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Farmers Market Price Prediction Model

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Abstract

The stability and growth of Zimbabwe's economy is directly linked to the performance of the agricultural sector. The majority of Zimbabwean population depend heavily on agriculture for their livelihood. One of the prominent agriculture sectors is local horticulture; where farmers produce various crops and sell them at designated farmers' markets throughout the nation. The prices of these produce vary from day to day depending on the demand, quality or availability of the produce. Popular product prices are published on various national radio stations, newspapers and online media to guide consumers and producers. However so far in Zimbabwe there is no mechanism or tailor-made solution which assists farmers in predicting the future prices for each crop on seasonal basis. Prediction of probable prices of products allows farmers to project their profits and be able to make informed decisions in the type of crop to produce in a given season. The thrust of the paper is to design a model that can forecast future prices of tomatoes sold at Mbare Farmers' Market and be able to predict their market demands. The model uses Support Vector Machine algorithm to come up with the most likely prices of these products.

Keywords: Data mining, Price Prediction, Support Vector Machine

Introduction

Agriculture is one of the major activities in Zimbabwe. It has been the main contributor to the growth rate and employs about 30% of the working population. Some farmers mainly concentrate on maize production and other crops whilst others do fruit and vegetable production. After farmers have produced their fruits and vegetables, they target different markets in order to sell their produce. Some farmers supply directly to wholesales, some send to municipal markets such as Mbare Musika in urban areas, some supply directly to schools, hospitals, hotels and other government organizations and some sell directly on roadside kiosks together with street vending. (Anon 2016b)

On a daily basis, the prices of fruits and vegetables are broadcast on national radio and in newspapers in order to guide consumers. The information only acts as a guide at that particular moment but does not help a consumer or a framer to make future decisions. It is of paramount importance to have a system that enables price forecasting so that consumers and farmers can be guided accordingly. This paper introduces the concept of vegetable price prediction with particular reference to the Mbare Musika municipal market. There is need for that data to be collected and arranged in such a way that the trends can give a proper meaning and allow accurate decision making.

The rest of the paper is organized as follows: In the next section, we give the background and related work, Data collection and Data preparation follows, then we give the model design and architecture in the next section, we give the results and analysis in the next section and in the final section we give the conclusion and future work.

Background and Related Work

Background

Most farm products are sent to the municipal markets and each city or town has got its central municipal market. The markets are the main source of determining the producer, wholesale and retail prices of fruit and vegetables. Farmers mainly determine their prices by considering the cost of production, transport costs and then add a little profit. Supply is seasonal for almost all the fruits and vegetables hence there exist peak season prices and low season prices. The prices are usually high at the beginning of the season, average at full season and rise again out of season. The general cycle in Zimbabwe is that during winter, there is an oversupply of fresh produce whilst in the rainy season supplies reduce drastically leading to low and high prices respectively. The perishable nature of farm produce also makes its price go a little bit high because farmers will be making an effort to compensate for the produce lost due to wilting, rotting and general damage.

Related work

Nasira and Hemageetha 2012 proposed a vegetable price prediction model based on neural networks for the Indian market. They collected their data for the price of one vegetable (tomato) and used it as experimental data. They normalized the data and exposed it to a three layer feed forward network structure which they used for prediction. The conclusion made was that, neural networks were a suitable method to use in predicting the price of vegetables because the predicted results were not deviating too far away from the actual price.

Luo et al. 2010 proposed a vegetable price prediction model using a Neural Network Model Based on Genetic Algorithm. The main purpose for the Genetic Algorithm in the model was for optimisation of the neural network that is Gene Encoding; according to the BPNN, gain its weight number. Every weight is on behalf of a gene. This method proved to be more accurate with 75% accuracy than Neural Networks without Genetic Algorithm.

Both this work portrays some similarity to our proposed model in that both are predicting the price of vegetables; however the difference is that in our proposal we intend to compare the accuracy of using Support Vector Machine against Linear Regression.

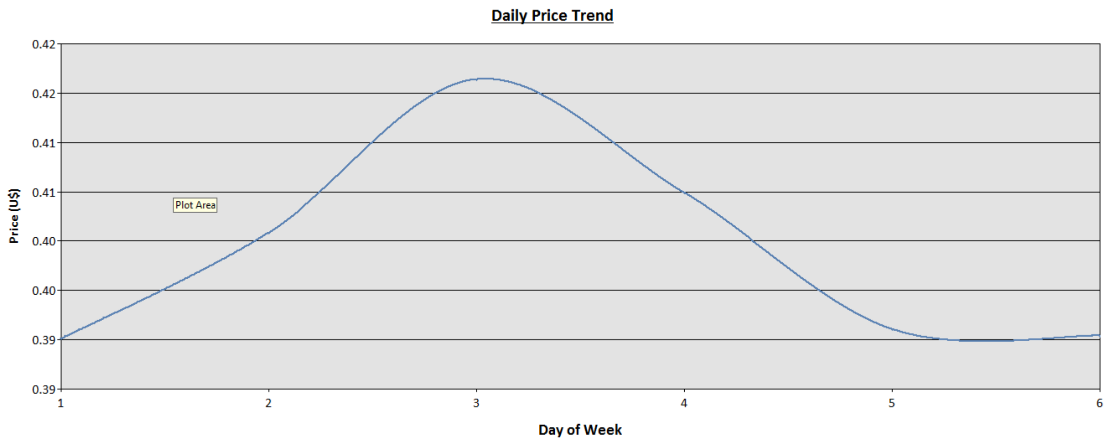

Figure 1. Daily Price Trend

Data Collection and Data Preparation

The data was collected for the vegetable prices at Mbare Musika. We concentrated on only one product; tomatoes. Our initial intention was to analyse historical data spanning more than three years backwards but we could only find data from January 2015 to date. The data has the following attributes; the month (coded from 1 to 12, January being month 1, February month 2 and so on), week (each month has four weeks with a few exceptions with five weeks), day (coded from day 1 to 6, Monday being day 1 through to Saturday which is day 6; Sunday was excluded as all the markets will be closed) and the price. The data was collected from two sites (Anon 2016b) and (Anon 2016a). The collected data exhibited some interesting trends which informally proved the authenticity of the data. The first highlight of the data is that the price of the tomatoes was highest mid-week and lowest during the weekends as shown in Fig 1. The second highlight was that the prices were highest towards month-end and lowest mid-month as illustrated in Fig 2.

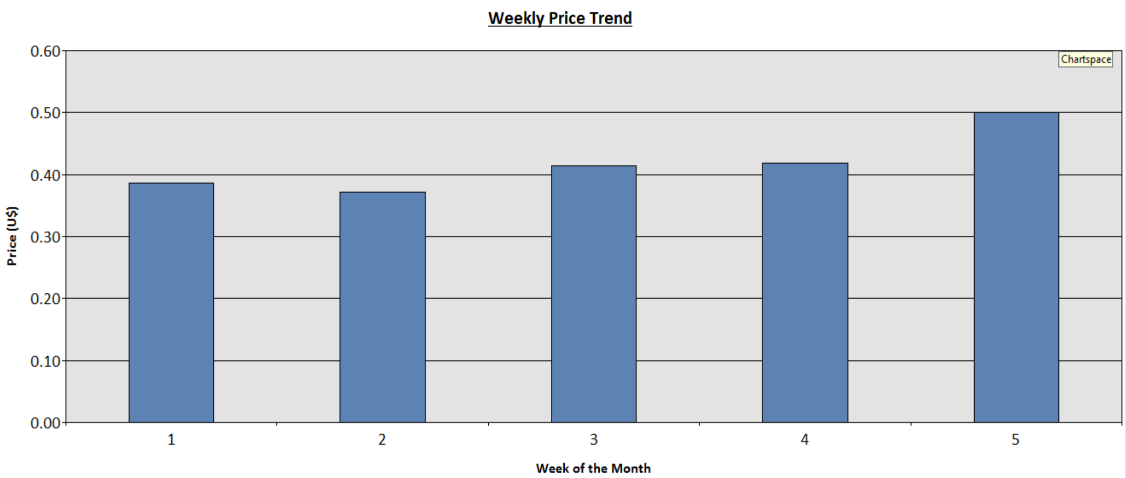

Figure 2. Weekly Price Trend

Feature Engineering

From the onset of the research, we expected that feature engineering would be the most challenging component of this project, as the price data alone offers little insight into future price movement. This difficulty has been amplified by the prevailing harsh economic environment, which makes business very unpredictable. The business landscape has become so inconsistent that it is now difficult to discover any meaningful trends. We have gathered the daily price fix data spanning only from January 2015 to June 2016, where 6 out of every 7 days are eligible data points, which yields about 500 training examples/tuples.

Quantitative research on price prediction often uses a variety of calculated technical indicators. In general, vegetable prices should follow many of the principles of predicting financial markets. Past work on price prediction highlighted some of these methods (Gu, Chen, and Zhu 2006, (Wu, Wu, and Kang 2005) which include;

Trend lines: The ability to recognize the current price trend is vital to the accurate prediction of future prices. Not only can determining the trend over the previous time period provide a rough estimate of continued price movement, but it can also prove useful in spotting a trend reversal (uptrend to downtrend, or vice versa) (Potoski 2013).

Rate of Change: Momentum measures the difference between the price on day x and the price n days before. Rate of change (ROC) is essentially normalized momentum (Potoski 2013).

Ratios: The ratio between ROC calculated over different time intervals (particularly *ROCn / ROCm for m > n*) is informative because it lends insight into how the change in price (similar to the first derivative of price) is changing over time (similar to the second derivative of price) (Potoski 2013).

Since the features in our data were too sparse to be useful in future prediction, we had to find another feature which was correlated to price in order to increase the accuracy of our prediction model. The extra feature we derived was Demand, which we calculated using the following formula:

Demand = [AvgDailyPrice * (6/22)] + [AvgWeeklyPrice * (4/22)] + [AvgMonthlyPrice * (12/22)]

Where **AvgDailyPrice** is the average price for each individual day of the week e.g. the average price for Mondays is different from Thursdays as shown in Fig 1;
AvgWeeklyPrice is the average price for the weeks in a month e.g. week 1 will have a different average as compared to week 4 of the month as shown in Fig 2.
AvgMonthlyPrice is the average price for a particular month e.g. average price for March is different to that of August.

We derived the weights from the total number of days in the week, weeks in a month and months in a year which is 22; the weight for AvgDailyPrice was number of days in a week divided by the total (22). The proposed formula for demand factored in the three indicators mentioned above i.e. trend-lines (how the tomato prices fluctuated), rate of change (how the prices changed within the defined time periods namely daily, weekly and monthly) and the ratios (the weights of the defined time periods)

Model Design and Architecture

According to Bashiri Behmiri and Pires Manso 2013, there are two main methods of price forecasting namely Quantitative and Qualitative methods. Quantitative methods utilize numerical variables that impact product prices and they can be further segmented into two categories: (i) econometric methods and (ii) non-standard methods. Econometric models are further sorted into the three classes of models: (a) time-series models, (b) financial models, and (c) structural models (Bashiri Behmiri and Pires Manso 2013) whereas there are two non-standard methods; Artificial Neural Networks and Support Vector Machine. Qualitative methods are used to anticipate the impact of rare incidents such as wars and natural disasters on the prices of a product.

In this paper we chose to use a non-standard quantitative method; Support Vector Machine (SVM). This choice was motivated by one key factor; our data was non-linear. We used *scikit-learn version 0.17.1* as our tool to implement the SVM algorithm. The tool comes with in-built SVM functions. The model we followed is shown in Figure 3 below. To avoid overfitting we used the ***k-fold cross-validation (CV) method*** where we randomly split the dataset into training and test sets. We used the in-built train_test_split helper function to split the dataset. With the k-fold CV, the training set is further split into k smaller sets. The following procedure is followed for each of the k "folds": (1) A model is trained using k-1 of the folds as training data; (2) The resulting model is validated on the remaining part of the data (i.e., it is used as a test set to compute a performance).

The performance measure that we used in this paper is the accuracy values computed in the loop of k-folds which we then averaged to formulate the overall accuracy of the model. This approach was computationally expensive, but was best suited for our scenario because it does not waste too much data. K-fold CV also avoids the most common situation of choosing a comparatively small test window consisting of an uneven representation of all possible examples (Potoski 2013). We used k=15.

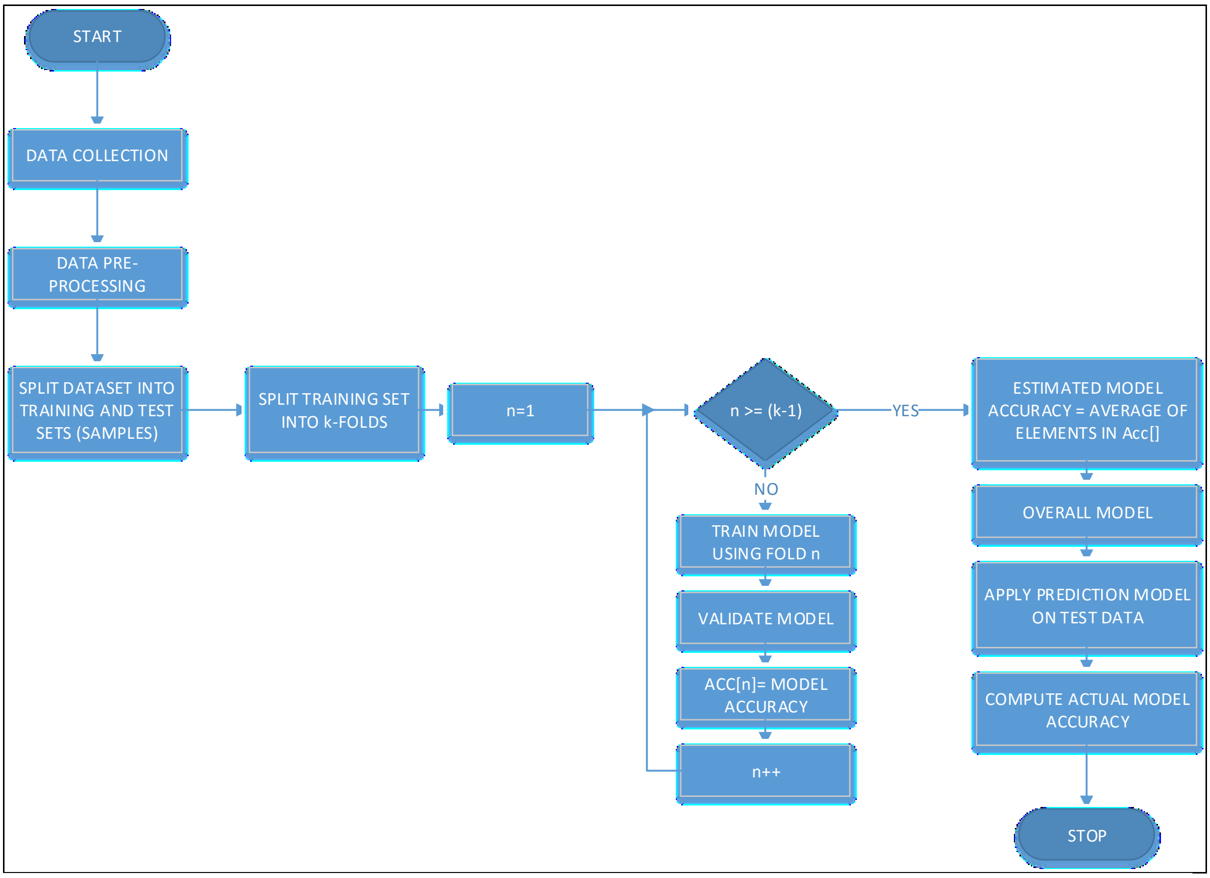

Figure 3. The Price Prediction Model

Results and Analysis

To compute the actual prediction accuracy we implemented the `cross_val_predict` function which returned, the prediction that was obtained for the PRICE element when it was in the test set. We did 10 epochs and they yielded approximately the same values. Table 1 below shows the results obtained. The results show poor price prediction accuracy; below what we anticipated. This was mainly attributed to three factors:

i. We had too little data to come up with a "meaningful" model. The data that we had had to be split into training and test set which further stretched it. The data that was left for training was also further split into k-folds. The folds could not properly train the model.
ii. The data that we used came from two different sources. Initially the data had different formats and layout so we had to standardise it. This introduced a lot of noise at the same time knowledge leakage since we had to make a lot of assumptions. For example when the price for a particular day was missing we assumed the price of the previous day. Also, at some instance we would only find the average price for a week, and in such cases we would put the same price from Monday till Saturday.
iii. The prevailing economic terrain is not ideal for price prediction. The business environment is too volatile which makes future predictions next to impossible. Fortunately, the farmers' market is slightly immune to the environment as compared to other sectors that is why we managed to get an average of 62% accuracy.

Table 1. Prediction Results

	Estimated Accuracy	Actual Accuracy	Variance
1	61.782	63.345	1.563
2	64.892	66.124	1.232
3	59.002	57.893	-1.109
4	67.09	65.341	-1.749
5	62.894	62.928	0.034
6	56.893	60.378	3.485
7	61.839	61.092	-0.747
8	62.648	63.682	1.034
9	62.784	62.345	-0.439
10	63.193	62.478	-0.715
Average Values	**62.3017**	**62.5606**	**0.2589**

Conclusion and Future Work

We were not satisfied with the prediction accuracy that we got. We mainly blame the fact that we did not have adequate data to train our model. However, to increase the accuracy of the model there is need for more historical data for training.

For future work we hope to use other machine learning algorithms such as Artificial Neural Networks for the same data and compare the accuracy.

Acknowledgements

The authors would like to acknowledge the developers of the two sites (*http://agrimarket.co.zw and http://ama.co.zw*) which provided us with data. If it was not for these sites this project would not have been possible.

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Agricultural Market Portal for rural communities

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Abstract

Mobile phone technologies have proven to be essential elements in rural communities. They are used in voice communication, messaging, accessing the internet, mobile applications and e-commerce platforms. There is growing availability of mobile phones in rural areas hence the need to use these technologies for sustainable development of the community. In a rural set up kind of agricultural markets, villagers normally travel long distances looking for agricultural products for consumption at home. A mitigation strategy would save them money and time. This paper envisage the design and development of a Rural Agricultural Market Portal (RAMP) for the rural fork. It is an interactive, mobile phone technology-based marketing system that collects data from farmers and broadcast it to the local community. The collected data show names of products available in village markets, their prices and trading times. RAMP also allow prospective traders to make enquiries. RAMP has a centralised repository of agricultural products and their prices. It registers clients for services and broadcasts product name, price and location according to the client's requests. The portal enables clients to enquire about the products, their prices and market location. In this way, clients would avoid traveling from market to market looking for agricultural products hence saving time and money.

Keywords: Mobile phone, mobile applications, community, portal.

Introduction

Literature has it that mobile phone ownership across the rural areas is rocketing. It is estimated that 78% of rural household own a cell phone (Gallup, 2012). The rural communities do not use these cell phones in rural agricultural set up and development. They normally use them for communication in social networks, short message services and voice calls. This is a motivation towards the design and development of RAMP. It is an interactive system that makes use of mobile technology for information and data collection and processing. The system accepts enquiries on product availability in the village markets providing agricultural stakeholders like farmers, households and traders with market information such as agricultural products, their prices, location of the market and trading times. The portal also facilitates direct marketing campaigns using short messaging service (SMS). The system seeks to address the problem where villagers travel long distances to the market to find out and buy agricultural products for consumption. This wastes their valuable time and hard earned money. So the developed system would then rescue these rural communities and place them in an advanced technology edge in a rural set up.

Mobile phones in agriculture

A mobile phone is a hand held device capable of sending and receiving messages and calls while moving around a wide geographical space (Hackemer and Peterson, 2005). It connects to a cellular network provided by mobile phone operator with access to public telephone networks. In addition to telephony, smart mobile phones offer other services such as text messaging, email, Internet access, short-range wireless communications business applications, gaming and photography. Rural communities are moving with technology as most of them have managed to buy smartphones which have more computing power than the previous ones. Most of the functions and capabilities of these phones have not been exploited in agriculture due to the kind of set up that exists in rural agriculture although its penetration by 2013 reached 103,5% (Kabweza, 2014). The advent of the mobile phones and other mobile technologies has given rise to the need for harnessing such technologies. These make transactions handy, as evidenced by the banking sector over the years in which they introducing internet banking and SMS banking. The mobile phone has penetrated a most of the sectors in the form of mobile money, EcoCash, TeleCash and OneWallet which allow subscribers to send and receive money and make transactions such as paying utility bills. So this is not an exception, especially in rural Zimbabwe where the majority of people live.

India developed an E-Choupal System to assist farmers. E-Choupal is a business system embedded with social goals, designed to empower farmers and triggers a virtuous cycle of higher productivity, higher incomes and enlarged capacity for farmer risk management (Annamalai and Rao, 2010). On the other hand a Esoko system was developed as a conceptualised single market Marketing Information System (MIS) operated by a centralised organisation such as a government agency or other interested party that gathered and distributed market prices using the Internet and Global Systems for Mobile (GSM). The system was accepted across Africa because of its simplicity and portablity. Esoko was designed and developed to make transaction chains through the creation of access points to markets for all stakeholders in an agricultural value chain. The Esoko MIS is a repository of current market prices, buy and sell offers and contacts that are accessible through SMS and the Internet. Esoko's web application is built mainly in PHP and Java and the mobile-enabled aspect of the technology works through SMS on any phone and network (Bartlett, 2011). MIS is a global system, it's not specific to a particular rural community with specific needs and prefences.

Traditional media and Information and Communication Technology (ICT) have played a major role in diffusing information to rural communities and now have much more potential. The pre-paid credit has enabled mobile phone users to send relatively cheap SMS text messages across distances that would otherwise take days to travel, hence changing life for the better. By using mobile phones and messaging technology, farmers get access to valuable market data. Studies in Pakistan showed that information on prevailing market prices for seed cotton strengthened farmers' positions when bargaining with traders. The availability of market information also enables farmers to check on the prices on prevailing market (Nazli, 2010) on a global scale.

The existing systems have their advantages and disadvantages. One other challenge that RAMP addresses is the fact that not many people have access to the internet hence a web-based portal does not fare well. It would not be readily accessible to the rural folk. The ordinary mobile phones do not have access to internet services, hence the use of the SMS platform brings the service to all who have access to mobile phones. Mobile phone penetration is very high meaning that almost every household if not every individual has access to a mobile phone.

Methodology

The Rational Unified Process (RUP) is a full lifecycle software engineering process that uses Unified Modelling Language (UML) as a modelling language. RUP is an object oriented software development methodology that emphasises on the development and maintenance of modules rather than focusing on producing large amounts of paper documents. RUP mainly focuses on ensuring the production of high quality software that meets the needs of its end users, within a predictable schedule, time and budget (Brewer et al, 2005). As a results RAMP is design and developed using RUP. Interviews with the rural farmers and potential clients were conducted to ascertaining the existence of the problem in the rural areas. Farmers and other stakeholders expressed concern about the distance they travel in search of agricultural products, time and money spent. At times their travelling becomes fruitless hence they applauded the development, adoption and implementation of the system to circumvent this disparity.

Development tools

Tools used in software development have a direct impact on delivery and the quality of the software. An object oriented approach is used in system design and development. These tools include PHP, MYSQL, JavaScript, Unified Modelling Language (UML), Adobe Dreamweaver and NetBeans 8. A Short Message Service gateway application is used to interface the system with the mobile phones. This allows for the processing of requests and saving of data in the database. It also provides a platform for sending responses to queries made from mobile devices. Before messages can be received a connection to the modem has to be configured. This connection allows the system to receive SMS messages from clients, process them and send back responses according to the queries or requests.

Agriculture Market Portal Architecture

A portal is a point for harnessing information or data from diverse sources for display and processing. So the agricultural Market portal is for harnessing agricultural data or information for rural farmers, buyers and other stakeholders for trading purposes.

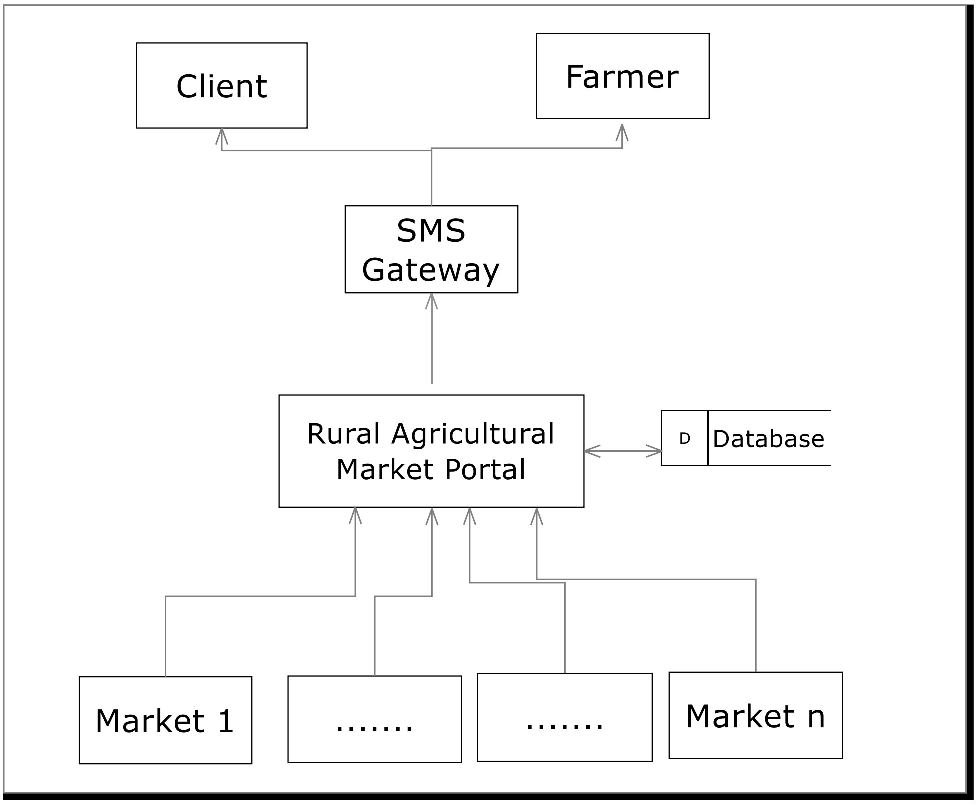

Figure 1. Agricultural market portal architecture.

Figure 1 shows an architectural design that specifies the major components of the application and how they communicate with each other. These are functional components given according to software systems architectural principles. One of the principles states that the system architecture should depict functional components instead of technology components. The developed RAMP conforms to this principle as shown in Figure 1. The clients interact with the system through an SMS gateway. The SMS gateway provides the interface between the system and the mobile phones that are used by the clients to send requests and receive responses from the system. A database is used to store data on markets, products and prices associated with each product. Each market provides data on the products and the price of each product. Each market has to modify its records as to whether the product is available or not. For simplicity purposes, four markets (Market 1, Market 2, Market 3 and Market 4) were used, though the system remains exponentially scalable as depicted in the architectural figure 1.

Market Portal System

Figure 2 shows the system process flow, interface, components interrelationships and interactions following software principles.

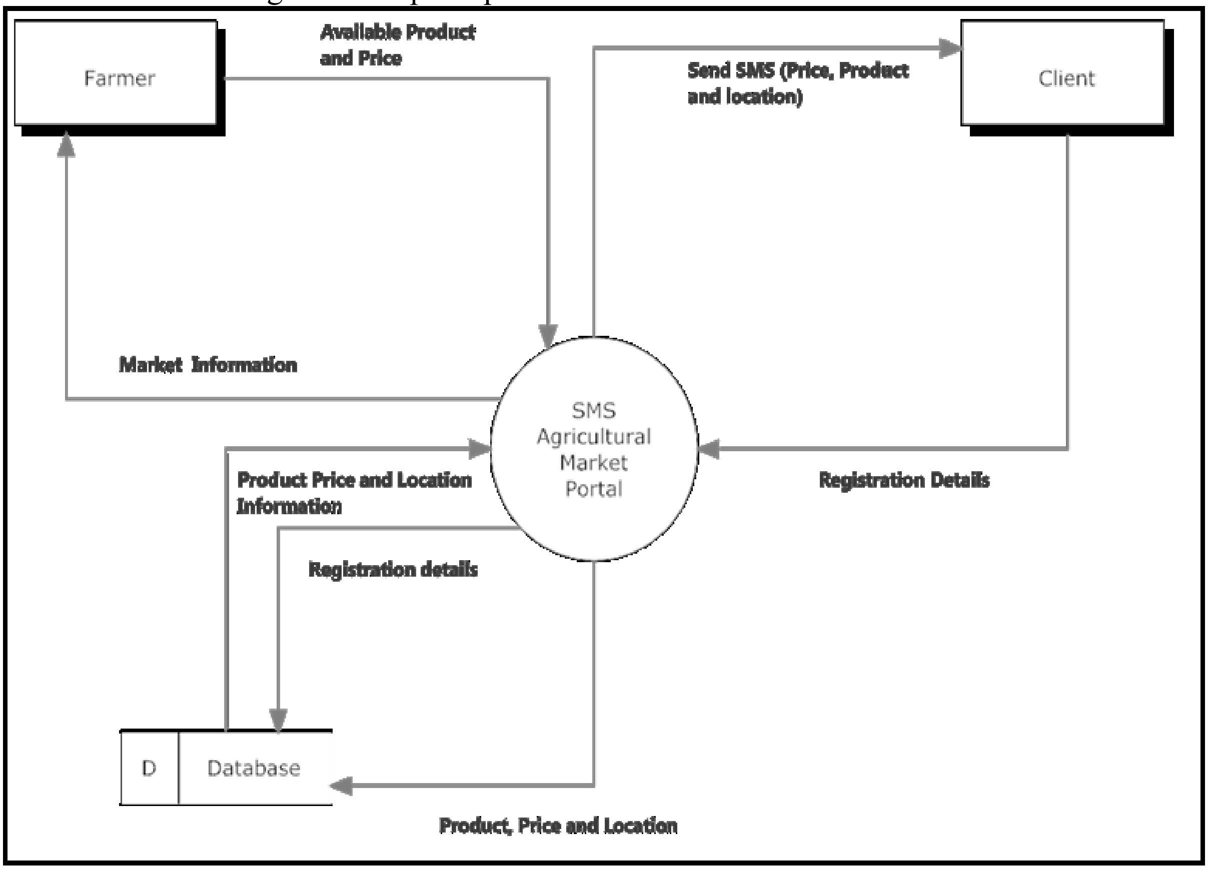

Figure 2. Agricultural market portal System

The clients can check for specific available products from the markets. The system gives information on the market in which the product is available and its corresponding price. The client has to be registered to use the system and any unregistered users are not able to use the system or access the database.

System Implementation

Implementation was done using a MySQL database and PHP. The users at the various markets add products and prices of their products. The system automatically picks the location since each user has a specific market they are assigned to. The user also checks for the availability and adjusts records accordingly. This assist the client to know whether the product is available or not. The Administrator administers the system and can add, modify and delete users and can reset passwords, add, modify and delete markets and products and can access all modules in the system. The user who works at a specific market can change or modify password and products in specific markets. The user can also modify the product prices. The client can register, unregister and request product price and location of a market.

Markets

This module allows the administrator to add, delete and modify markets. As new markets are established they are added to the system. This ensures that the system provides accurate information.

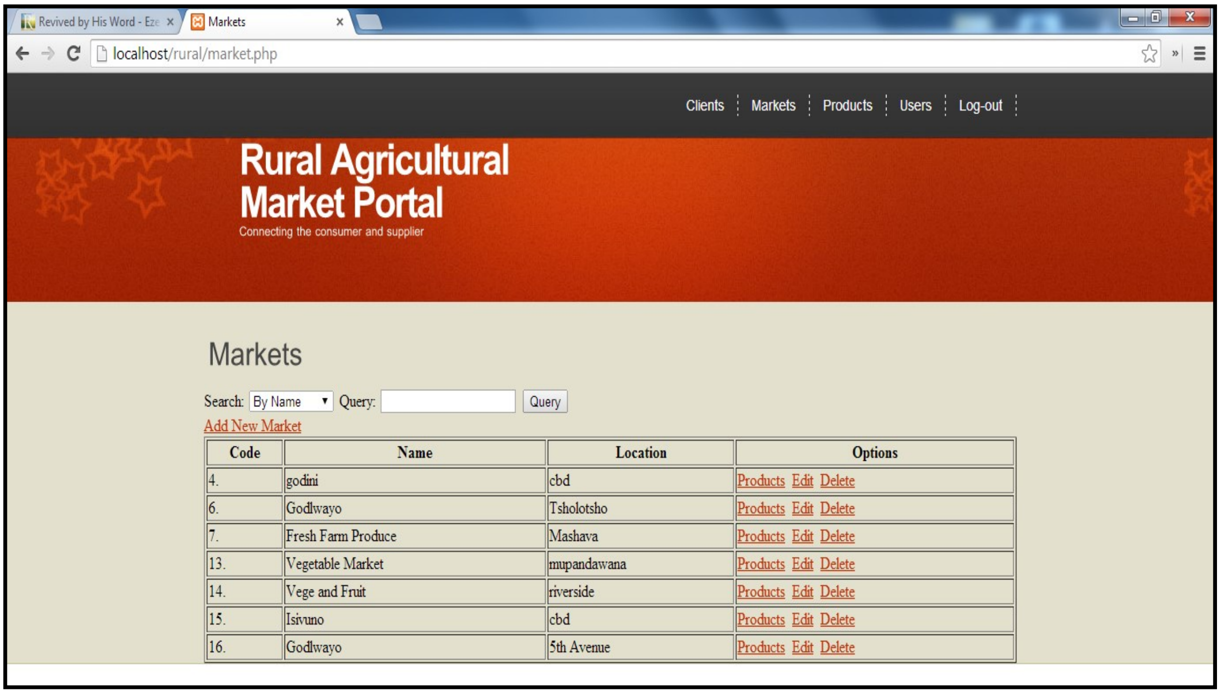

Figure 3. Markets Screenshot

Products

This module allows the user assigned to each market to add, delete and modify products. As new products are introduced they are added to the system. When the prices change, their corresponding entries are modified. The availability of the products are also modified as and when the products are available or not available. This ensures that the system provides accurate information.

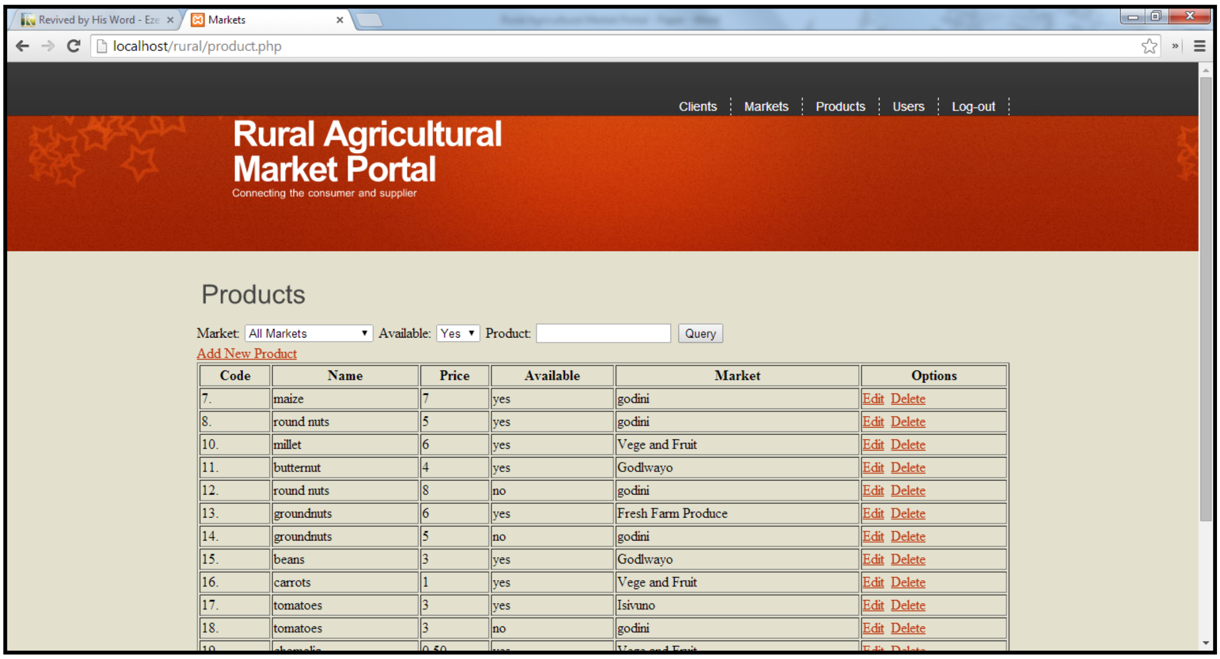

Figure 4. Products Screenshot

Clients

This module registers the clients on the system and enables them to use the system by making enquiries on product, price and market location. It collects the clients name, mobile number and location. As the client sends enquiries, the system populates and increments the activity log which logs the number of times a client has used the system.

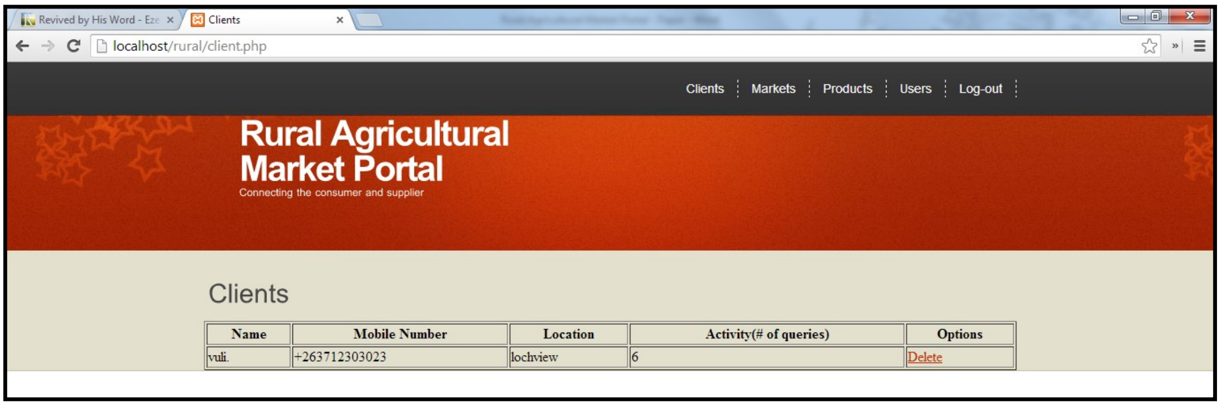

Figure 5. Clients Screenshot

Client Side

The client uses SMS to send enquiries to the system, which responds by sending a message back to the client. The client is able to register as a user, to unregister and delete their user account. The client is also able to check whether a product is available in a market, to find all markets that have a product and to get the location of a market.

Conclusion and Recommendations

The strengths associated with RAMP include, the ease of use of the SMS platform as opposed to the web-based platform. The system is usable in any part of the country where there is network and is not dependent on data from the users. However, RAMP is not all that user friendly. There is a challenge in interpreting the syntax of the commands which may be misinterpreted by the users of the system. Further improvements can be made on RAMP so as to improve its functionality and broaden its scope. This includes the use of indigenous languages to allow those who may not be able to read English or understand it. This can be done through the inclusion of a language interpreter. It can be expanded to allow for the broadcasting of specials at specific markets. This can also incorporate the use of Unstructured Supplementary Service Data (USSD) to avoid syntax errors in typing requests. There is also need to further develop security features to protect the system from misuse. Future work with regard to evaluation and acceptance of the system may be carried out in a selected rural district in Zimbabwe.

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Characterisation of compression and flexural properties of a composite made from cotton stalk fibres and phenol formaldehyde resin

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Abstract

The use of natural material in the manufacture of composite is attracting interest owing to environmental concern posed by synthetic non-degradable materials. In the current study, cotton stalk fibres and phenol formaldehyde resin were used to fabricate a fibreboard composite. Cotton stalks are waste agricultural material that are normally disposed from the fields to prevent the growth of pests such as the polyphagous mealybug. Fibres were extracted from the cotton stalk through natural retting and manual decortication process. A hand-lay technique was used to fabricate a composite with fibre mass fraction (M_f) varying from 10.96 to 38.11%. The fabricated composite was characterised by flexural and compressive strength. Regression analysis was carried out using Minitab software to study the effect of M_f on the studied strength properties. The determined compressive strength of the composite was 0.67MPa - 1.85MPa while the flexural strength varied between 46.39MPa – 170MPa depending on the M_f used. The fabricated composite compared well to standards for fibreboards and could find use in furniture board applications and ceiling boards.

Keywords: Compressional strength, cotton stalk fibres, flexural strength, phenol formaldehyde resin

Introduction

Cotton plant is cultivated primarily for textile fibres, and little use is made of the cotton plant stalk. The cultivation of cotton generates plant residues equivalent to three to five times the weight of the fibre produced (Reddy N, 2009). Available in Zimbabwe is 300,000 hectares of cotton farmed land making available almost a million metric tonnes of cotton stalks (Mseva 2011). After harvesting the cotton bolls, the entire plant consisting of the stalk and leaves are residue which remains in the field and the farmers normally discard it through burning (Binod P 2011). Burning agricultural residues causes environmental problems such as air pollution, soil erosion and decreases soil biological activity (Copur Y 2007). On average around 0.85 million metric tonnes of CO_2 equivalent is released per million tonnes of cotton stalks burnt (C.Sundaramoorthy 2009). Other greenhouse gases are emitted such as nitrous oxide and methane as shown in table 1.

Table 1. Showing emission of greenhouse gas per million tonnes of cotton stalks burned in the field.

Green House Gas	Emission Factor ($g.kg^{-1}$)	Total Emission (Mn MT)	Total Emission (Mn Mt Co_2e)
NO_x	2.68	0.00265	0.7898
CH_4	2.7	0.0027	0.0675

**NO –Nitrous oxide, *CH_4 – Methane, *Mn Mt Co_2e – Million Metric tonnes of carbon dioxide equivalent*

The cotton stalks can be used to extract suitable bast fibres that can be used in composite manufacture. Fibres can be produced from many lignocellulosics and form the raw material for many composites, most notably fibreboards. Because lignocellulosics are fibrous in nature, fibreboards exploit their inherent strength to a higher degree than particle boards (Brent English 1997). Medium density fibreboards (MDF) are denser than plywood or particleboards thus widening its applications (S.Mahzan, 2010). Reinforcing polymer matrix with lignocellulosics materials has several advantages such as lower density, high stiffness, less abrasive to equipment, biodegradable and lower cost (R.M.rowell, 1993), (M.Jacob, 2004). Fibreboards also have several advantages such as having nearly double the strength of particle board (Bloch, 2012), can be painted, can be drilled and screwed, good insulator, sound proofing attributes, fungus/mold resistant, flammable but difficult to ignite and can be recycled.

Micro buckling or kinking of fibres are now understood to be the mechanism by which fibre reinforced composites fail under compression. Micro buckling is the buckling of fibres embedded in matrix foundation. Kinking on the other hand, is a highly localised fibre buckling. Kink bands are formed after attainment of the peak compressive load when the region between the fibre breaks is deformed plastically (S.Kumar, et al. 1999). The compression failure can be explained using Rosen's model which is one of the most cited work on compression modelling (Rosen, 1965). This model is based on the micro-buckling approach considering 2D composite. Its postulates two modes of failure namely, extension mode in which the fibres buckle out of phase and shear mode in which fibres buckle in phase (S.Kumar et al, 1999). A significant number of previous experimental results have revealed that material failure (usually at microstructural level) such as fibre micro buckling or kinking in laminae where the fibres are aligned with the loading axis are initiated mechanisms of compressive failure that lead to global instability (Sohi, 1987). This was visible on the tested composite fibreboard after compression fibre buckling and kinking was visible.

Flexure testing is often done on relatively flexible materials such as polymers, wood and composites. Reliable data on the bending properties of fibreboards is important to end users, such as manufacturers and design professionals.

Available literature on cotton stalk fibre reinforced polymer composite are scare. Hence the present work has been undertaken to develop cotton stalk fibre reinforced phenol formaldehyde composite. Research carried out by Ajith Joseph (2015) showed that composites prepared from banana fibres and phenol formaldehyde resin had flexural strength that varied between 25.31MPa – 36.05 MPa with varying fibre length from 10mm to 40 mm. Seena Joseph (2002) also carried out research on banana fibre an phenol formaldehyde resin with varying fibre mass fraction and obtained flexural strength that varied between 25MPa – 50MPa respectively.

According to Amar Singh (2008) reinforcement of phenol formaldehyde with hibiscus sabdariffa lignocellulosic fibre gave composite that could bear compressional loads of between 3387.5N to 4701.0N for fibre volume fraction of between 10 and 40 percent respectively (Amar Singh Singha, 2008). This gave the composites a compressional strength of between 0.8MPa to 1.5MPa for fibre volume fraction of between 10 and 40 percent respectively.

Materials and Methods

Development of Composite

A composite was fabricated using hand layup method. The cotton stalk fibres were extracted through natural retting and manual decortication (Nkomo, et al. 2016) and laid as a mat on a stainless steel mould covered with polyvinyl alcohol release agent. The fabrication mould used is as shown in Figure 1a and 1b. Phenol formaldehyde resin was then poured over the fibre mat, distributed and consolidated evenly using a roller. The wetted fibres were then heated at 130°C for 45 minutes under compression ensuring thickness of 5 mm for each of the samples.

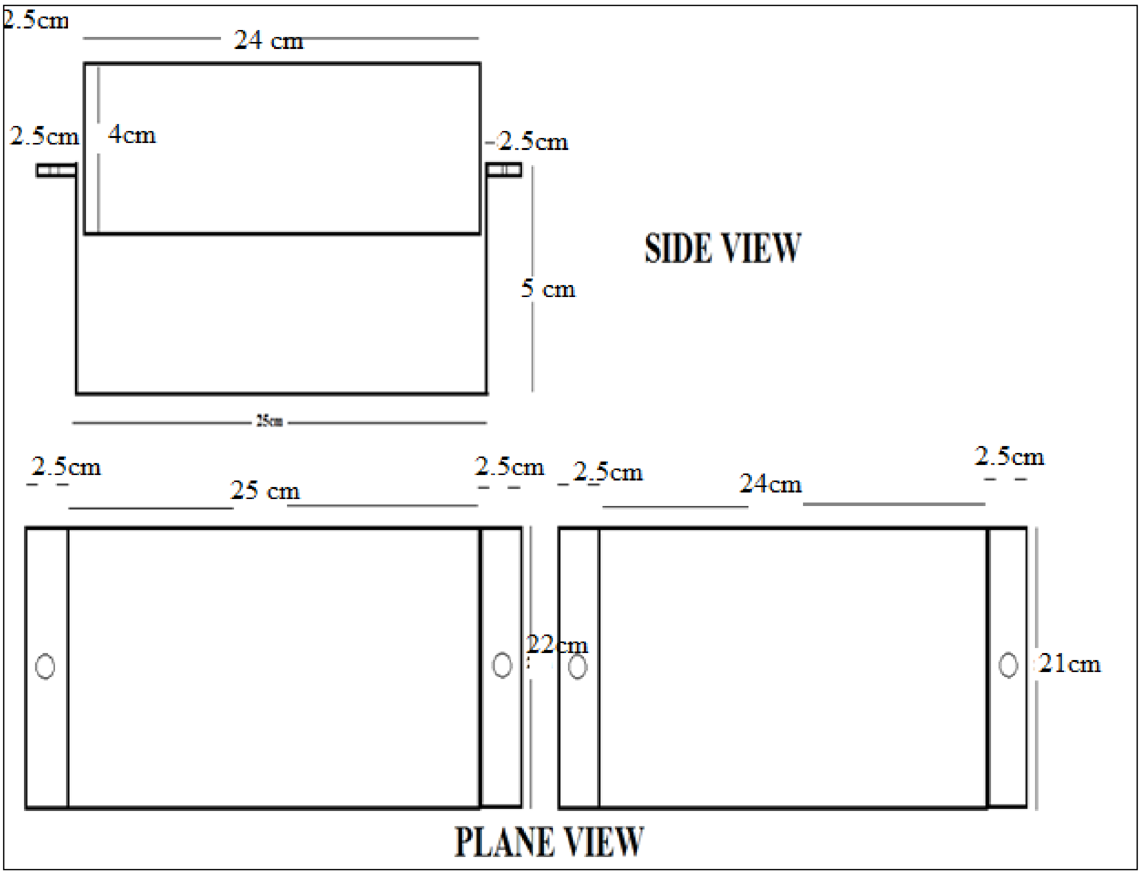

Figure 1a. Showing schematic of stainless steel composite mould used

Figure 1b. Stainless steel composite mould used for fabrication of composite

The fibre mass fraction was varied between 10.96% - 38.11%. The density of the fibreboards was maintained between 500-800 kg/m^3. Table 2 shows the experimental design followed in fabricating the fibreboard samples.

Table 2. Composite fabrication experimental design

No.	Fibre Mass Fraction	Fibre weight	Resin	Resin Volume Fraction	Resin weight	Total Weight	Calculated Density
	%	g	ml	%	g	g	kg/m^3
1	0%	0	140ml	100.00%	155.4	155.4	586.4151
2	10.96%	25	140ml	89.04%	155.4	180.4	680.7547
3	19.76%	50	140ml	80.24%	155.4	205.4	775.0943
4	26.98%	75	140ml	73.02%	155.4	230.4	869.4340
5	33.00%	100	140ml	67.00%	155.4	255.4	963.7736
6	38.11%	125	140ml	61.89%	155.4	280.4	1058.1132

Composite compressive strength measurement

Compression strength test was carried out in accordance with ASTM D695 standards on a beam press CCT24 machine (serial number 210/6). The test specimen width, thickness and length was 25mm, 5mm and 150mm, respectively measured at a precision of 0.01mm. Only specimens free from any visible surface flaws were tested. The specimen were placed between surfaces of the compression machine taking care to align the centre line of its long axis with the centre line of the plunger to ensure that the ends of the specimen were parallel with the surface of the compression tool. The specimens were loaded at a rate of 1.3mm/min until fracture in accordance with ASTM D695 (ASTM Standard D695-15 2002).

The test speed used for compression strength test was calculated by use of a standard chart for the compression tester machine which indicates the conversion factor as shown in table 3. Hence the loading rate used was 45kN/minute for compressing the composite samples. The conversion factor used is 2.5 as indicated in table 3.

Table 3. Extract of standards for compression machine showing loading rates

Area in mm^2	**Loading rate kN/minute**	**Conversion factor :kN to MPa divide by**
2500	45	2.5
4900	88	4.9
10000	180	10.0
22500	405	22.5

The compressive strength (MPa) was calculated using equation (1).

$$\textbf{Compressional Strength (MPa)} = \frac{\textbf{Ultimate strength (kN)}}{\textbf{Conversion factor}} \quad (1)$$

Composite flexural strength measurement

The composite flexural strength test were performed using a three point bending method according to ASTM D790 (ASTM Standard D790-00 2002) standard procedure. Specimen of 25mm width, 5 mm thickness and length of 150mm were used in the tests. A Universal Tensile Machine (CCT24 Beam Test serial no. 214/16) using a 5KN load cell was used. The load was placed midway between supports and the crosshead speed was adjusted to 0.05KN/sec. The experimental set-up is shown in Figure 2.

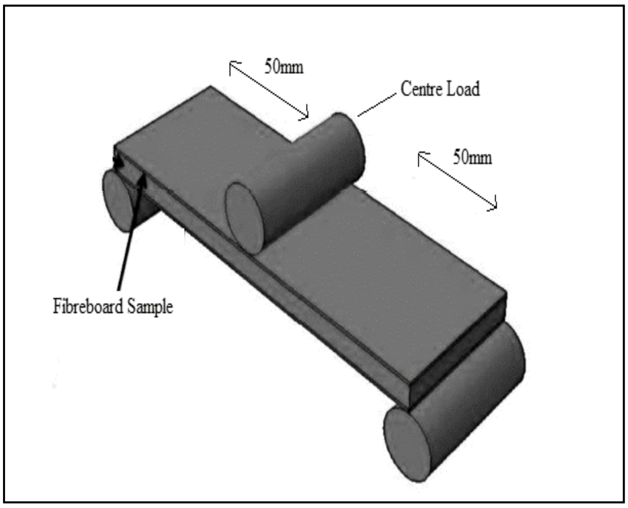

Figure 2. Mounting of fibreboard composite sample on flexural tester

The flexural strength was computed using the formula given in equation (2) (A Mosawi, et al. 2012).

$$\mathbf{f_{cf}} = \frac{\mathbf{3F\ X\ L}}{\mathbf{2b\ X\ d^2}} \tag{2}$$

Where f_{cf} is flexural Strength (MPa), F is maximum load (N), L is distance between axes (mm), b is width of specimen (mm) and d is depth (mm).

Results and Discussion

Composite Compressive strength

A compression strength test determines behaviour of materials under crushing loads. In compression, it is usually known that that the ultimate compressive strength of the composite is mainly dependent on the strength of the matrix and the extent of fibre/matrix adhesion. (Mylsamy and Rajendran, 2011).

Figure 3 shows the variation of composite compressive strength as a function of its fibre mass fraction (M_f).

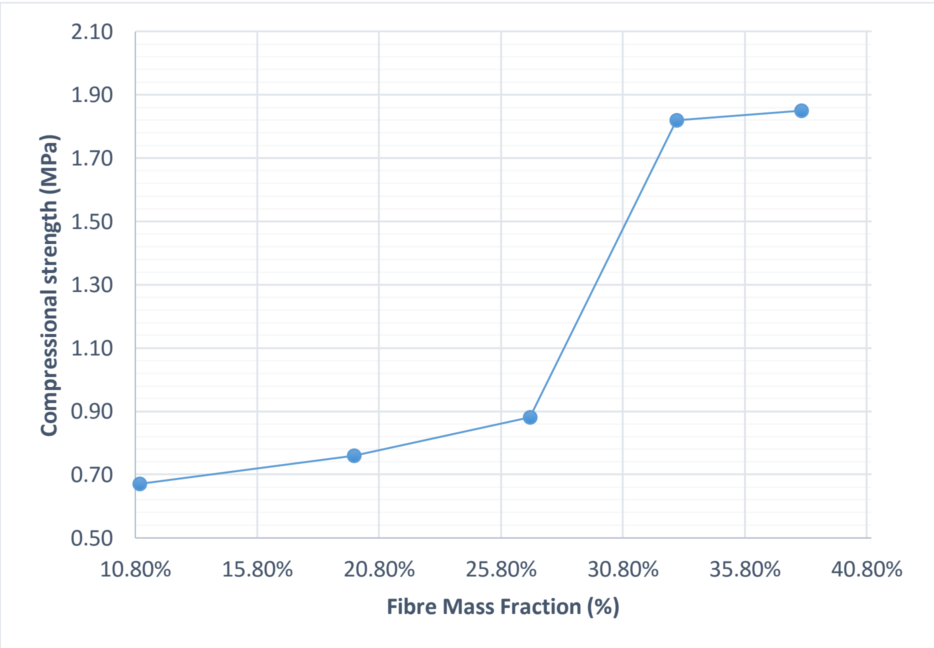

Figure 3. Fibre mass fraction against composite compressional strength

The compression strength of the composite increases steadily with increase in fibre mass fraction from 10.98% to 26%. During this stage the compressional strength increases from 0.7MPa to 0.9MPa. From M_f of 26% to 33%, a sharp increase in compressional strength up to 1.8MPa occurs after which no significant increase in compressive strength is noted as M_f increases to 38.11%. However beyond a certain mass fraction there is not much increase in strength since the failure mode is mainly matrix dominated. The increase in compressive strength as fibre mass fraction was increased may be attributed to load distribution among greater quantity of reinforcement hence increasing resistance to local buckling or kinking within each fibre. Fibre crushing occurs when the axial strain in the composite attains a critical value equal to the crushing strain of the fibres (Fleck and Jelf, 1990). Compression failure is a design limiting feature of fibre composite materials (N.A.Fleck, 1993). The dominant failure mode that was observed for the composite under compression was compressive buckling or kinking. Other failure modes such as fibre crushing also occurred. When the fibre buckles, the matrix-fibre interface may fracture in shear and lead to ultimate failure (El-Tayeb, 2008).

Composite flexural strength

Flexural strength is an important parameter that helps determine potential end uses of composite fibreboards. This is calculated at the surface of the specimen on the convex or tension side. Figure 4 shows the variations of flexural strength of composite with the fibre mass fraction with the data fitted using linear regression. An increase in composite's M_f leads to an increase in flexural strength from 46.39MPa – 170MPa. This is in agreement with other study carried out by Kabir (2014) and has been attributed to a reduction in voids within the composite structure (Kabir, et al. 2014). Joseph et al (1999) attributed the increase in the flexural modulus to the increasing fibre to fibre contact when the fibres were impregnated (Joseph, Kuruvilla and Thomas 1999). This suggests that for increase in flexural rigidity, higher fibre mass fraction is desirable. Regression analysis was carried out to come up with the relationship between flexural strength and corresponding fibre mass fraction after checking that no violation of regression laws was present.

A simple linear regression was calculated to predict flexural strength based on the fibre mass fraction Minitab statistical software was used. A significant regression equation was found ($F(1, 3) = 150.45$, $p < .001$), with an R^2 of 98.04%.. Flexural strength is given as shown in equation 3.

$$\boldsymbol{Flexural\ strength\ (MPa) = -5.47 + 437.9M_f} \quad \textbf{(3)}$$

This model applies to randomly laid cotton stalk fibre composite. The model allows for direct computation of the cotton stalk fibre composite in terms of flexural strength to suit the desired end use by varying the M_f. This model was formulated assuming a linear relationship between flexural strength and fibre mass fraction after checking that it does not violate any laws of linear regression.

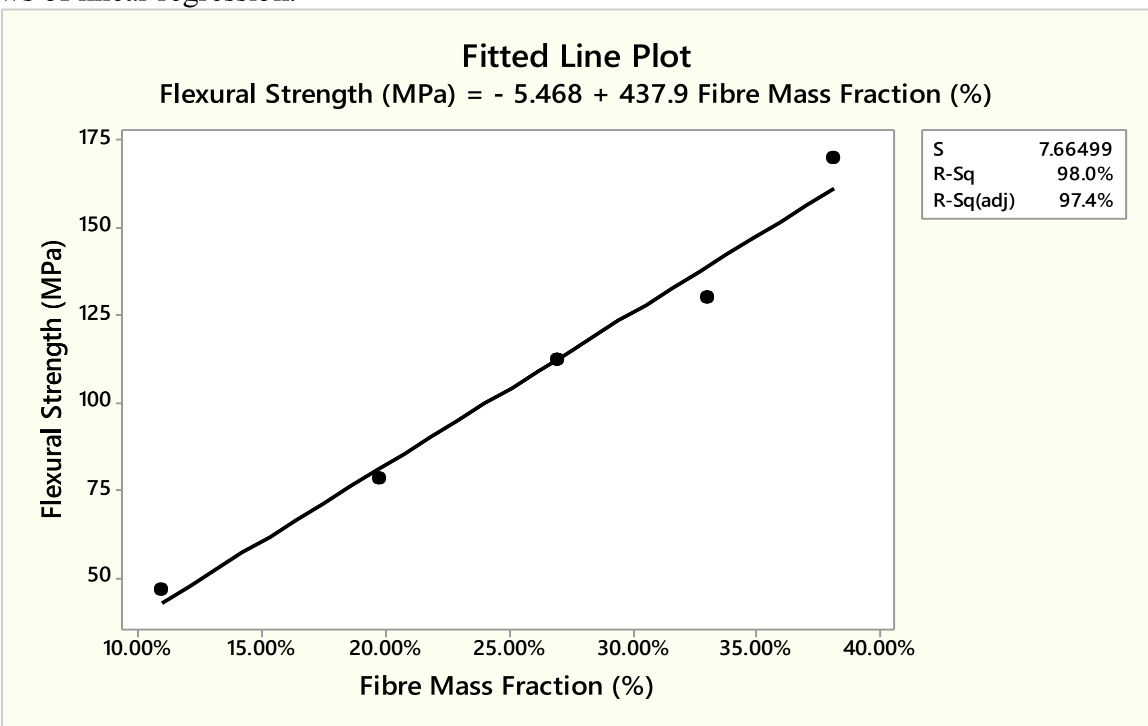

Figure 4. Fitted line plot for ultimate flexural strength vs fibre mass fraction

Comparison of fabricated composite to standards

The flexural strength of the cotton stalk fibreboard was well above the standard of 44MPa. The flexural strength ranges from 46.39 to 170.00MPa depending on the fibre mass fraction. The density of the fabricated cotton stalk fibreboard varied from 644-1004 kg/m^3 which is well within the range of the standard MDF of equal thickness (5mm) which has density of between 780-860 kg/m^3. The fibreboard compressional strength was lower than the standard of 10MPa for medium density fibreboards due to the brittleness of the phenol formaldehyde resin.

Table 4. Comparison of fibreboard mechanical properties with standards

Property	**Cotton stalk board**	**Typical Standard for MDF** (EWPAA 2008)
Compressive Strength (MPa)	0.67-1.85	10
Flexural Strength (MPa)	46.39 – 170	44
Density (Kg/m^3)	644-1004	780-860

Costing of the produced fibreboard

The major cost, which constitutes 68% of the total cost of the fibreboard is the resin. The resin used was imported from South Africa Resinkem Company at a cost of $1.20/kg. The mould release agent used was also an imported chemical from NCS Company in South Africa. Table 5 shows a comparison in the fabricated board cost against the selling price of boards in the market.

Table 5. Showing comparison of cost of producing cotton stalk fibreboard to other available boards

Types of board	**Cost /m^2**
Cotton stalk fibre board	$5.56
Zimtex particleboard	$5.80
Softwood timber partition boards	$16.00

The cotton stalk fibreboard costs approximately $5.56/m^2 to manufacture which is cheaper than the locally manufactured Zimtex particleboards which cost $5.80/ m^2. The fibreboard is far much lower in cost as compared to the softwood which costs $16.00/ m^2. The cost of producing the cotton stalk fibreboard can be brought down with bulk purchase of the chemicals and raw materials such as the cotton stalks can be transported in bulk. This will bring down the cost due to the economy of scale.

Conclusion

In conclusion the present study fabricated composites using phenol formaldehyde resin and different proportions of fibres extracted from the cotton stalk. The compressive and flexural strength of the composites were evaluated and the following conclusions drawn from the study:

- The determined flexural strength was 46.39MPa – 272MPa which corresponded with the Mf of 10%-38%. The increase in Mf significantly improves the behaviour in tensile for flexure. This compared well with standard values required for fibreboards and particleboards.
- The determined compressive strength was 0.7MPa -1.8MPa, also corresponding with the Mf of 10-38%. The addition of fibres does above 33% M_f does not significantly affect the compressional strength of the composite as this failure is more matrix dominated. The compression failure can be explained using Rosen's model which is one of the most cited work on compression modelling (Rosen, 1965).
- The determined properties of the composite made it suitable for end uses such as flooring, decking, ceiling boards, furniture, door panels and partitioning boards. In addition, the utilisation of the waste cotton stalk fibres in composite manufacture may help alleviate the problems of environmental pollution due to the burning of these stalks as well as create value addition to cotton farming process.

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Agriculture information dissemination mobile application

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Abstract

Agriculture plays an important role in the social and economic development of most African countries. It is the main contributor to economic growth and stability in the Zimbabwe, a developing country in Southern Africa. Through agriculture, Zimbabwe was once the bread basket of Southern Africa. Nevertheless, the small farmers are currently faced with many challenges regarding the access, efficiency and affordability of agricultural information useful for uplifting agricultural productivity. It has been noted that modern information and communication technologies (ICTs) have the potential to both alleviate these barriers and improve the dissemination of timely and updated agricultural information for better productivity and marketing. This paper discusses the use of a mobile application developed to function as an acquisition and dissemination tool for timely and reliable agriculture information presented in local languages to small scale farmers in Zimbabwe. The contents of the mobile application relate to information about types of crops and livestock, market prices, logistics for farming, budget, weather etc. Two hundred small scale farmers conducted the validation and verification of the system and the results prove that the application is a reliable and efficient tool for both the information acquisition and dissemination for the benefit of the small scale farmers. The developed mobile application proves to be a solution to the persisting unaffordability, unavailability and inaccessibility of agriculture information, a that has been faced by the small scale farmers in remote areas far from the agriculture extension officers

Keywords: Information and communication technologies, small-scale farmers, Agriculture, Zimbabwe, mobile phone, mobile application.

Introduction

The agricultural sector has been described as the "engine for economic growth and improved livelihoods in Africa" (Munyua, Adera and Jensen 2009). Like other African nations, Zimbabwe is an Agriculture country (C. T. Chisita 2010) with the majority of population living in rural areas and mostly dependent on agriculture as a source of income and livelihood (Vitoria, Mudimu and Moyo 2012). Small scale farmers have been defined as those farmers in possession of approximately 2–5 hectares of land and own 10–20 head of livestock practising a mixture of both commercial and subsistence farming (Munyua, Adera and Jensen 2009). This type of farming is dependent on the members of the family for labour. For an improved productivity these farmers require access to improved technologies, best practices, and to appropriate, timely and comprehensive information and knowledge on production (Munyua, Adera and Jensen 2009). In addition, information and knowledge are considered to be indispensable tools for empowering and enabling small scale farmers to make informed decisions (C. T. Chisita 2010).

ICTs refer to the combination of hardware devices and software programs that enable the acquisition, storage, processing, transmission and management of information. These technologies include the traditional radios and televisions. They also include the modern technologies such as the desktop computers, laptops, tablet pcs, the internet, and cellular phone among other computing and communication devices. The latter having permeated Zimbabwe such that it confirms the observation that what was once an object of luxury and privilege for the elite has become a basic necessity in Africa, (Chisita and Malapela 2014), particularly in the agricultural sector in Zimbabwe.

However existing research shows that small scale farmers are faced with barriers to agricultural productivity. The major challenge to small scale farming is the lack of access to valid and reliable information on how to achieve agricultural productivity and marketing. This problem could be attributed to the unavailability of extension staff in these farmers' locality for consultation or advice (Asenso-Okyere and Mekonnen 2012). In agreement, the number of extension workers is said to be decreasing while farming numbers have been increasing (Gakuru, Winters and Stepma 2009). The small holder farming systems are also much less productive and profitable because of a lack of access to information and the skills gap that constrains the adoption of available ICTs (Chisita and Malapela 2014). This paper therefore proposes a prescription to both the problem of agriculture information unavailability and the limited use of ICTs in Agriculture in Zimbabwe. The next section discusses the domain of agriculture in Zimbabwe, followed by the application of ICTs in agriculture, then the research methodology preceding the proposed solution and the research results and finally the conclusion.

Agriculture industry in Zimbabwe

Agriculture is the backbone of Zimbabwe and it underpins the economic, social and political lives of the majority contributing significantly to the Gross Domestic Product (GDP), employment and foreign exchange earnings (Maiyaki 2010). It still accounts for about 20 percent of the gross domestic product (GDP) of the country and has been stable at that since 2012 (Vitoria, Mudimu and Moyo 2012) Both commercial and subsistence farming is practiced in Zimbabwe where various crops and livestock are produced due to the rich agricultural resources available in the country. The principal crops produced include but are not limited to maize, cotton, sugar, groundnuts, beans and cow peas. The commercial crops are the Tobacco, Cut-Flowers, Raw Sugar Cane, Cotton, Chilled Vegetables, Coffee, Fruit, Tea while commercial ranching is mainly based on cattle and wildlife production.

Use of ICTs in Agriculture

Several studies have been carried out that show how the afore mentioned problems facing small scale farmers could be either reduced or mitigated. For example, ICTs have become increasingly integrated into information disseminated to farmers (Gakuru, Winters and Stepma 2009). Some of these ICTs have been identified in (Asenso-Okyere and Mekonnen 2012),

> One promising area to do agricultural extension to reach large number of farmers is using information communication technologies (ICTs): mobile telephony, innovative community radio and television programs, mobile phones in combination with radio, video shows, information kiosks, web portals, rural tele-centers, farmer call centers, video-conference, offline multimedia CDs, open distance learning, etc.

The positive impact of ICTs in Agriculture are well documented in literature. ICT-based agricultural extension brings incredible opportunities and has the potential of enabling the empowerment of farming communities. It has also been observed that modern ICTs such as mobile technologies, social media and blogs enable farmers not only to transmit or exchange but also to create agricultural information to increase productivity (Chisita and Malapela 2014). The benefits of ICTs and Information that farmers require on agriculture include, trends in food production, demand and processing, market prices, new environmentally sound production techniques and practices, trade laws and indigenous knowledge (Pade, Mallinson and Lannon 2005). The information also include issues related to the crop and livestock diseases as well as how to both prevent and cure them. Such information could be accessible to farmers at little or no cost. For example, villagers in rural India who previously incurred high transport costs to consult with Government officials can now easily access required agricultural information through the Government-owned computer network (Pade, Mallinson and Lannon 2005).

ICT Application to agriculture

ICTs have multiple capabilities in agriculture such as faster access to digital information in the text, audio, video and photographic format, which can be transmitted to various people who are connected over long distances at a lower cost. Such ICTs could be the traditional radio and television as well as the modern Internet, wireless technologies etc. Although with an advantage of conveying agricultural information in a local language understood by the majority of farmers, the former ICTs are limited to general discussions rather than the more specific and individual agricultural issues and concerns. It is on this premise that this paper's focus is on the latter as discussed in the subsequent section.

The Internet

The Internet is a powerful tool capable of capturing, storing and disseminating agricultural information through its popular services like the electronic mail and the world wide web. Through internet based services like the social networking sites, the farmers could access relevant and updated information from such stakeholders as government agriculture extension workers, non-governmental organisations (NGOs), agricultural research and documentation centres, and agricultural input and equipment suppliers (Pade, Mallinson and Lannon 2005).

The wireless technologies

These ICTs can be combined with application software like Whatsapp to provide agricultural information to farmers in dispersed locations. For example, the cellular phones due to their affordability have become more available and accessible to many people even in the developing nations such as Zimbabwe. The proliferation of these ubiquitous devices has been increasing fast in the Zimbabwean environment (Kabanda 2013) as indicated in Figure 1 and has since increased to 100% penetration in Zimbabwe. The affordances of such wireless technologies could be taken advantage of by the farmers in Zimbabwe to facilitate access to agricultural information and enhance productivity, markets products, network and create virtual communities of practice (Chisita and Malapela 2014). Cellular and smart phones with built-in cameras can enable farmers to photograph a pest and then send the picture to an extension researcher for diagnostic purpose (Pade, Mallinson and Lannon 2005), thus saving the farmer both money and time lost in the current trend of face-to-face consultations with the geographically dispersed agriculture extension officers. A detailed discussion of these technologies is found in (Gakuru, Winters and Stepma 2009).

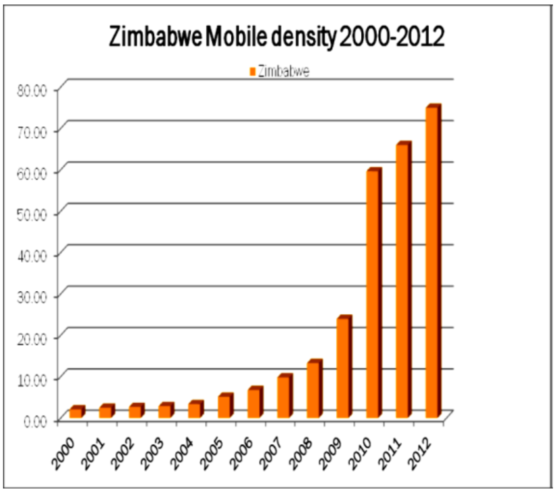

Figure 1. The proliferation of cellular phones in Zimbabwe adapted from (Kabanda 2013)

Figure 1 is an indication of the permeation of the cellular and smart phones in Zimbabwe. It shows that even though the possession of these ubiquitous devices had very slow beginnings, by the year 2012, the devices, proliferation was nearing 100%, meaning that at least every adult would be having a cellular or smart phone. This could be attributed to the low cost, battery life, light weight and the affordances of such devices.

Methodology

This research is based on the use of secondary sources of data and is a prescriptive study. The researchers reviewed existing literature to determine the challenges currently faced by the small scale farmers in Zimbabwe. They also did a literature review on the affordances and the application of ICTs in Agriculture. In addition to the secondary data, the researchers also developed a mobile application following the action research methodology discussed in the next section. The mobile application was developed and tested with the help of small-scale farmers registered with the Hurudza project in Harare, Zimbabwe. The mobile application was developed following the stages of the action research methodology discussed in the next section.

Action research methodology

The research approach followed is the Action Research methodology. In Action Research the researcher tries to provide a service to a research "client", often an entity, and at the same time add to the body of knowledge in a particular domain. In a technology-related domain, an Action Research study could involve the researcher introducing a new technology, and at the same time studying the effects of the technology in that entity. The methodology best suits the problem at hand as it involves the participation of the subjects in the provision of a solution to the lack of farming information problem. Action research is used in real life situations, rather than in artificial, experimental studies, as its primary focus is on solving real life problems. It can be used by social scientists for preliminary or pilot research. It is mostly used when the situation is too ambiguous to come up with a precise research question. Mostly it is chosen when circumstances require flexibility, the participation of the people in the research, or when change must take place quickly or fully. Figure 2 depicts the phases in an Action Research methodology.

Figure 2. Stages in an Action research methodology adapted from (Baskerville 1999)

Figure 2 shows the stages involved in an action research methodology. The process is iterative and includes the diagnosis, action planning, action taking, evaluating and the specifying learning as discussed in the following sub sections.

Stage 1. Diagnosis

The diagnosis stage involves the identification of an enhancement opportunity or a general problem to be solved at the client entity. An enhancement opportunity has been identified in the provision of timely and accurate information to the small scale farmers. The provision of valid information to farmers can increase the decision making process and the agricultural productivity.

Stage 2. Action planning

Action planning involves considering the alternative solutions to attain the enhancement or solve the identified problem(s). The possible solutions include the use of the traditional media such as the newspapers, radio, television systems, voice calling through the land line or cellular phones. These media have a limitation on the information provided that is rather general than specific to an individual farmer's needs. It is claimed that personal travel or a newspaper are expensive while landlines or radio are not readily available in resource-starved regions and radio only provides price information for specific products and markets on a weekly basis (Chisita and Malapela 2014). Another alternative is to design, develop and: implement a centralized database to store all the anticipated farming information such that the farmers use desktop or laptop computers to access it. The challenges of this approach are related to the unavailability of infrastructure and compatibility with the traditional media. There is lack of access to telecommunication infrastructure in many rural and remote areas; capital cost of technologies, high cost of on-going access and support (Asenso-Okyere and Mekonnen 2012). Another available option is to use available mobile-based market information systems and services to provide farmers an opportunity to send short message services (SMS) text messages to a specific number which then gives them wholesale and retail prices of crops (Chisita and Malapela 2014). The disadvantage of this method is the cost of sending the SMS. We therefore chose to develop a mobile application that accessible even offline and in local languages. The mobile application takes advantage of the android smart phones already owned by the majority of small scale farmer. This is the best option since the farmers can access available agricultural information at no cost and the android smart phones are both affordable and available at a cheaper price.

Stage 3. Action taken

In the action taking stage the best course of action among those considered in the previous stage is selected and implemented. The alternative selected to implement a solution to the problem is the design, development and implementation of the mobile application. There are a number of reasons why this option was selected. They include affordability of smart phones, the availability of resource to develop and implement the application as well as the ease of access to the agricultural content in a local language. These are affordances missing in the mobile applications such as the Esoko and the Eco farmer platforms, which depend only on use of the SMS to disseminate information on prices, daily weather, new market and farming tips, credit ratings, financial linkages and other important information to guide farmers in their decision making (Odunze and Hove 2015).

Stage 4 Evaluation

This stage involves the study of the outcomes of the selected course of action. Unlike the two popular mobile communication platforms with Zimbabwean farmers, the Esoko platform and the Eco farmer platform (Odunze and Hove 2015), our mobile application has proved to be a very reliable as it does not depend only on the SMS, but uses email, chats and video conferencing tools for agriculture information acquisition and dissemination. It is a more affordable, readily available, accessible and user friendly agriculture information and dissemination platform. The information is delivered to the intended farmers on real time. Equipped with this information a farmer can then make informed decisions about both agriculture productivity and marketing,

Stage 5. Specifying learning

The specifying learning stage reviews the outcomes of the evaluating stage and builds knowledge in the form of a model describing the situation under study. The major challenge faced by Zimbabwean farmers is lack of locally base mobile application that could be produce information understood by the farmers especially those who are small scale and not very educated. The mobile application we have proposed enhances access to timely and up to date information about the crops, livestock, the weather, market etc.

Solution

This study discusses a mobile application developed locally and suitable for the farmers in Zimbabwe to achieve what we refer to as m-farming. Mobile applications are either pre-installed or downloadable software programs developed for small low-power handheld devices such as mobile phones or tablets (Chisita and Malapela 2014). Our mobile application is intended to provide timely and relevant agricultural information to small scale farmers in two most common indigenous and local languages in Zimbabwe, namely IsiNdebele and chiShona. Although, Zimbabwe has a highest literacy rate in Sothern Africa, there is a possibility of a certain percentage of small scale farmers who may not be conversant in English based agricultural terms who might require information to be presented to them in indigenous languages for a better understanding and interpretation. This is contrary to most existing mobile applications whose primary language is "English" depriving effective use by farmers more comfortable dealing with information in their local languages. Furthermore, rather than being too general, the uploaded and downloadable content through our mobile application relates to indigenous farming produce, weather, pests and diseases.

Utilising the services of the major mobile networks, Econet, Netone and Telecel, the application provides a platform for farmers to consult with the agriculture specialists as well as chat among themselves. The mobile application enables the small scale farmers to both upload encountered farming problems and download solutions from agriculture information in a database a server we affectionately named "Hurudza". Farmers can also check the weather information as well as market related issues. Through our mobile application, farmers can also chat and discuss among themselves and also seek advice from agriculture specialists enrolled on the mobile system.

Our platform has two ends, the front end for farmers and the back end for administration. The front end has been developed using the java programing language and the extended mark-up language (XML). The back end representing the server was developed using PHP while the database system was created using the MySQL database management system. Farmers have to use an android smart phone to register and become an active consumer of the information accessible on our mobile application. The small scale farmers can access the information both on line or offline from our database installed in a central server as indicated in Figure 3.

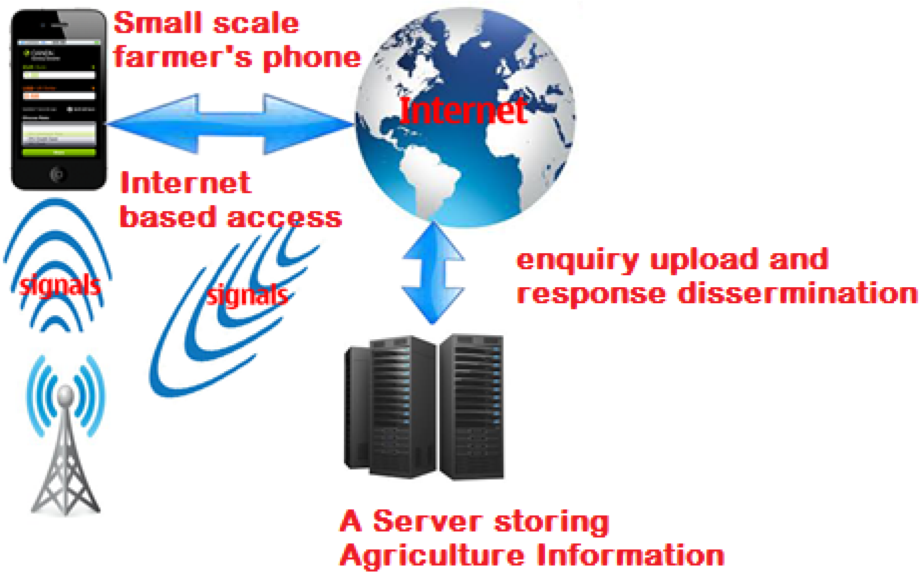

Figure 3. The architecture of the mobile application system for use by the small-scale farmers

Figure 3 is the architecture of our proposed mobile application. The small scale farmer uses an android based smart phone to both upload into and download information from a database hosted on the Hurudza server,

Results and Discussion

Our mobile application is available online for download by small holder farmers interested in accessing general agricultural information. For more detailed information and consultations, the farmers need to register and utilise the services of the local payment platforms such as ecocash for their subscriptions. After successfully testing for connectivity, the application was tested for usability proper use of local terminology as opposed to common scientific terms in English language by the agriculture extension offices in Harare. More tests were done through the services of Hurudza Africa, which provided live agricultural and farmers' data relating to farmers particularly in the Harare area in Zimbabwe. The small scale farmers also had an opportunity to interrogate the mobile application for system functionality and the proper use of the local language regarding farming products, pests, diseases, market, the local weather condition and the farming seasons. The unit, module, system and user satisfaction testing process took approximately fifteen weeks involving two hundred small scale farmers in the Makoni and Mutasa communal districts in Mashonaland in Zimbabwe. These farmers raised a few concerns and also made suggestions about add on tools such as the chat services and the photographing of the pests and diseases to be captured and remotely accessed by specialists for better advice and informed decision making. There are four thousand farmers' country-wide who are currently using the mobile application after it successfully met their conditions. These farmers like the application and applaud it for being a low cost but user-friendly and useful information acquisition and dissemination system. For farmers not in possession of smart phones, they recommended that we cater for their needs too, hence the decision to have a USSD based system in future for such farmers.

The application has various functionalities that were tested and confirmed satisfactory such as the provision of the weather information on a real time basis for a particular day or a forecast for the whole week as shown in Figure 4.

Figure 4. Week long daily weather forecast, source: our mobile application

Figure 4 shows the output of a seven-day weather forecast after the farmer's inquiries from the mobile application. Another functionality provided by the mobile application is the access to information regarding the budget for crop or livestock farming from the initial stages to the maturity stage as depicted in Figure 5.

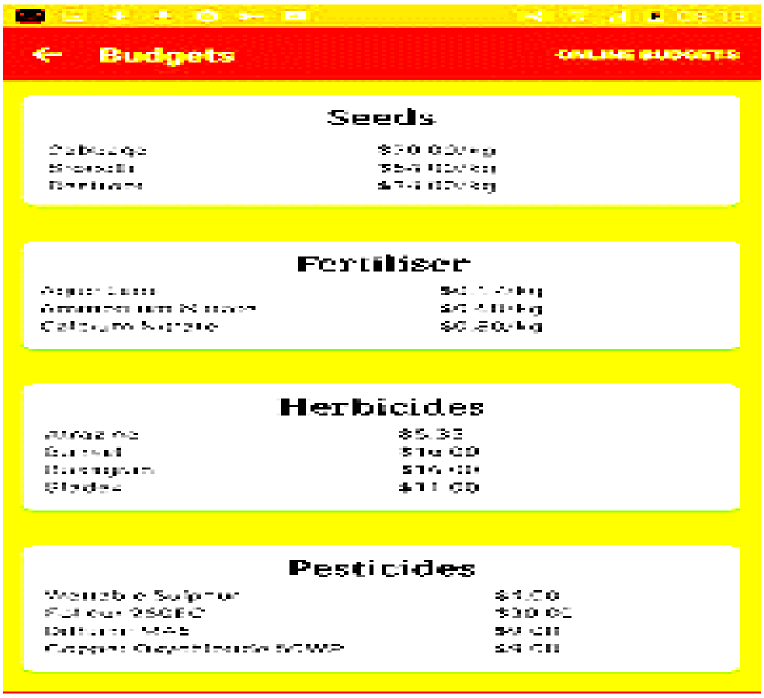

Figure 5. Farming financial resources' budget, source: our mobile application

Figure 5 shows the financial resources a farmer requires to grow cabbages, broccoli and beetroot. The budget includes the costs for seed, fertilizers, herbicides and pesticides. With this information a farmer has been equipped with what is required in considering whether to embark on a project or not. The farmer can then make a decision on either to embark on crop or livestock farming or both depending on the availability of the financial resources required. The choice can be made after analysing the information provided to the farmer on the different types of crops and livestock.

Figure 6. Types of crops and livestock available to farmers, source: our mobile application

For example, Figure 6 shows the various types of crops and livestock to focus on. A farmer has a choice of growing groundnuts, roundnuts, soya beans etc. or to rear beef or dairy cows as shown in Figure 6. The farmer can click on their choice to see more about the requirements for their choice. Suppose a farmer chooses the groundnuts, the result will be as shown in Figure 7.

Figure 7. Groundnuts related information, source: our mobile application

Figure 7 shows the information provided to the farmer regarding the growing process of the groundnuts. The information includes that of the variety, nursing, transplanting, the crop development, pre-harvest and harvest information and finally knowledge about the market. All the farmer has to do is to click the link of their interest. The application also provides the farmer with the opportunity to know about the export markets is shown in Figure 8.

Figure 8. Commodity prices information, source: our mobile application

Figure 8 depicts the current commodity costs on the international market for the produce such as the bananas, coffee, cotton, tea, groundnuts and tobacco. Equipped with this information and knowledge the farmer can make an informed decision on where to sell their produce for more profits. An additional functionality of the application not found in the existing mobile applications is its ability to allow a farmer to enquire from the agriculture specialist about a problem or an issue of their concern. The farmer can send a text message or attach a picture showing the problem they have, which requires the attention of a specialist. The specialist uses the same platform to send the reply to the farmer as indicated in Figure 9.

Figure 9. Information on the farmers' communication, source: our mobile application

Figure 9 is a representation of the conversation through the email function that takes place between the farmer and the specialist. There is also evidence of the attached files be it in text, picture or video format that can be exchanged between the farmer and the agriculture specialist. The farmer can also consult with fellow farmers interested in the same farming area, the is made possible by registering with the system and being grouped by the system according the type of farming the farmers are interested in. Once in a group, the farmers have a platform for discussing issues, failures and successes and can even advice each other. Figure 10 shows a profile of one of the farmers affiliated in a group with which they can chat and discuss with.

Figure 10. Small scale farmers' profile information, source: our mobile application

Figure 10 depicts the profile of one of the farmers registered with the system. It shows the name of the farmer, the contact number, their line of farming as well as the group they are affiliated in for the sake of peer discussions. The farmer is also assisted by the application to make mathematical conversion that may be challenging especially for small scale farmers in rural areas. These conversions are shown in Figure 11.

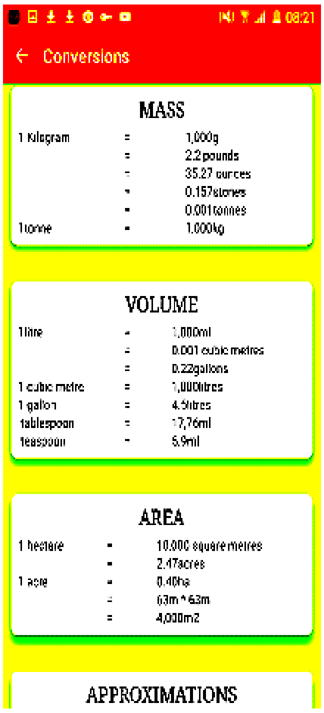

Figure 11. Mathematical conversions, source: our mobile application

Figure 11 demonstrates the valid information for the farmer to be accurate regarding measurements involved in the farming activity they are undertaking.

Conclusion

In conclusion, the present study has provided a new mobile application that has proven to be very efficient and reliable in bridging the information gap currently experienced by small scale farmers in Zimbabwe. This mobile application is also cost effective and user friendly with content displayed in local languages for the benefit of the small scale farmers who are not eloquent and conversant in English language. It has various functionalities not available in the mobile applications such as the Esoko and the Eco farmer platforms which are only limited to the rather costly SMS feature. Through our mobile application, access to timely and relevant agriculture information is increased thus solving the problems of unaffordability, unavailability and inaccessibility of agriculture information currently in the custody of the few geographically dispersed extension officers. Our mobile application has been tested and verified as a cheaper tool for both the acquisition and dissemination of the much needed agriculture information particularly by small scale farmers in remote parts of the country. Such farmers can even consult on any farming issues without incurring additional travel, SMS or voice calling costs.

Acknowledgements

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