One condition to participate was that the farmer should be in possession of mobile phone. About 52 farmers of varied age participated including both subsistence and commercial farmers. Demonstrations were carried out for the participants to get insights of how to use the system, navigate around its features and also to be able to upload and download data. The demonstrations also helped to highlight issues to those participants about 8% who were not fluent in English.

Analysis of tasks: We adopted ISO 9241-11 to carry out our usability testing as to ensure the effectiveness and satisfaction. ISO 9241-11 defines usability testing and explains how to identify the information which is necessary to take into account when specifying or evaluating usability of a visual usability display terminal in terms of measures of user effectiveness and satisfaction.

In this study, effectiveness was evaluated based on the fact that users could successfully complete a task such as registering on the system, upload or download information in any form that included text data, images and videos. Based on this evaluation of tasks, user's satisfaction was measured by the use of a questionnaire.

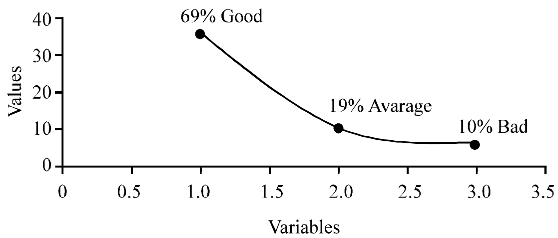

Fig. 5: Flexibility and efficiency of use

Table 1: Tasks completed by participants

Task	Completed with help (%)	Completed without help (%)
Register	10	90
Update user details	0	100
Login	5	95
Post information	10	90
View information	0	100

Table 2: List of tasks and time limits of each task

Task	Time limit (min)
Register	4
Update user details	0.30
Login	0.30
Post information	2
View information	1
All task combined	7.6

The 90% of the users completed the task of registering on the system easily without any assistance and 10% of users required help, some were not able to validate password they created in terms of required length and special characters required. On the login screen 5% of users couldn't login due to incorrect username or/and password entered. When they have to post information 10% couldn't navigate properly to get images if they want to include them but 90% could post both text and images properly as shown in Table 1. The 100% of the users were able update their accounts and were able to view information which is posted and comments made by other users and they were able to download images. The 69% of the users found MISS flexible and efficient as shown in Fig. 5. Using the map, it's easier to find the desired location and it provides accurate weather forecasts. When testing we had to observe time taken in completing every task given to them so that we can ensure the efficiency of our mobile application.

Uploading and downloading images was a bit slow in certain areas due to network changes from 3G-2G but all tasks combined the average user takes about 7.6 min as shown in Table 2. Most users found the visibility of system status clear and good as we have 78% of users who responded positively about the system status as shown in Fig. 6. This is where users can see whether they are getting system feedback of every task being executed, displaying of error messages, input fields are properly labelled. We have 5% of users who say it's bad and 17% of users who say we need to improve it. We have 56% of the users who agree and are satisfied that our system is navigable, meaning the menu choices are ordered in the most logical and understandable way. The system users can easily login and move back and forth between screens. However, 22% of users rated it as bad and another 22% who said its average as shown in Fig. 7. User's response shows that the system is simple to use. We have 61% of users who agreed that the labels in interfaces, i.e., command buttons, drop down menus, etc. are stated clearly and the language is understandable. We have 22% of users who are not satisfied for the fact that the system doesn't provide tool tips for better understanding. The 17% of users are in between of which they say it's neither bad nor good due to their own reasons as shown in Fig. 8.

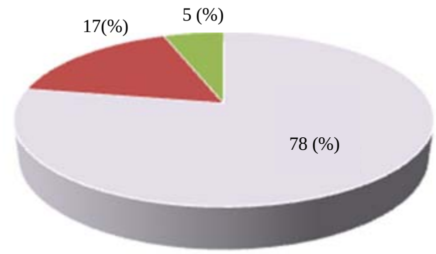

Fig. 6: Visibility of system status

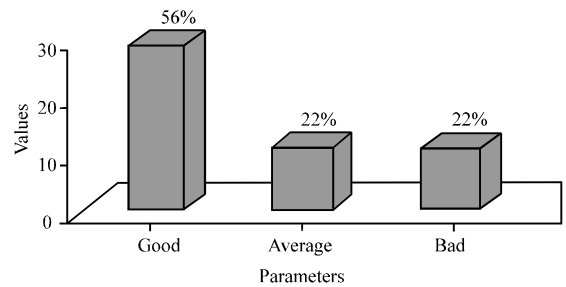

Fig. 7: Navigational structure of the system

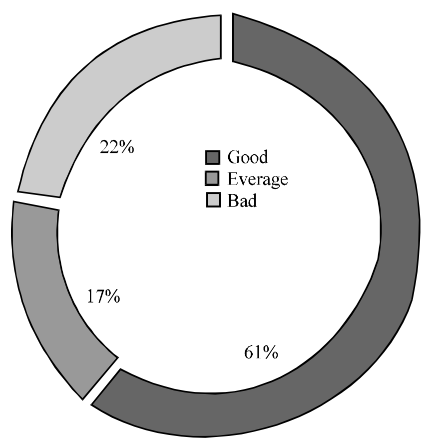

Fig. 8: Simplicity of the system

The user control of the system seems to be on the good and expected standard since, we have 83% of the

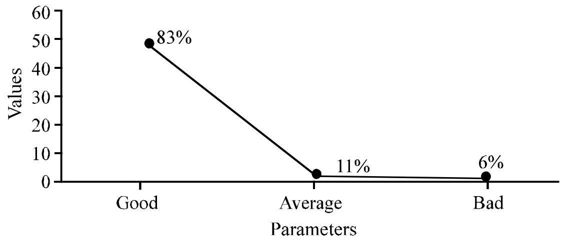

Fig. 9: User control of the system

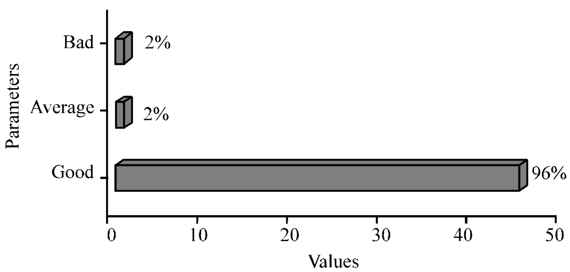

Fig. 10: Error handling

users who found it good as shown in Fig. 9. Users agree that they can explore interfaces easily, meaning they can move backward and forward between all screens, the system does inform them where they are on the system and how to undo their actions, they can create and manage their accounts, they are able to confirm through commands after data input.

The 96% of users say that error handling or prevention is good, meaning they agree that the system can warn them in time if they are about to make a potentially serious error, i.e., wrong input. The 2% of users deem it average and 2% of them say it's bad as shown in Fig. 10. As part of evaluation we also took cognizance in observing errors that users came across. There were both system and user generated errors we picked up. In registration screen some users asked to be assisted some couldn't match the password correctly but some were able to do exactly as required. In the login screen some forgot and some couldn't match their username and password. Some users couldn't upload and download images due to network barrier.

We had incidents where users asked to be assisted when registering on the application and some forgot their passwords. Overall incidents percentage is 33% as shown in Table 3. When users are updating their profile, we had few incidents of system and server error. Overall was 4% as shown in Table 4.

During the login task some of the users couldn't type the correct password and username. The overall percentage of the incidents was 10% as shown in Table 5.

Table 3: Register usability error analysis

	Errors	
Task/Register	No. of incidents	Incidents (%)
User ask to be assisted	12	33
System or server error	0	
User left some required field empty	2	
ID field not validated correctly	0	
Password doesn't match	3	
User don't know where to click to register	0	

Table 4: Register usability error analysis

	Errors	
Task/Update user details	No. of incidents	Incidents (%)
User ask to be assisted	0	4
System or server error	2	
User don't know where to click to update details	0	

Table 5: Login usability error analysis

	Errors	
Task/Login	No. of incidents	Incidents (%)
User typed username incorrect	2	10
User typed password incorrect	3	
System or server error	0	
User ask to be assisted	0	

Table 6: Post information usability error analysis

	Errors	
Task/Post information	No. of incidents	Incidents (%)
System or server error	2	12
Posted information doesn't appear	1	
User can't navigate to images	2	
User doesn't know where to comment	0	
User ask to be assisted	1	

When uploading and downloading information, few incidences were experienced, server error and some users asked to be assisted. Some users couldn't retrieve data they posted as shown in Table 6. The overall percentage of the incidents was 12%. Few errors were encountered when users view their post. The overall incident percentage is 2% as shown in Table 7 and 8.

User satisfaction: The users were asked what other tasks we could add to the application, so that it can be more beneficial. Most users felt the system was great and perfect but some suggested that the system at least should allow them to upload video clips. Some of the comments made by the participants included:

- "The mobile should be implemented as soon as possible"
- "Very good application for weather alert, due to fluctuating weather we having as South Africa it will be good now to be alerted through this application"

Table 7: View info usability error analysis

Task/view information	Errors: No. of incidents	Errors: Incidents (%)
System or server error	0	2
Image can't be retrieved	1	
User ask to be assisted	0	

Table 8: Feedback categorization

Component that need addressing	Status and comments
When the user login on the system, he/she must get a welcome text by his/her name	Addressed
At picture field, ensure that the description says "please upload a picture of the product" instead of saying photo	Addressed
At date and time field, only date must be kept, time must be removed	Addressed
Include the telephone number of the inventor/ representative	Addressed
Tool tips are needed	Addressed
Map search should also support search by coordinates	Addressed

- "As people from rural areas it will be good for us to know precise medication for our livestock before we go buy them"
- "This will definitely improve our yields"
- "Can this application be deployed to smart phones so that it will have good visualization"

Most farmers are extremely happy as they say it won't just impact them but it will uplift agriculture in South Africa as a whole.

CONCLUSION

In this study, we have managed developed a cloud computing model that augments the use of ICT to improve agriculture in MRAs. The developed model includes a cloud architecture which is a Mobile Information Sharing System (MISS) that is used by farmers to share information about the farming techniques, markets, seeds and any other farming related information. We have also managed to narrow the digital divide through the developed MISS application enhancing food security and poverty reduction in marginalized rural areas. The developed cloud computing architecture curbs their challenges and improves their yields and live hoods in marginalized rural areas. In this study, the heuristic method was adopted to evaluate the MISS application. Usability testing was conducted as to ensure the effectiveness and satisfaction of the users.

RECOMMENDATIONS

There are a number of likely future plans for improving agriculture using ICT as the tool. Firstly, in future we propose the development of any agricultural information sharing application to be able to support multiple platforms, e.g., develop using codename one. Secondly, the upcoming applications should allow farmers from rural areas to be able sell and purchase their yields online.

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REFERENCES

Dorward, A., J. Kydd, J. Morrison and I. Urey, 2004. A policy agenda for pro-poor agricultural growth. World Dev., 32: 73-89.

Fernando, N., S.W. Loke and W. Rahayu, 2013. Mobile cloud computing: A survey. Future Gener. Comput. Syst., 29: 84-106.

Firdhous, M., O. Ghazali and S. Hassan, 2013. Cloud computing for rural ICT development: Opportunities and challenges. Proceedings of the International c Conference on Computing, Electrical and Electronics Engineering, August 26-28, 2013, IEEE, Changlun, Malaysia, ISBN:978-1-4673-6232-0, pp: 680-685.

Hori, M., E. Kawashima and T. Yamazaki, 2010. Application of cloud computing to agriculture and prospects in other fields. Fujitsu Sci. Tech. J., 46: 446-454.

Leeuwis, C., 2008. Communication for Rural Innovation: Rethinking Agricultural Extension. 3rd Edn., John Wiley & Sons, Oxford, England,.

Lu, N. and S. Perreau, 2005. Sustainable agriculture mobile commerce (SamCom)-extending the rural grocery supply chain through M-commerce. Proceedings of the International Conference on TENCON 2005 IEEE Region 10, November 21-24, 2005, IEEE, Adelaide, South Australia, ISBN:0-7803-9311-2, pp: 1-6.

Mannade, R.B. and A.B. Bhande, 2013. Challenges of mobile computing: An overview. Intl. J. Adv. Res. Comput. Commun. Eng., 2: 3109-3114.

Martin, B.L. and E. Abbott, 2011. Mobile phones and rural livelihoods: Diffusion, uses and perceived impacts among farmers in Rural Uganda. Inform. Technol. Int. Dev., 7: 17-34.

Mell, P. and T. Grance, 2011. The NIST Definition of Cloud Computing: Recommendations of the National Institute of Standards and Technology. NIST Special Publication, USA., pp: 800-145.

Momba, M.N.B., Z. Tyafa, N. Makala, B.M. Brouckaert and C.L. Obi, 2006. Safe drinking water still a dream in rural areas of South Africa. Case study: The Eastern Cape Province. Water SA, 32: 715-720.

Ocholla, D., 2006. Information Accessibility by the Marginalized Communities in South Africa and the Role of Libraries. University of Arizona, Tucson, Arizona,.

Othman, M., S.A. Madani and S.U. Khan, 2014. A survey of mobile cloud computing application models. IEEE. Commun. Surv. Tutorials, 16: 393-413.

Shaikh, F.B. and S. Haider, 2011. Security threats in cloud computing. Proceedings of the 2011 International Conference on Internet Technology and Secured Transactions (ICITST.), December 11-14, 2011, IEEE, New York, USA., ISBN:978-1-4577-0884-8, pp: 214-219.

Simelane, P.T., O.P. Kogeda and M. Lall, 2015. A cloud computing augmenting agricultural activities in marginalized rural areas: A preliminary study. Proceedings of the 2015 International Conference on Emerging Trends in Networks and Computer Communications, May 17-20, 2015, IEEE, Pretoria, South Africa, ISBN:978-1-4799-7707-9, pp: 119-124.

Toluwase, S.O.W., 2010. Agriculture! A veritable tool for reducing the rate of unemployment in Nigeria. Proceedings of the 2010 International Conference on Bioinformatics and Biomedical Technology, April 16-18, 2010, IEEE, Ikere-Ekiti, Nigeria, ISBN:978-1-4244-6778-5, pp: 378-381.

Zhang, S., S.F. Zhang, X.B. Chen and X.Z. Huo, 2010. Cloud computing research and development trend. Proceedings of the 2nd International Conference on Future Networks, January 22-24, 2010, Sanya, Hainan, China, pp: 93-97.