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A Knowledge Management System for Indigenous Crops Production: Case of Sorghum Farming in Tharaka South

By

JOHN KIMANI

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Supervisor

Dr. Robert Oboko

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God bless you all.

Declaration

This research is my original work. It has not been presented for a degree in any other university. No part of this research may be reproduced without the prior permission of the author or the University of Nairobi.

John Kimani Gakingo
P58/63210/2011

Signature __________________________

Date ______________________________

This research has been submitted for examination with my approval as the University Supervisor.

Dr. Robert Oboko

Signature __________________________

Date ______________________________

Abstract

Kenya continues to struggle with the challenge of an endemic food insecurity problem with over 50% of the population classified as food insecure (FAO, 2015). Recent research has shown that a food security strategy that's dependent entirely on exotic crops which are greatly affected by sporadic rainfall is not sustainable. There needs to be conscious shift to indigenous crops which are more tolerant to unpredictable weather patterns. Sadly though, very little shareable knowledge exists on production of these crops; the production know-how is passed by word of mouth and demonstration across generations and sometimes lost in the process. This research seeks to show how this gap can be addressed using a knowledge management system. One of the key factors that distinguishes the intelligent production process of the 21st century is the emphasis on data, information and ultimately knowledge. Agriculture is no exception, the importance of knowledge management systems in agriculture can simply not be over emphasized.

This research started off with an exploratory pre-study to identify the key functionality that needed to be captured by the knowledge management system. The researcher used purposive stratified sampling to identify the key informants who would be approached for the exploratory study. These key informants were selected with a specific purpose being the information they would be able to provide towards development of the knowledge management system. The researcher chose to use participatory action research for the pre-study, which strengthened the research by emphasizing participation and action through collective inquiry based on social history and experience.

The pre-study brought to the fore the need for use of information technology in improving the sorghum production process. Three key themes emerged from the pre-study namely identification of best practices, convenient way of disseminating information to stakeholders and finally enhancement of research processes through use of information technology. These functional needs formed the basis for development of the knowledge management system. The prototype was developed using an evolutionary prototyping approach, where the prototype was continuously improved based on feedback from the key informants and test users. The prototype was evaluated using a usability testing approach, which focused more on the users' interactivity with the application and general responsiveness, or lack thereof, to the features presented in the prototype.

The researcher recommends that further work be done to expand the solution to include more climate change crops to provide the small holder farmers with a wider crops option.

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List of Abbreviations and Acronyms

ABCIC	African Biodiversity Conservation and Innovations Centre
ASAL	Arid and Semi-Arid Land
AWSC	African Women Studies Centre
ERD	Entity Relationship Diagram
FAO	Food and Agriculture Organization of the United Nations
GOK	Government of Kenya
ICT	Information Communication and Technology
IT	Information Technology
KARI	Kenya Agricultural Research Institute
KM	Knowledge Management
KMS	Knowledge Management System
KNBS	Kenya National Bureau of Statistics
UML	Unified Modelling Language
UN	United Nations
UON	University of Nairobi
WFP	World Food Programme

Chapter 1: Introduction

1.1 Background

According to (WFP, 2015), a country is considered to be food secure when its people have consistent availability and access to sufficient, safe, nutritious food which meets their dietary needs and food preferences for an active and healthy life.

The UN in 2000 carried out a special summit dubbed “the millennium summit” where global leaders committed themselves to the Millennium Development Goals. The first of these goals was eradication of extreme hunger by 2015. FAO is mandated to track progress towards this goal and through its annual State of Food Insecurity in the World reports presents updated estimates of undernourishment and progress towards the MDG targets. According to (FAO, 2015) a lot of progress has made towards this millennial goal with the number of malnourished, food insecure people reducing from 23% in 1990 to 12.5% in 2015 globally.

Sadly though, wide differences persist across regions. There has been faster-than-average progress in Eastern Asia, Latin America and the Caribbean with these regions now accounting for much smaller shares of global undernourishment. Africa, however, presents a different picture with food insecurity levels of 27.7% in sub-Saharan Africa (FAO, 2015).

Kenya has consistently been categorised as a low-income food deficit country, which is a regular importer and occasional exporter of food security crops, primarily grain. According to (WFP, 2015) 54% of households in Kenya are food insecure, accounting for a total of over 15 million people in government estimates. 90% of the households interviewed faced shortages of food or cash to purchase food, with the cost of the minimum healthy food basket rising by 22%.

Kenya hence continues to grapple with the challenge of feeding it’s every growing population, currently at an annual rate of 2.7% according to (UNDP, 2015), against a declining food production capacity. Faced with environmental challenges such as sporadic, unpredictable rainfall, land degradation, a rural-urban migration of young, youthful labour, lack of proper extension services and other socio-economic constraints the Kenyan farmer remains under-productive and this effectively undermines any efforts towards attaining nationwide food security.

Although the government has had a specific food policy only since 1981, it has been focused on improving domestic supply of the country's key security crop, which is maize. A lot of research effort has gone into getting the right maize seeds and strains. Unfortunately, like most exotic crops, maize is prone to erratic weather conditions which Kenya has experienced in the last 10 years.

There has been a shift in policy in addressing food security by separating national and community level food needs. Kenya continues to position maize as the de facto national crop but allows for local communities to define their own local security crop. The goal is to start tackling food security at community level then cascade the results to national level. (Kamoni, et al., 2013)

Research has progressively shown that traditional crops such as cassava, sorghum, millet and African peas have the potential to end severe food insecurity due to their tolerance to drought and ability to thrive under a wide range of soils. These crops also build a socio-economic resilience into the community in the sense that they guarantee that poor communities will feed themselves. Unfortunately there's very little knowledge sharing when it comes to proper ways of farming these crops.

My research uses Tharaka South sub-county, in Tharaka-Nithi County, as a focus area since it is one of the five zones categorized by the Kenya government as having the most chronically vulnerable subsistence farmers, the other four being Siaya, Makueni, Tana River and Kitui. An estimated 80% of the county's population are subsistence farmers, defined as food crops farmers who consume more of their own production than they sell and who are considered to be the most vulnerable, after pastoralists, to food insecurity.

Crop farming in this county is also characterized by low productivity and yield due to unpredictable, erratic weather patterns.

Over the past, Tharaka South small holder farmers have focused largely on exotic crops such as maize, beans and peas but there has been a recent shift in focus by these farmers to traditional crops such as millet, sorghum and green grams which are deemed to be drought tolerant. This is partly as a result of the work done by both government and donor agencies to educate communities on the nutritional value of crops which were previously perceived to be "a poor man's meal" such as sorghum. Local communities have slowly embraced these foods in their diets and as a result starting to build on reserves that stretch through drought periods.

The biggest challenge with traditional crop farming has however been the isolated pockets of indigenous knowledge on growing these crops as well as best practices for each crop. Research has shown that traditional corps farmers tend to know more about their local agroecosystems than anyone else. This knowledge is usually preserved by adults and passed down to younger generations by word of mouth, practice and informal educational system originating from the elaborate social interaction systems. This indigenous knowledge is unique and dynamic in nature changing through creativity and innovativeness (Kilongozi, et al., 2012).

The proposed knowledge management system will serve to consolidate these isolated knowledge sources into a centralized repository that can be easily accessed by farmers, preferably through mobile devices. The knowledge can be extended to incorporate expert knowledge based on research carried out by scientific researchers in institutions of higher learning as well as agricultural research centres.

This system will be easily updated, and have the capacity to handle complex and unstructured information such as video and audio of interviews carried out with farmers in the local languages.

The overall goal of the proposed system is to reduce disparities in output and productivity among smallholder farmers by pushing laggards towards the frontier of the best-model farmers in sorghum farming. Once implemented, the system will diffuse best practices to the indigenous crops farmers.

1.2 Problem Statement

A lot of work has been done towards knowledge based systems for agriculture but all these systems focus exclusively on exotic crops and not on indigenous ones. Most of the knowledge on exotic crops is provided by multi-national seed, chemicals and fertilizer manufacturers who have consolidated knowledge from experts over the years and transfer this knowledge to local farmers. Challenge with these systems is that they are not structured to acquire local knowledge about traditional crops held by indigenous farmers.

Second challenge is that each region in Kenya has a particular crop that suits its soil and climatic structure. This knowledge as to which crop suits which zone is in isolated pockets, held by traditional farmers and is not in a readily shareable format.

1.3 Objectives

The overall objective of this research is to build a knowledge management system that can be used by indigenous crops farmers towards fighting food insecurity.

Specifically, the study aims:

1. To develop an approach for collecting best practices on sorghum farming in Tharaka from traditional farmers.
2. To develop an approach for zone profiling to determine the ideal traditional crop for Tharaka.
3. To build a knowledge management system prototype for indigenous crops production.
4. To test the knowledge management system prototype.

1.4 Assumptions

The knowledge dissemination phase assumes a ubiquitous reach of local mobile operator networks in the region under study.

1.5 Challenges

Anticipated challenges during the research were as follows:

1. Communication barrier in the pre-study and farmer interviews - some of the farmers might not be able to converse in Swahili or English.
2. Commitment to change, learn and adopt an innovative approach to production by the farmers.

Chapter 2: Literature Review

2.1 Introduction

The concept of food security was defined during the World Food Summit in 1996 as "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). Kenya has however consistently been unable to eradicate extreme poverty and hunger even though it is the leading economy in East Africa as well as regional business centre (Glopolis, 2013).

Over 54% of households in Kenya are food insecure, accounting for a total of over 15 million people (WFP, 2015). 90% of the households interviewed faced shortages of food or cash to purchase food, with the cost of the minimum healthy food basket rising by 22%.

The main environmental factor behind food insecurity in the country is deficient rainfall. The vulnerability of a household or area to food insecurity is determined not only by the amount of rainfall a place receives but also the seasonality of the rainfall. Recent studies show that even in high potential areas of Rift valley am irregular rainfall pattern subjects households to food insecurity during certain months of the year (Glopolis, 2013).

Another key reason that countries fail to achieve food security is due to ignorance of agricultural sector in development country's agenda (Rajaonarison, 2014). The Kenyan government every so often implements agricultural policies and programs related to food security. Over the years these policies have focused heavily on maize as the national staple crop but are now opening up to traditional crops as well.

The Agricultural Sector Development Strategy 2010 – 2020 (GoK, 2010) which sought to transform smallholder agriculture from subsistence to an innovative, commercially oriented and modern agricultural sector in line with Kenya's Vision 2030 (GoK, 2008). The ASDS has six pillars in total and through its fourth pillar "agricultural research, technology dissemination and adoption" set the foundation for support of traditional crops and use of technology in agriculture.

According to (KARI, 1999) the semi-arid eastern Kenya is a major consumer of maize and the traditional maize varieties grown by the farmers are poorly suited for the region. Growing of drought tolerant crops provides an opportunity for communities to better cope with climate change in the ASALs. In support of this approach, the Ministry of Agriculture has been promoting adoption of "orphan crops" (such as sorghum and millets) to alleviate chronic food insecurity in ASALs as part of its strategy to revitalize agriculture (GoK, 2009).

One key bold agenda in the promotion of indigenous crop farming is the concept of a devolved approach to food security, where each county can identify a county staple crop and work towards strategic reserves of this crop (Kamoni, et al., 2013).

2.1.1 Food Insecurity in Tharaka County

Tharaka Nithi County shares common borders with Meru to the North, North West and North East, Kitui to the East and South East, and Embu to the South. The county covers a total area of 2,638.8 km^2 and is made up of four constituencies namely Maara, Nithi, Tharaka South and Tharaka North. These constituencies also serve as the districts or sub-counties. With a population of 365,330 (GoK, 2009), Tharaka Nithi is the seventh most populous county in Kenya.

Additionally, more than one in five (21 per cent) children aged between 6 and 59 months in Tharaka are moderately and severely underweight and four per cent are classified as severely underweight (KNBS, 2011).

As a result of the periodic food shortages occasioned by drought, the county from time to time becomes a net food importer and occasionally benefits from food relief programs.

Table 5.9 (NU.9): Food relief

Percentage of households registered as beneficiary of food distribution program, and of those registered time of last receipt of food and whether meeting their full requirement or not, Tharaka district, 2008

Characteristic	Percentage households registered as beneficiary of food distribution	Total number of households	Percentage of households by time last receipt of food distribution: Within one week	Between 1 week and one month	Between 1-3 months	After 6 months	Total per cent	Percentage of households reporting sufficient supply	Household registered as food beneficiary
Wealth index									
Low	(6.7)	(520)	(6.0)	(6.0)	(2.1)	(85.9)	(100.0)	(0.9)	35
Medium	3.2	478	(*)	(*)	(*)	(*)	(*)	(*)	15
High	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	0
Total	**4.4**	**1135**	**5.3**	**4.1**	**5.3**	**85.4**	**100.0**	**0.5**	**50**

Table 1: Food Relief Statistics in Tharaka-Nithi, 2014

Source: Kenya National Bureau of Statistics

As shown in Figure 1, 50% percent of the population in Tharaka-Nithi are registered for food relief while 4% registered for the food distribution program. Among those registered for food distribution, 5% received food supplies weekly while another 4% receive monthly (KNBS, 2014).

2.1.2 Indigenous crop farming in Tharaka-Nithi

According to the last national census, 98.2% of households in Tharaka-Nithi engage in crop farming with high altitude areas focusing on tea, coffee and export horticultural crops while the low altitude areas which are extensively dry focus on livestock husbandry (County Strategy Plan, 2012). The county has great potential in dry-and agriculture and the dry areas are already focusing on millet, cassava and sorghum which are better adapted to arid climatic conditions. Research evidence shows that sorghum and millets are among the well adapted crops to the ASALs (Taylor, 2003).
Tharaka Nithi County exhibits one of the highest crops diversity in Kenya with farmers often preferring traditional crops such as sorghum and green-grams over maize. One of the most popular traditional crop among the small holder farmers is sorghum grown primarily in the south of the county, which experiences the lowest rainfall levels.

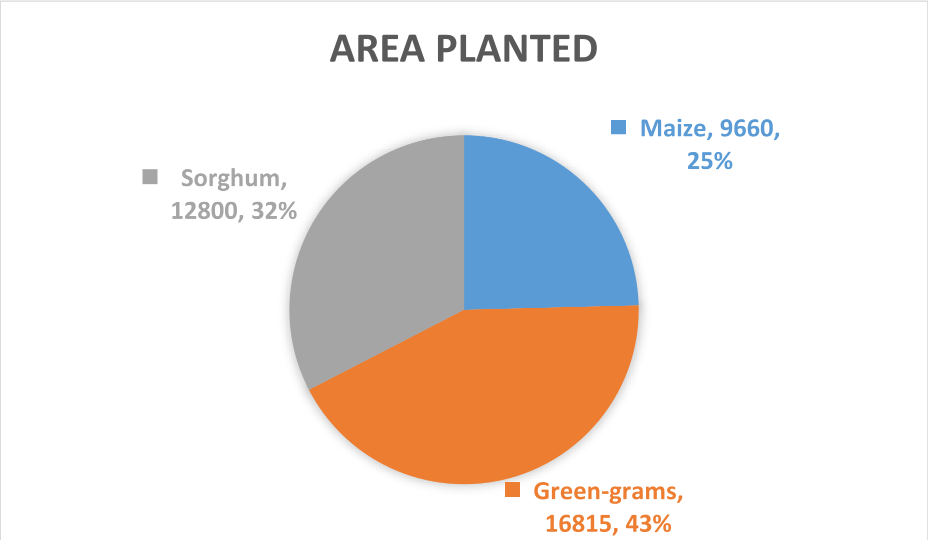


Figure 1: Rain-fed crop cultivation – area planted in 2013 in Tharaka Nithi

Source: Ministry of Agriculture, Tharaka-Nithi County

As shown in Figure 1 above, the county had 75% of cultivated land under traditional crops, with green-grams having a higher percentage than sorghum. This is an indication that awareness of traditional crops is on the increase among small holder farmers. Over reliance on maize as the primary food crop is slowly reducing.

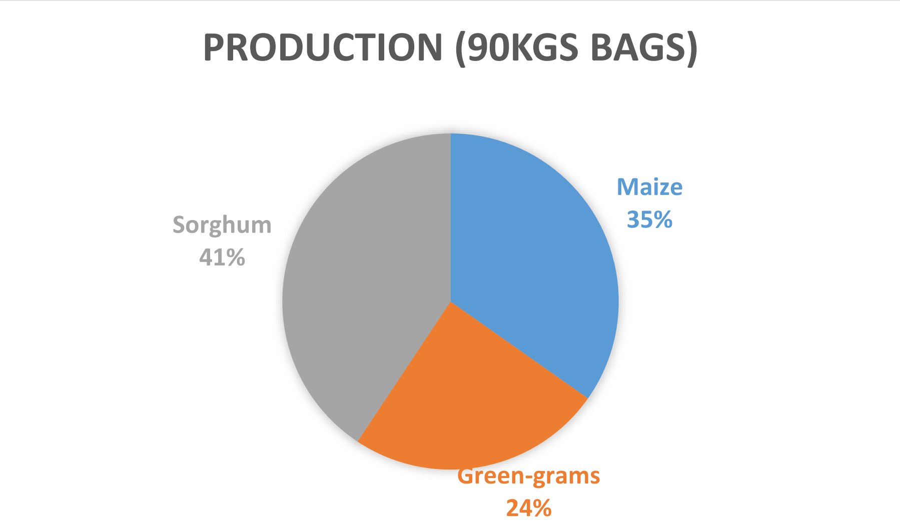


Figure 2: Crop harvest, 2013 in Tharaka-Nithi

Source: Ministry of Agriculture, Tharaka-Nithi County

As indicated in Figure 2 above, sorghum had a better yield at the end of the crop cycle. This is because the region experienced reduced rainfall levels in 2013 which led to a lower green-grams and maize yield. Sorghum on the other hand is drought resistant and had a good yield despite the low rainfall levels.

The county strategic plan under a global objective of growing the county's economy underlines the need for diversification of food production and consumption.

2.2 ICT in Agriculture

According to the (World Bank, 2012), the strategic application of ICT to the agricultural industry, the largest economic sector in most African countries, offers the best opportunity for achieving food security in the on the continent.

Agriculture in Kenya is still largely traditional and practiced by small holder farmers. This type of agriculture has low-yielding production and lacks access to critical information such as market prices and best practices on production. The role that ICT can play in addressing these challenges is increasing as personal computing devices, especially mobile phones, are becoming more widely available. ICT, when embedded in broader stakeholder systems, can bring agricultural development and growth as it can help bridge critical knowledge gaps.

Various ICT solutions have been proposed to address different problems in the agriculture production process. These can be categorised as follows:

1. Information Systems which include Decision Support Solutions, Geographic Information Systems and General Information Management Systems.
2. ICT enabled learning and knowledge exchange solutions – are typically knowledge driven solutions.
3. Modelling solutions
4. Sensory and proximity devices
5. ICT-Enabled networking solutions
6. Online commerce tools – typically built to address access to market challenges.

Any attempt to use ICT in agriculture must however view the farming life cycle as a three-stage process (see Figure 3):

1. Pre-cultivation – includes stages such as crop selection, land selection, calendar definition, access to credit and access to seeds.
2. Crop cultivation and harvesting - includes land preparation and sowing, input management, water management and fertilization and pest management.
3. Post-harvest - including marketing, transportation, packaging, food processing and storage.

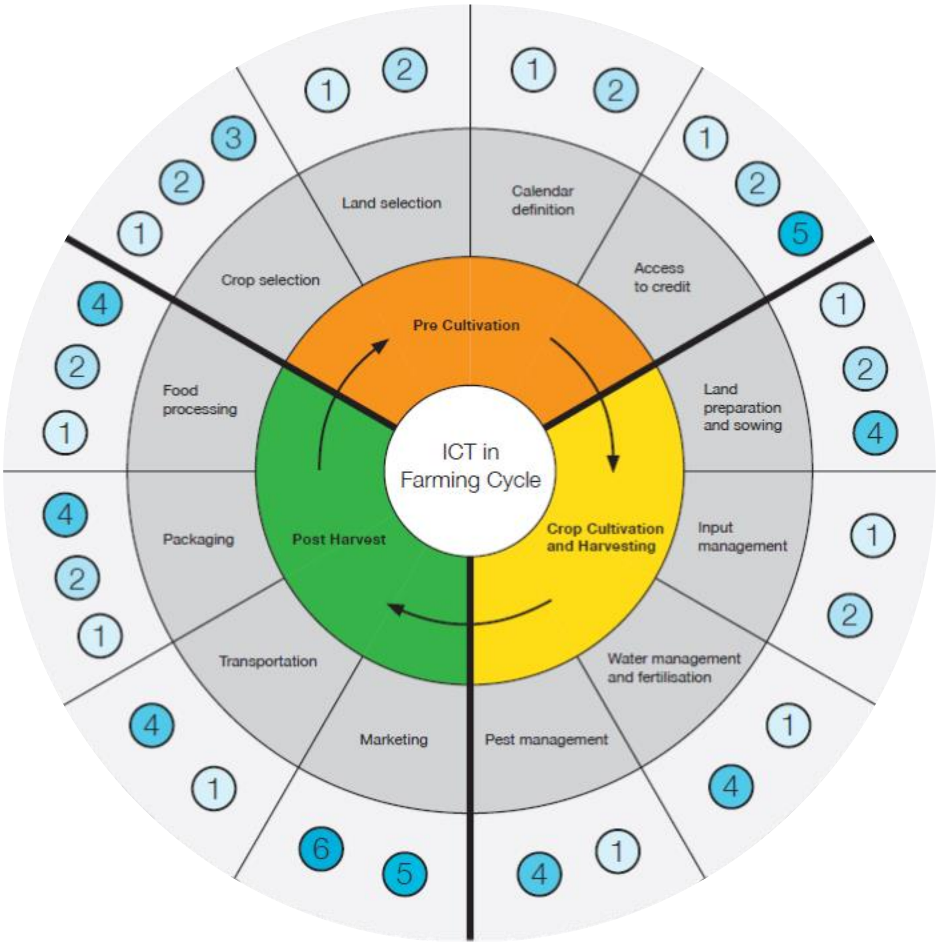


Figure 3: ICT in Agriculture Framework

Source: eTransform Africa, AfDB

This framework provides a useful basis for identifying the most ideal ICT solution for each stage of the agricultural production process. A knowledge exchange solution cuts across 67% of the farming life cycle stage underlining the importance of knowledge management in agriculture.

2.3 Knowledge Management

2.3.1 Concepts

According to (Davenport & Prusak, 2000), knowledge is a mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. In any organized process, knowledge often becomes embedded not only in documents and repositories but also in organizational routines, processes, practices and norms.

(Davenport & Prusak, 2000), assert that knowledge is not neat and simple, it is complex with a mixture of various elements. It is also intuitive and therefore hard to capture in words or understand completely in logical terms. The fact that knowledge exists in people means that it is part and parcel of human complexities and unpredictability.

As knowledge develops over time, it borrows from different learning avenues such as books and mentors and becomes experience. Experience refers to what an individual has done in the past and results in individuals becoming experts in their domains. This results in a new form on knowledge which has been built over time. This knowledge born of experience recognizes familiar patterns and can make decisions based on a historical perspective. (Davenport & Prusak, 2000)

According to (Davenport & Prusak, 2000) most knowledge management projects have one of three aims:

1. To make knowledge visible and show the role of knowledge in an organization
2. To develop a knowledge-intensive culture by encouraging and aggregating; behaviours such as knowledge sharing (as opposed to hoarding) and proactively seeking and offering knowledge;
3. To build a knowledge infrastructure-not only a technical system, but a web of connections among people given space, time, tools, and encouragement to interact and collaborate;

The (World Bank, 1998) states that knowledge, not capital, is the key to sustained economic growth and improvements in human well-being. It then examines three critical steps that developing countries must take to narrow knowledge gaps: acquiring knowledge, absorbing knowledge, and communicating knowledge.

Knowledge is built primarily from information that is derived from data. Any knowledge management process must therefore, first and foremost, support this process of transforming information into knowledge.

According to (Tiwana, 1999), knowledge classification is done along four key dimensions namely complexity, life span, dynamics and focus (operational or strategic). Complexity includes categories and types and specifies the degree of context needed to make data useful. If we classify knowledge using the complexity dimension we then come up with two basic types of human knowledge:

1. Explicit knowledge which refers to all aspects of formal, systematic, recorded, communicated and shared knowledge that is made accessible through a variety of information delivery systems.
2. Tacit knowledge which on the other hand is highly personal, created by doing, trial, error, reflection and revision.

Indigenous farming knowledge is tacit in nature and speaks to an individual farmer's "know-how" of the agricultural production process.

2.3.2 Knowledge Management Framework

Knowledge management is a discipline that takes a comprehensive, systematic approach to the "information" assets of an organization by identifying, capturing, collecting, organizing, indexing, storing, integrating, retrieving and sharing them (Duhon, 1998). Such assets include intellectual capital, employee expertise, business and competitive intelligence, and organizational memory. It strives to make the collective knowledge, information and experiences of the organization available to individual employees or organizational groups for their use and to motivate them to contribute their knowledge to the collective assets. It seeks to create or identify communities of practice or interest, especially to identify lesson learned and best practices.

Knowledge management should be an indispensable part of individual and collaborative decision-making as it enables knowledge creation, sharing and retention. Knowledge management is what allows enables organizations to create greater value from core human resource competencies.

Knowledge management encompasses processes and practices concerned with the creation, acquisition, sharing and use of knowledge, skills and expertise and follow a circular flow and a nonstop process that continuously updates itself (Cong, et al., 2007).

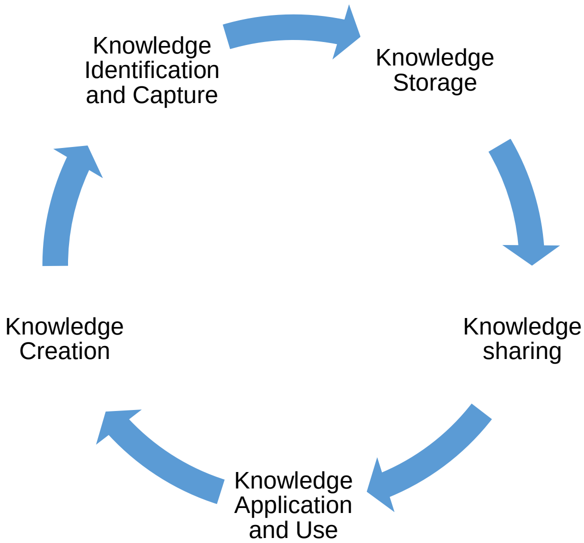


Figure 4: Knowledge Management Process

Source: Cong et al, 2007

Knowledge Acquisition

This is the process if development and creation of insights, skills and relationships. Data-capture tools with filtering abilities, intelligent databases, keyboard scanners, note-capture tools and electronic white boards are examples of information technology components that can support knowledge acquisition.

Knowledge Sharing

This stage comprises disseminating and making available what is already known. Knowledge is fundamentally collaborative in nature and collaborative problem solving, conversations, and teamwork generates a significant proportion of the knowledge assets that for a particular process.

Knowledge Utilization

Knowledge utilization comes into the picture when learning is integrated into the organization. Whatever is broadly available throughout the organization can be generalized and applied, at least in part, to new situations.

2.4 Knowledge Management Systems

Knowledge management systems (KMS) refer to a class of information systems applied to managing organizational knowledge. That is, they are IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage, retrieval, transfer, and application (Alavi & Leidner, 2001).

According to (McKenna, 2008), a good knowledge management system, should exhibit the following key characteristics, amongst others:

1. Empower the users and allow them to work faster and smarter.
2. Be focused on the core business objectives/outcomes.
3. Be needs drive, not technology driven.
4. Make the business more competitive, efficient and profitable.
5. Connect to all sources of knowledge, including tacit knowledge
6. Flexible and configurable enough to adapt to the organization's changing needs.
7. Produce timely, accurate, concise and precise information that can be utilized to make high quality decisions.

2.4.1 Knowledge Management Tools and Generators

KM tools are the technologies used to acquire, store and distribute knowledge with most modern tools being computer based (Ruggles, 1996). Unlike information management tools, knowledge management tools are designed to handle the richness, content and context of the information and not just the information itself.

KM tools are the basic technological building blocks of any specific knowledge management system and can be combined to form a particular KMS that performs particular functions. KM generators are self-contained technologies typically consisting of a number of tools such as document management, intelligent agents, and groupware that can be customized to build a specific KMS. (Gallupe, 2000)

Tool Name	Description
Intranets	Private, local networks using web-browsers to share knowledge
Information Retrieval Programs	Tools to search corporate knowledge/data bases as well as external knowledge sources to provide access to a wide variety of knowledge.
Database Management Systems	Combine with intranets and information network tools to provide a platform to build specific knowledge management tools.
Document Management Software	Provide the means for capturing, storing, and distributing knowledge in the form of documents as opposed to discrete data.
Groupware	Software and hardware that enables workgroups to communicate, collaborate and perform such tasks as generating ideas (create new knowledge) and reaching consensus.
Intelligent Agents	Software programs that can filter out the knowledge that the user really needs. This may be particularly important in knowledge intensive situations where particular knowledge sources need to be monitored.
Knowledge-Based or Expert Systems	Store the knowledge of experts in the form of rules or cases and then provide that knowledge to novices or other experts.

Table 2: Tools to Support Knowledge Management Systems

Source: (Gallupe, 2000)

2.4.2 Knowledge Management System Research Framework

A research framework is useful in establishing boundaries around study area of KMS. It is also useful in identification of the main components that make up the KMS so that relationships can be examined. A number of research frameworks have been proposed before to guide research into knowledge management systems.

The most ideal framework for an agricultural KMS is the “knowledge lifecycle framework”. This framework follows knowledge through the stages of life cycle from creation to disposition (Ruggles, 1996). At each stage, knowledge management systems can be created and studied to examine their impact on knowledge within each stage. This framework has the advantage of being conceptually simple in that KMS can be categorized and studied through identifiable stages.

This framework is also ideal for this research since knowledge is constantly being refined and improved though each farming cycle. This framework provides a foundation for continuous system improvement as new best practices are identified and passed into the system.

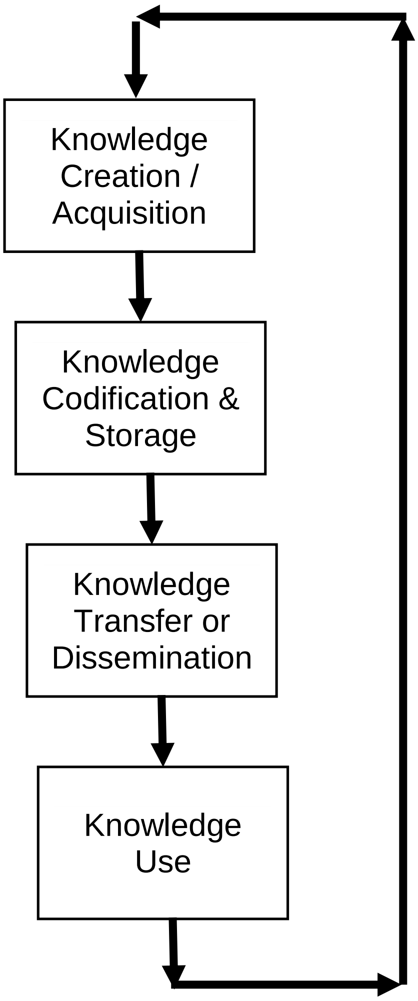


Figure 5: Knowledge Life Cycle Framework

Source: (Alavi & Leidner, 2001)

According to (Rao, 2012), we can extract the requirements for each phase of the knowledge lifecycle framework and map the appropriate tool to address these requirements.

Phase	**Requirements**

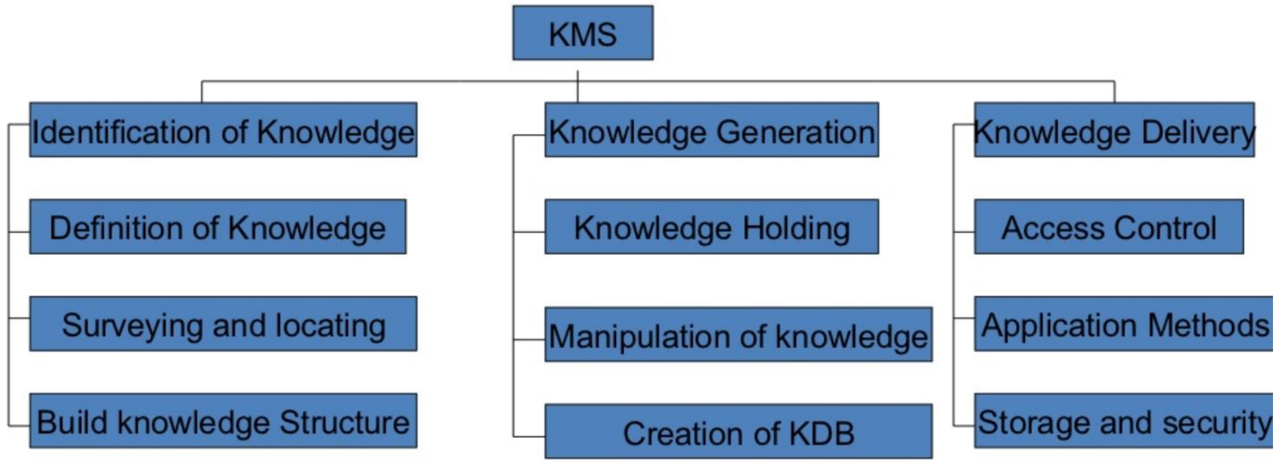
Knowledge Creation/Acquisition	The process of knowledge creation points to the ideas and actions undertaken towards the generation of new ideas or objects (Mitchell & Boyle, 2010). In this phase knowledge is acquired from internal workers (farmers in this case) and externally from experts (e.g. researchers). This phase requires a knowledge "self-reporting" instrument where each knowledge source can be interrogated.
Knowledge Codification	This category of tools will attempt to save knowledge in a structured way.
Knowledge Retrieval	Powerful search algorithms capable of unearthing created knowledge in a precise and fast manner.
Knowledge Transfer	Online collaboration tools for online work coordination

Table 3: Tools to support the knowledge lifecycle framework

Source: (Rao, 2012)

2.4.3 Knowledge Management System Architecture

A knowledge management system architecture provides the basis for dealing with knowledge through identification, generation and delivery to eventual end users (Alavi & Leidner, 2001)



Source (Alavi & Leidner, 2001)

2.4.4 Knowledge Management System Continuous Improvement

Continuous improvement is the planned, organized and systematic process of ongoing, incremental and organization-wide change of existing practices aimed at improving performance (Boer, 2015).

According to this definition, continuous improvement first and foremost a philosophy which calls for a defined purpose and a broad involvement in pursuit of that purpose. This philosophy needs to be then supported by a structured process that works towards achieving the stated purpose.

The knowledge stored in a knowledge management system needs to be continuously improved as users interact with the system. This interaction will result in new insights which were previously either overlooked or did not exist in the first place.

2.5 A Review of Knowledge Management Systems in Agriculture

The link between knowledge management and information systems for collaborative decision-making has been for a long time been accepted as a source of improvements by organizations. Efforts have been made towards realizing these gains in Agriculture as well.

Agricultural knowledge management takes the position that the agricultural production process can be managed in the more or less the same way that most organizational processes are managed. The key elements or phases of the production process can be managed by creating a favourable environment in which the knowledge can be created and shared. The idea of knowledge managed systems in agriculture emphasizes the application of technology to transform and improve production processes.

2.5.1 Sissili Vala Kori, Burkina Faso

Sissili Vala Kori (Sissili farmer’s voice) is an ICT based platform developed for the small holder farmers in Sissili province in Burkina Faso to help them improve their agricultural production methods. The general objective of the project is to improve the farmers’ information and knowledge on production methods by the implementation of an improved knowledge management platform (Menoir, 2009). This platform seeks to improve the production levels of smallholder farmers in the Sissili area by supporting them to move from subsistence farming to market farming, through the following activities:

1. Agricultural technology transfer - this transfer is made in collaboration with INERA (National Institute of Environment and Agricultural Research) through the introduction of varieties testing and farm monitoring. The objective is to identify high-yielding varieties in order to popularize them among producers.
2. Family farm management (GEFA) - GEFA is a techno-economic tool intended to help producers make predictions about crop-yield speculations and to determine the amount of inputs to invest for the crop year. It also entails providing assistance to producers in accounting pertaining to farm business and fertilizers, and the technical monitoring of farming activities.
3. Training courses - these include, among other courses, technical training in the area of crop production (maize, sorghum, sesame, etc.) and literacy.

Within the space of three years, the Federation's trainers have trained some 8,000 farmers (2,500 of whom are supervised directly by the Federation's advisors and leaders) in innovative techniques of food production and processing, sales techniques, organic fertilizer production, as well as in techniques for sustainable management of natural resources, by using videos, photos and other digital media.

One quantifiable impact that has been felt within the organization is the improved competence of agents and advisors following the introduction of ICT. These professionals in the region did not lack a general knowledge, but since they do not come from that locality and were not trained in ICT, they often lacked some key information about the situation on the ground. The organization's agricultural innovation and information gathering and sharing techniques enable these agents to be much better informed. This has gained the organization recognition for this expertise at the national level too.

2.5.2 ARENET, Uganda

The Agricultural Research Extension Network (ARENET) in Uganda is a web portal created to strengthen the links between the National Agricultural Research System (NARS) and the National Agricultural Advisory Services (NAADS) program and its related extension service providers.

ARENET provides 3 basic services:

1. Agricultural documents system: an internet tool for documenting, storing, sharing and disseminating simple technical agricultural information applicable to farmers and extension agents.
2. Question and Answer service (Q&A): an internet tool for solving technical problems related to agriculture and rural development. It was developed with the aim of helping farmers to get answers to different questions. Farmers, extension workers and service providers post the questions online under the appropriate category. The questions are answered by the best experts in each field and then posted for all to access. The questions and their appropriate answers are then stored in a data repository.
3. News and events: a system to enable districts and research sites to post news or events announcements

2.5.3 Banana Information Line, Kenya

The Banana Information Line project is a text-to-speech telephone service which provided farmers in Kenya with information related to how to plant, grow, and harvest bananas, in either English or Kiswahili. According to the organisers, because anyone with a land line or mobile phone can access the information line, communities that are more difficult to reach by traditional means can more easily access agricultural information. A TTS service bypasses the need for literacy, as well as the problem of reaching farmers living in very remote areas, and can easily be kept up-to-date by extension workers. Farmers could call the line any time of day, every day. This project ran as a pilot for several months in 2006, but has now been superseded by the recently-launched National Farmers Information Service (NAFIS) information line (see www.nafis.go.ke) which covers a wider range of crops and livestock.

2.5.4 NAFIS, Kenya

Launched in May 2008, the National Farmers Information Service (NAFIS) is a farmers' information service where the Kenya's farming community receives and exchanges timely news and information on agriculture, weather patterns and other related issues through their mobile phones.

The service allows over 4.5 million farmers access to agricultural extension information through the web and mobile phones. The system is constantly updated via a web platform by field extension officers and the same information updated IVR service accessible by any kind of phone.

NAFIS is designed primarily as a voice-based service, intended to serve farmers' needs in rural areas where internet access is limited.
Farmers receive summarised information using mobile phones by calling a specified access number then moving around the service by pressing the appropriate keys on phone's keypad.

2.6 Gaps in Current Knowledge Management Systems in Agriculture

There has been a conscious effort towards development of knowledge management systems for the agricultural sector. There are however gaps in the current implementations:

1. Current systems do not address the production process of indigenous crops.
2. Current systems take the position that there are external experts who provide knowledge for the farmers. They do not consider farmers to be domain experts and there cannot handle the collection of traditional best practices knowledge resident in local communities.
3. Current systems generalize knowledge on the production agricultural production process and do not customize it for particular regions. The practices that work best for a particular ecological zone might not necessarily work in the next one.

Chapter 3: Methodology

3.1 Introduction

Research is the search for knowledge through objective and systematic method of finding solution to a problem (Kothari, 2006). The goal of research methodology is to provide a standard method and guidelines to ensure that a research is completed on time and conducted in a disciplined, well-managed, and consistent manner that promotes the delivery of quality product and results.

The research design will focus on the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research and is consistent with the objectives stated (Kothari, 2006).

3.2 Research Pre-study

3.2.1 Introduction

A pre-study was carried out with the goal of carrying out an exploratory study to identify the key aspects of the sorghum production process which needed to be captured by the KMS. The researcher also had to understand the key reasons that resulted in low sorghum production levels in Tharaka-Nithi.

According to (Siew, et al., 2013) one of the biggest challenges in building new software for communities is identifying and employing methodologies to identify relevant functionality for inclusion in the software. The methodologies should not only encompass the technological aspects but also the complexities of the communities and intended users (Siew, et al., 2013).

The researcher chose to use participatory action research for the pre-study, which encompassed participatory observation and note taking, informal as well as semi-structured interviews. This approach strengthened the research by emphasizing participation and action, by providing an avenue for collective inquiry based on social history and experience.

The first step of the research was to identify the “experts”. An expert in this case was any individuals or institutions who had any form of knowledge on the sorghum production process. The first group of experts in this case were the indigenous crop farmers. They were termed as experts because they had social history and experience in growing sorghum even when modern research was unavailable to support them.

The goal was to better understand their approach to the production process and areas they felt needed to be improved.

The second group of experts were the agricultural researchers who worked in research institutions and had built their knowledge through formal scientific research. The third group of experts were the e-extension officers who had largely acquired their knowledge through trainings and interaction where the first and second group of experts. These two groups have explicit knowledge on the sorghum production process but this knowledge has not yet been transferred to the farmers. The researcher sought to identify the right way of building interface between the three groups of experts.

3.2.2 Research Design

The research design allowed the researcher to plan for the collection of relevant data, analysis and interpretation of observations. The researcher chose to use qualitative research since it's concerned with depth rather than the breath of information (Denscombe, 2007). It is also useful in investigating the complex interaction between technology and organizations (Plummer, 2001).

Qualitative approaches are generally (though not always) concerned with theory generation rather than theory verification and researchers typically employ methods such as interviews, documentary analysis, case studies, focus groups, observations and so forth (Barbour, 2008).

3.2.3 Sampling Technique

To avoid sample bias caused by simple random sampling, the researcher resulted to taking a stratified sample so that the stratified population structure is reflected in the sample structure. The researcher identified key informants through purposive typical case selection with the aim of diversity across the production process knowledge ecosystem.

This form of sampling is non-probability where research participants are not chosen at random and consequently are not representative of the population as a whole (Denscombe, 2007). Purposive sampling is "sampling in a deliberate way, with some purpose function in mind" (Punch, 2005).

Research participants were deliberately chosen because of the data they were able to produce. The underlying premise was that these participants could add valuable insights and contribute to a greater understanding of the research area.

Stratum	Stakeholder Type	Members
1	Tacit Knowledge	Traditional sorghum farmers
2	Explicit Knowledge	KARI researchers
		NAFIS
		East African Maltings Limited
		Ministry of Agriculture
		Kenya Seed Company
		Agri-Seed Co Limited
		Modern contract sorghum farmers

Table 4: Sampling and sample size of stakeholders

The selection of key informants was done on the basis of level of involvement in the actual sorghum production process. Preference was made for informants who had interacted with farmers directly on the production process.

Stakeholder Type	Institution	Informant	Role
Tacit Knowledge	Individual	Sorghum Small Holder Farmers	Traditional Farmer
Explicit Knowledge	Smart Logistics	Extension Officer 1	Extension Officer
Explicit Knowledge	KARI	Researcher 1	Researcher
Explicit Knowledge	KARI	Researcher 2	Researcher
Explicit Knowledge	Ministry of Agriculture	Data Analyst, Ministry of Agriculture	Analyst
Explicit Knowledge	NAFIS	Data Analyst, NAFIS	Analyst

Table 5: Key informant information

3.2.4 Data Collection

The data collection process refers to a systematic gathering of data for a particular purpose from various sources, including questionnaires, interviews, observation, existing records, and electronic devices. More often than not, it is realized that data at hand is inadequate to enable one perform a meaningful research study and thus one needs to collect adequate relevant data to the problem area (Kothari, 2006).

Both primary and secondary data was used during the research. The secondary data was explicit in nature, from research publications and publicly available data sets on sorghum production from organizations such as FAO, WFP and the Ministry of Agriculture.

Primary data was collected using personal, face-to-face interviews where the researcher played an interpersonal role by asking identified key informants questions designed to elicit answers pertinent to the research problem.

The researcher used semi-structured interviewing with all the participants. This involves the researcher having a number of clear topics to discuss with the participant, but the interview is conducted in an informal and flexible way with regards to the order in which topics are explored (Denscombe, 2007). Semi-structured interviewing is very useful for this type of study as it allowed the interviewer to place some direction on the interview but gives the interviewer and interviewee a certain flexibility to expand on topics that he / she feels are important (Denscombe, 2007). The interviews lasted between 1 and 2 hours depending on the type and depth of knowledge the informant had.

3.2.5 Data Analysis

Data analysis involves computation of certain measures with a view to finding patterns of relations between the variables, and subjecting the same to statistical tests to determine significance to determine the validity of the 'conclusion'. The researcher used this phase to discover regularities and patterns in data and to draw inferences and conclusions from the overall research process.

The researcher carried out qualitative data analysis on the collected data by following a two staged process:

1. Coding - a process by which interview responses were grouped into various classifications of a concept to determine meaningful categories. Two key categories were considered in this case, with the respondent generating either tacit or explicit knowledge.
2. Interpretation - this stage involved the use of both descriptive and inferential statistics for decision making and drawing inferences. Descriptive statistics

involved the use of frequency distributions especially in determining best practices for a particular phase of the sorghum production process.

3.3 Pre-Study Results

3.3.1 Introduction

The purpose of this chapter is to outline and present the major findings of the pre-study. The major findings are presented as themes and each theme has sub-themes that help to further break down the findings into granular detail.

In presenting the results of the interviews, the researcher anonymised the participants in order to respect the individual privacy and that of the organizations that they work for.

3.3.2 Themes and Sub-Themes

The major findings of the study are presented in tabular form as follows:

Theme	**Sub-theme**
Knowledge Acquisition	1. Knowledge sources
	2. Enhancing research
	3. Identifying best practices
Knowledge Dissemination	1. Access to best practices
	2. Interactivity with farmers

Table 6: Pre-study themes and sub-themes

3.3.3 Knowledge Acquisition

The key informants interviewed commented on the fact that there was no easy way of identifying and acquiring knowledge from the different sources available.

3.3.3.1 Knowledge Sources

The stakeholders interviewed identified the following 3 broad categories of knowledge sources namely researchers, seed companies and farmers. Both researchers and seed companies fall in the expert category and act as a source of tacit knowledge. All their research work is well documented and made available to farmers mostly in the form of product brochures.

The second category of knowledge sources consists primarily of traditional farmers, who have been growing sorghum for a long period mostly without reference to the tacit knowledge sources. It is however difficult to identify these traditional “experts”.

3.3.3.2 Enhancing Research

The researchers interviewed were raised the fact that researchers are currently limited to the few model farms in agricultural research centres. This makes it difficult to ascertain how the seeds would perform in open farms outside of the controlled research environments that they currently use. They were keen on a solution that would allow them to scale their research findings beyond the controlled environments at research institutions and be able to collect data from open farms as well once a seed variant was available for public use. Small holder farmers would be allowed to opt into the program and the researchers would then be able to remotely use their data to improve on their research findings and recommendations.

3.3.3.3 Best Practices

The tacit knowledge informants commented on the challenge of identifying best practices from the different knowledge sources. There was general agreement that farmers are forced to compare knowledge from different sources for them identify what is ideal for their farms. There is need for a simplified way of aggregating knowledge from all these sources and identifying the best approaches to production that cut-across.

These informants also raised the second challenge of continuous improvement of these best practices based on farmers’ production experiences.

3.3.4 Knowledge Dissemination

The key informants interviewed were in agreement that a lot of tacit knowledge has been collected over the years from studies by seed companies and research institutions. This knowledge however sits with these institutions and despite varied attempts to deliver this knowledge to farmers, none has been deemed to be effective.

3.3.4.1 Access to Knowledge

The farmers interviewed were in aware that research institutions and seed companies have a lot of knowledge that would help in improving their farming practices. They were however not satisfied with current attempts to pass this knowledge to them. The primary method of knowledge dissemination used was product catalogues and brochures. These are however not updated regularly and lacked the detail required on particular processes. The brochures provided were very brief and did not have the detail that farmers were looking for.

The second challenge was the fact that most brochures are provide in English, a language that most farmers were not comfortable with.

Another challenge with the brochures provided was the fact that they were not regularly updated. Most seed companies for example have kept the same product brochures for close to 5 years, which rendered the knowledge therein inutile for current farming challenges.

3.3.4.2 Ecosystem Interactivity

Most farmers interviewed commented on the fact that there was no easy way of interacting with experts. Experts all tend to be located at centralized locations, mostly at research and training institutions and were very few in number. Seed companies do provide extension field officers but just like the ones provided by the Ministry of Agriculture are very few in number. This means that the extension efforts are not scalable and farmers do not have an easy way of interacting with these tacit knowledge experts.

3.4 Proposed Solution

3.4.1 Overview

This research proposes an integrated KMS that supports the sorghum production process in Tharaka-Nithi. The first phase of the proposed system will provide an interface for collection of common practices by farmers for the pre-cultivation and cultivation and harvesting stages of the production process. The farmers in this case will serve as the primary experts, albeit with tacit knowledge. The system will also consider input from the secondary experts, in this case researchers and extension officers who have explicit knowledge on the sorghum production process.

Once this data is collected, it will be aggregated in a centrally hosted RDBMS. This RDBMS will be hosted on a public cloud environment for fast and secure access.

This database will be continuously updated by farmers as they proceed with the sorghum production cycle. The solution will maintain an individualized calendar of activities for each farmer throughout the production cycle.

The proposed solution will have a logical layer which will analyse the collected common practices and determine sub-sets of best practices for each phase of the production process. This layer will have a set of algorithms which will constantly update the best-practices as new information is introduced into the system.

This knowledge on best-practices for the sorghum production process will be disseminated to farmers primarily via mobile telephony upon request. According to (Communications Authority of Kenya, 2015) mobile phones penetration in Kenya currently stands at 82.6% making it the most ubiquitous technology end-point in Kenya. Farmers will have the opportunity to access the KMS either via a smart mobile application or through SMS and USSD. The system will also be built with IVR integration in mind.

3.4.2 Proposed Architecture

(Unhelkar & Murugesan, 2010) developed a framework to be used for enterprise mobile applications which was meant to provide a systematic and comprehensive solution to mobile applications development and maintenance.

According to (Unhelkar & Murugesan, 2010), the Mobile Applications Development Framework (MADF) brings together elements of software architecture and design and the required supporting communication infrastructure (network and protocols) and different types of information accessed across multiple sources.

The framework brings out important aspects that should be considered in developing mobile applications that can handle complex business logic using a middle tier, transfer data back and forth over the mobile network and also facilitate data storage to a database. It also allows multiple-access to the application's backend either from a single mobile application or a suite of applications. MADF presents a good reference point towards implementing mobile applications and gives clear pointers on the basic components of a mobile applications development model.

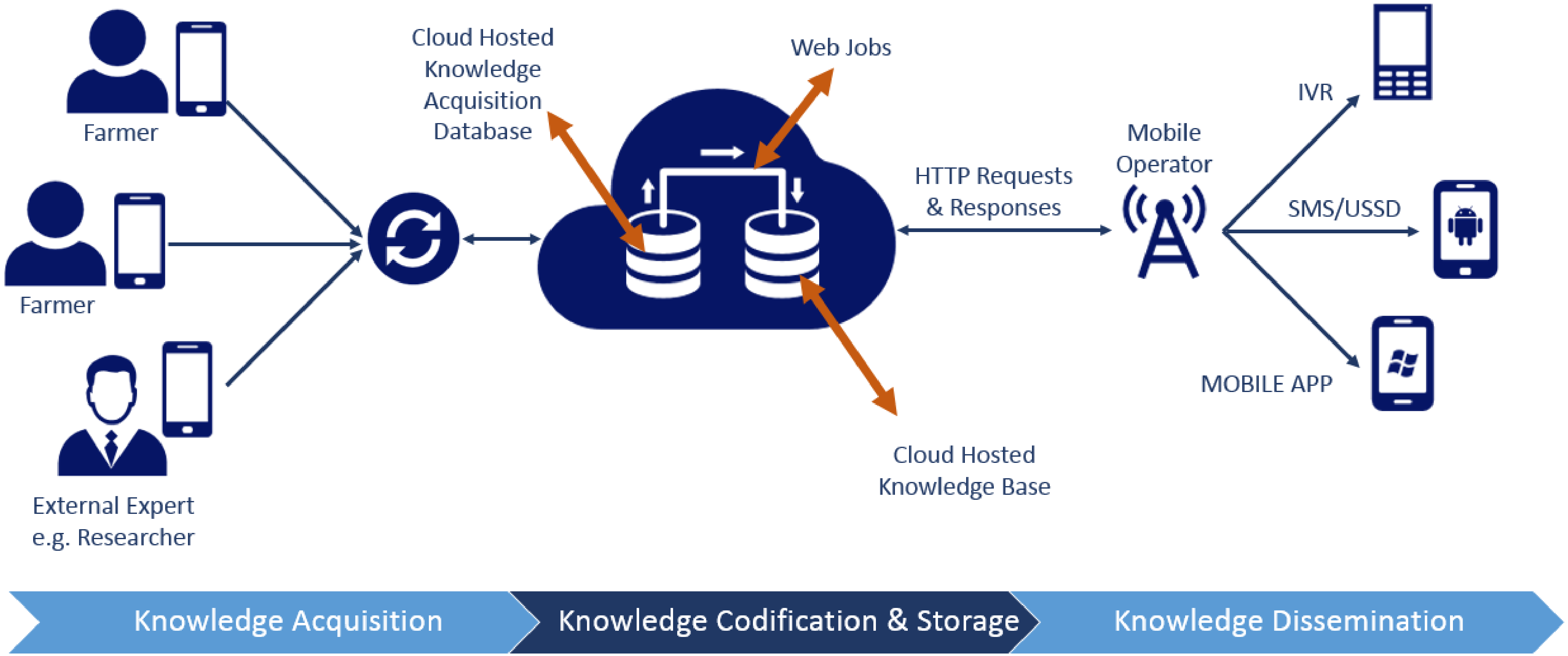


Figure 6: Proposed Solution Architecture

The proposed solution architecture in Figure 6 above incorporates the design principles outlined by (Unhelkar & Murugesan, 2010) in the Mobile Design and Architecture Framework. The primary interaction end point for any end user category (researcher, extension officer or small holder farmer) is a mobile device. The interfacing mobile device can either be a smart device or a feature phone accessing the platform via USSD. The scope of this research is limited to a smart mobile device. This device will provide the end user with more flexibility as well as ability to consume rich media content from the mobile device.

3.5 Prototype Implementation

Prototyping is a systems development method in which a prototype (an early approximation of a final system or product) is built, tested, and then reworked as necessary until an acceptable prototype is finally achieved from which the complete system or product can now be developed (Sommerville, 2010).

The researcher chose to use an evolutionary prototyping approach where an initial prototype is refined through a number of stages to the final system. This approach used an iterative process continuously matures the product as the user environment changed. Advantages were that it provided an accelerated delivery of the prototype and secondly provided the users with an opportunity to engage with the system as it evolved.

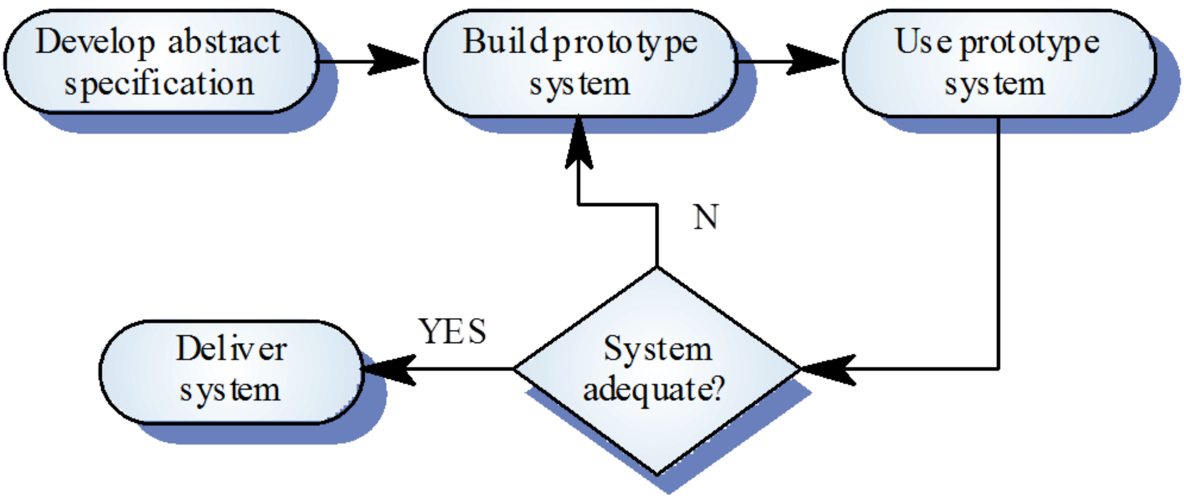


Figure 7: Evolutionary prototyping process

Source: (Sommerville, 2010)

3.5.1 Use Cases

A use case is a list of all the ways of using a system to achieve a particular goal for a specific user (Jacobson, et al., 1992). Combined, the set of all the use cases provides a unified way of using the system, and illustrates the value that it will provide. The interactions between users and systems are represented by the use of use case diagrams. Use case diagrams show the relationship between the user and the different use cases in which the user is involved (Jacobson, et al., 1992).

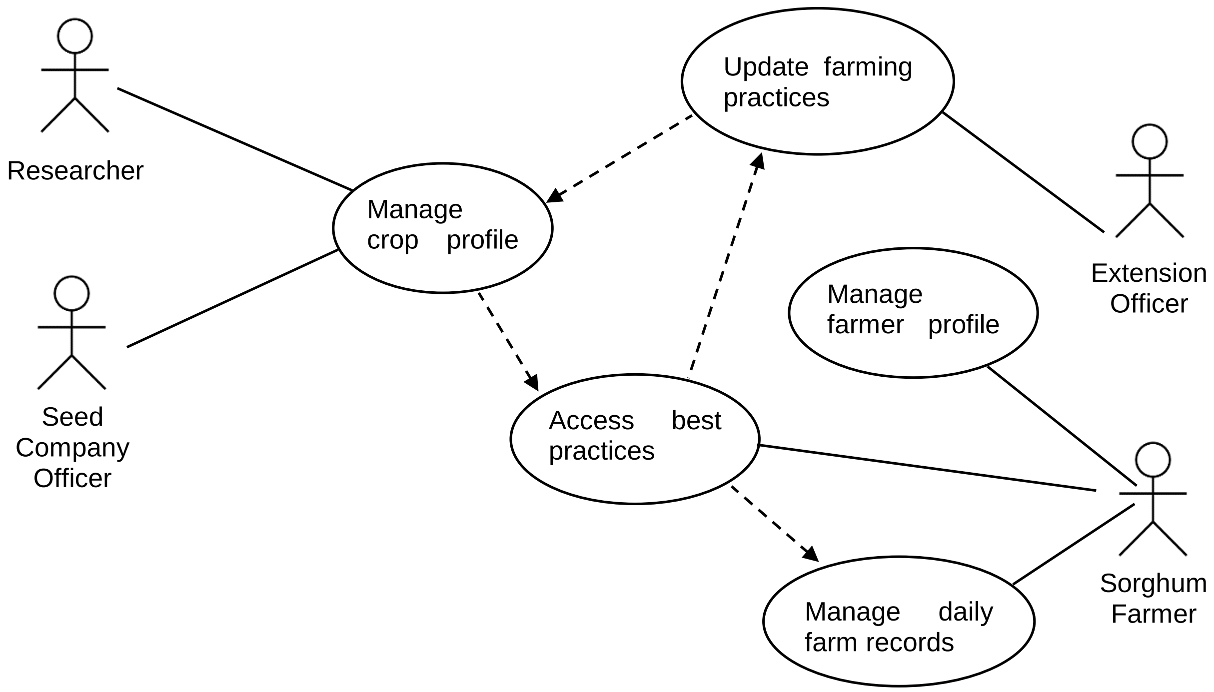


Figure 8: Overall system interaction

Figure 8 above illustrates the high level interaction between the system and the various actors identified for inclusion in the system. The initial set of data for inclusion in the system will be tacit knowledge from the researcher and the seed company. Collectively this will form the foundation on top which the traditional experts (indigenous small holder farmers) will build their knowledge.

Use case 1 – Add crop profile

Use case ID	UC01
Description	Adding a new crop profile to the system
Primary actor(s)	Researcher or seed company officer
Secondary actor(s)	Farmer Agricultural extension officer
Trigger	The actor must request to capture a new crop profile
Measurable result	New crop profile added
Main flow	User selects the new crop profile menu. The application gives the actor the option of saving newly entered crop profile data or cancelling the operation
Alternate flow	Actor enters incorrect values or fails to provide data for one of the mandatory fields. The application will not allow the actor to proceed and save the crop profile. An attempt by the actor attempts to enter a duplicate crop profile will also result in an error prompt
Post condition	Crop profile added successfully

Use case 2 – Edit crop profile

Use case ID	UC02
Description	Editing and existing crop profile
Primary actor(s)	Researcher or seed company officer
Secondary actor(s)	Farmer Agricultural extension officer
Trigger	The actor must display the list of existing crop profiles and request to edit a specific crop profile
Measurable result	Existing crop profile modified
Main flow	Actor selects edit crop profile menu. The application gives the actor the option of modifying an existing crop profile data or cancelling the operation
Alternate flow	Actor enters incorrect values or fails to provide data for one of the mandatory fields. The application will not allow the actor to proceed and save the crop profile. An attempt by the actor attempts to enter a duplicate crop profile will also result in an error prompt
Post condition	Crop profile modified successfully

Use case 3 – Add training material

Use case ID	UC03
Description	Add training material
Primary actor(s)	Researcher or seed company officer
Secondary actor(s)	Farmer Agricultural extension officer
Trigger	The actor must select an existing crop profile and request to add new training content
Measurable result	New training material added
Main flow	Actor selects an existing crop profile and clicks on the “add new” training material menu. The system gives the actor the option of adding new training material affiliated to a particular crop
Alternate flow	Actor enters incorrect values or fails to provide data for one of the mandatory fields. The application will not allow the actor to proceed and save the training content
Post condition	Training material added successfully

Use case 4 – Remove training material

Use case ID	UC04
Description	Remove training material
Primary actor(s)	Researcher or seed company officer
Secondary actor(s)	Farmer Agricultural extension officer
Trigger	The actor must select existing training material and request to delete it
Measurable result	Training material deleted
Main flow	Actor selects existing training material menu. The system gives the actor the option of deleting the training material that's affiliated to a particular crop. Actor can also choose to cancel the operation.
Alternate flow	If the application fails to delete the training material for any reason, an error message will be shown and the application will gracefully exit the operation.
Post condition	Training material deleted successfully

Use case 5 – View planning guide

Use case ID	UC05
Description	View planning guide
Primary actor(s)	Farmer, Agricultural extension officer
Secondary actor(s)	Researcher or seed company officer
Trigger	The actor must an existing crop profile
Measurable result	Planning guide accessed
Main flow	Actor selects existing crop profile. The system gives the actor the option of viewing the crop's description, planting calendar or associated training material
Alternate flow	If the application fails to load the planning guide for any reason, an error message will be shown and the application will gracefully exit the operation
Post condition	Planning guide accessed successfully

Use case 7 – Add farmer profile

Use case ID	UC06
Description	Add farmer profile
Primary actor(s)	Farmer
Secondary actor(s)	-
Trigger	First time usage of the application
Measurable result	Farmer profile added successfully
Main flow	User selects the new farmer profile menu. The application gives the actor the option of saving newly entered farmer profile data or cancelling the operation
Alternate flow	If the application fails to save the farmer profile for any reason, an error message will be shown and the application will gracefully exit the operation
Post condition	Farmer profile accessed successfully

Use case 8 – Edit farmer profile

Use case ID	UC08
Description	Edit farmer profile
Primary actor(s)	Farmer

Secondary actor(s)	-
Trigger	Need to modify an existing farmer profile
Measurable result	Farmer profile edited successfully
Main flow	Actor displays farmer profile and continues to modify existing data. The application gives the actor the option of saving or cancelling the operation
Alternate flow	If the application fails to load or save the farmer profile for any reason, an error message will be shown and the application will gracefully exit the operation
Post condition	Farmer profile edited successfully

Use case 9 – Add farm daily record

Use case ID	UC09
Description	Adding a new production record
Primary actor(s)	Farmer
Secondary actor(s)	Researcher, Agricultural extension officer, seed company
Trigger	The actor must request to capture a new daily record
Measurable result	New farm record added
Main flow	User selects the new farm record profile menu. The application gives the actor the option of saving newly entered farm record data or cancelling the operation
Alternate flow	Actor enters incorrect values or fails to provide data for one of the mandatory fields. The application will not allow the actor to proceed and save the farm record.
Post condition	Farm record added successfully

Use case 10 – Edit farm daily record

Use case ID	UC10
Description	Editing an existing farm daily operations record
Primary actor(s)	Farmer
Secondary actor(s)	Researcher, Agricultural extension officer, Seed Company
Trigger	The actor must display the list of existing farm records and request to edit a specific one
Measurable result	Existing farm operations record modified
Main flow	Actor selects the edit farm record menu. The application gives the actor the option of modifying an existing record or cancelling the operation
Alternate flow	Actor enters incorrect values or fails to provide data for one of the mandatory fields. The application will not allow the actor to proceed
Post condition	Farm record modified successfully

Use case 11 – View best practices

Use case ID	UC11
Description	Viewing a crop’s aggregated best practices
Primary actor(s)	Farmer, seed company, researcher, extension officer
Secondary actor(s)	-
Trigger	The actor must display the list of existing crop profiles and request to view farming best practices
Measurable result	Best practices accessed

Main flow	Actor selects and existing crop profile menu. The application gives the actor the option of viewing a list of best practices aggregated by the system over time
Alternate flow	Actor enters incorrect values or fails to provide data for one of the mandatory fields. The application will not allow the actor to proceed and save the crop profile. An attempt by the actor attempts to enter a duplicate crop profile will also result in an error prompt
Post condition	Crop profile modified successfully

3.5.2 Prototype Design

The use cases defined in the previous section helped to describe the steps that will guide the user into interacting with the system to generate useful output. These provided the foundation for the UML and ER diagrams that will form the basis of the prototype development.

The researcher chose to use an objected oriented design approach, which entails looking at the system design from the perspective of interactions between key objects. Objected oriented design relies on use cases as in input to the final UML diagrams used representing these dynamic interactions. Unified modelling language provides a standardized approach to systems components notation and provides an easy way for developers to understand the system to be developed (Jacobson, et al., 1992)

The conversion from use cases to UML class diagrams is a 4 stage approach as defined by (Jacobson, et al., 1992)

1. Identification of the key classes which perform a use case's flow of events. The use case flow-of-events approach focuses on the textual representation of what the system should do, and not how it should do it.
2. Distribution of use case behaviour to those classes, using use-case realizations.
3. Identification of responsibilities, attributes and associations of the classes. This involves transforming the use case include and extend relationships to class relationships.
4. Identification of usage of architectural mechanisms.

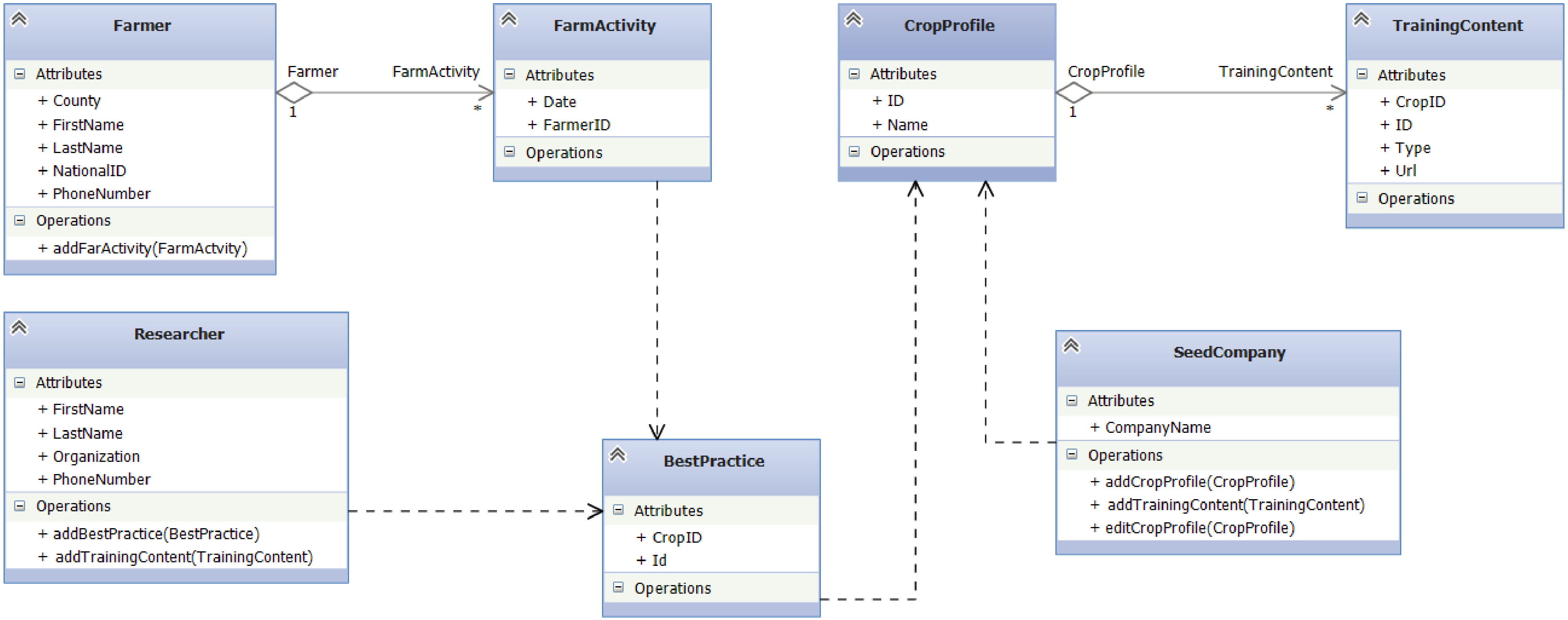


Figure 9: System class diagram

Design Approach Justification

The researcher chose to use an objected oriented design approach for the following key reasons:

1. Real-World Modelling - object-oriented design represents the real world in a more holistic and complete way with objects are organized into classes of objects, and objects are associated with behaviours. The model is based on objects, rather than on data and processing.
2. Improved reliability and flexibility - an object-oriented approach provides greater reliability in the accuracy of the system developed because new behaviours can be "built" from existing objects. It also allows for greater flexibility because objects characteristics and relationships can be quickly identified and altered if need arises.

The researcher chose to use structure diagrams instead of behaviour diagrams because they focus on the components that must be present in the system being modelled.

User Interface Design

A user interface is the interaction point between a system and users of that system. The goal of user interface design is to facilitate the accomplishment of the user's goal by making the system interaction as simple and efficient as possible. The researcher used a frontend mock-up as a design tool to visualize the application ahead of actual implementation.

Figure 10: Application mock-ups

3.5.3 Development

The researcher used a layered approach in implementing the system. A multi-layered software architecture is an approach to software design and architecture that uses different layers for allocating the different functionalities and attributes of a system.

This section analyses the overall structure of the system in terms of logical groupings of components into separate layers that communicate with each other.
The key components of the system are illustrated below.

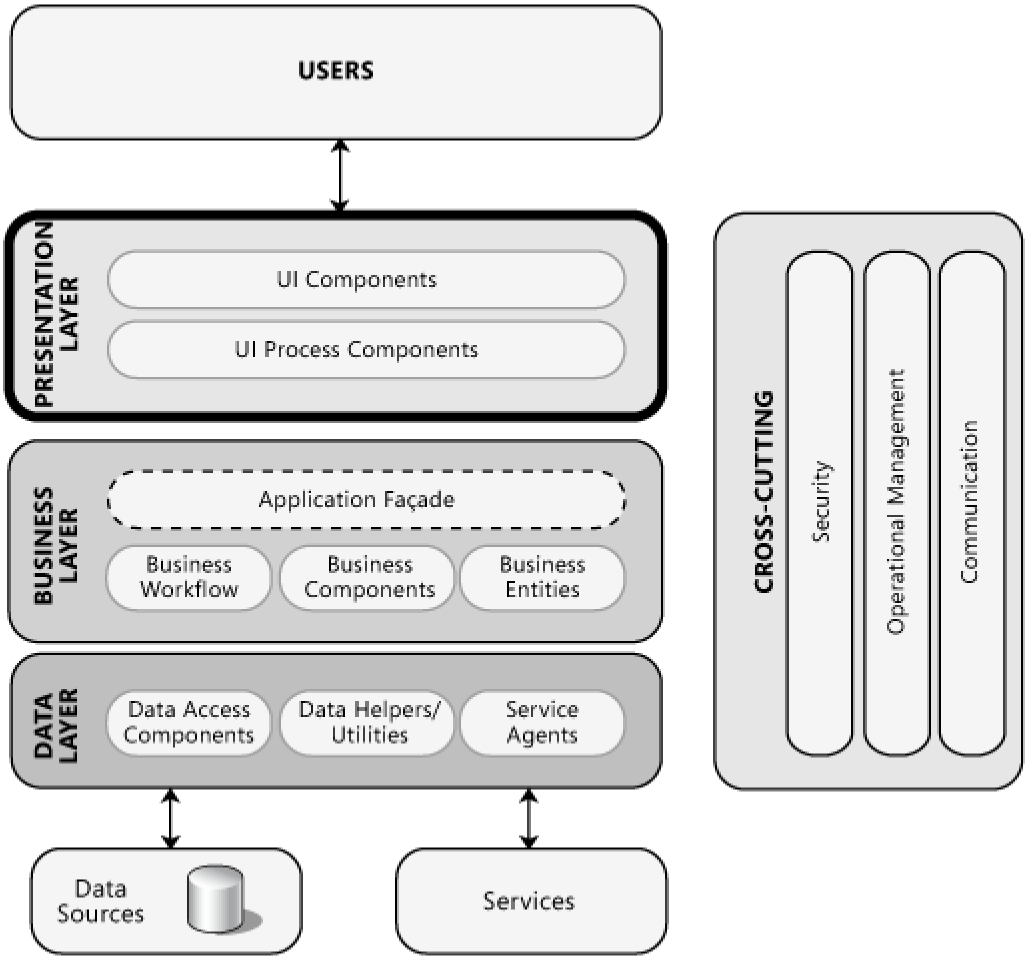


Figure 11: Multi-layered application implementation

Data Layer

This layer provides access to data hosted within the boundaries of the system, and data exposed by other networked systems; perhaps accessed through services. The data layer exposes generic interfaces that the components in the business layer can consume. (Buschmann, et al., 1996)

Business Layer

This layer implements the core functionality of the system, and encapsulates the relevant business logic. It generally consists of components, some of which may expose service interfaces that other callers can use (Buschmann, et al., 1996)

Presentation Layer

This layer contains the user oriented functionality responsible for managing user interaction with the system, and generally consists of components that provide a common bridge into the core business logic encapsulated in the business layer. (Buschmann, et al., 1996)

The researcher chose to use a mobile application as the primary interaction point for the following reasons:

1. A mobile application will provide the end users with the flexibility of using the application while working in field locations. The key user roles of the application i.e. farmers, extension workers, seed companies field agents and researchers care typically non-office workers.
2. Offline capability: The mobile application will provide the end users with the flexibility of data capture and retrieval while working in areas of limited or no connectivity. The application will then sync with the centralized backend server once connectivity is restored.
3. Cost of adoption: A mobile phone has a comparatively lower acquisition price point compared desktops and laptops currently available in the market. This will facilitate the adoption of the application by the targeted end users once the application is available for public use.

3.5.4 Initial knowledge capture and creation

The system requires an initial set of baseline data which will be refined and enhanced over time through data generated by actual utilization of the system by users. This baseline set of knowledge is collected from tacit knowledge sources i.e. books, publications by research institutions and product brochures.

3.6 Prototype Evaluation

The researcher used usability testing as the primary evaluation approach. Usability is a software quality attribute that assesses how end users interact with a system. Usability testing is a technique used in user-centred interaction design to evaluate a product by testing it on users. (Nielsen, 1994)

This is a fundamental practice in application development since it gives direct input on how real users use the system.

3.6.1 Test Users

According to (Nielsen, 2000) best usability test results come from testing no more than five users and running as many small tests as possible. He further supported the claim of "Five users is enough" using a mathematical model which states for the proportion of uncovered problems U,

$U = 1-(1-p)^n$

where p is the probability of one subject identifying a specific problem and n the number of subjects (or test sessions).

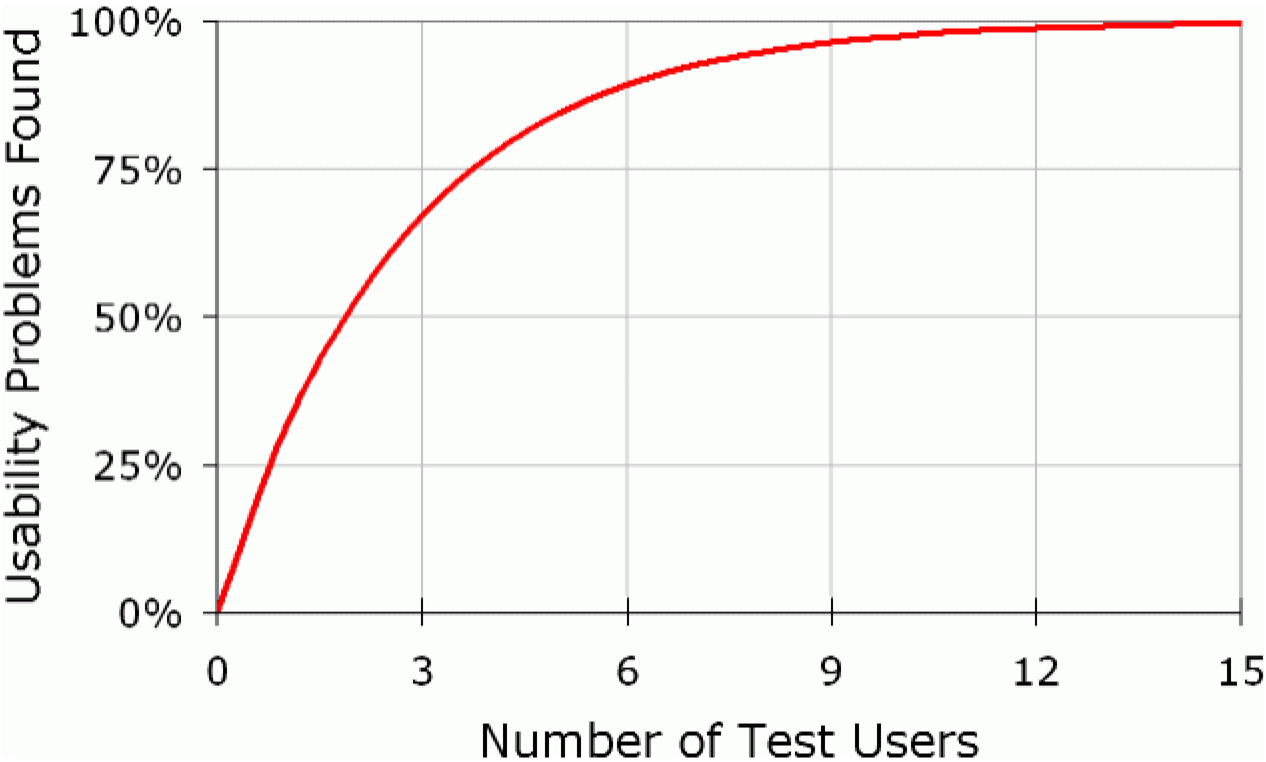


Figure 12: Usability testing

Source: (Nielsen, 2000)

As illustrated in the figure above, this mathematical model shows up as an asymptotic graph towards the number of real existing problems. As soon as data is collected from the first user, the number of insights gained tend to shoot up and then bottom out from the 12th user.

The researcher identified 3 categories of users for testing the application. First group of users were the researchers and extension officers, who served as the key informants during the research pre-study. These users were selected because they were already familiar with the research being carried out and had expressed interest in evaluating the application. The second category of users were small holder and contract sorghum farmers.

3.6.2 Tests Environments

The researcher provided the mobile devices for testing the application. First device was a Nokia Lumia 920 running Windows Phone 8.1 and connected to Safaricom 3G network. Second device was a Huawei Ascend W1 running Windows Phone 8.0 connected to the Airtel Kenya 3G network. The researcher provided different devices and networks to help in evaluating the application in different platform environments.

The first group of users tested the application from an office environment while the second group of users comprising mostly of farmers tested from an outdoor environment.

3.6.3 Test Conduction

The researcher started by providing each group of users with a background of the application and the problem/challenges the application was trying to address. This helped in providing the users with a background of what was expected of them. Users were encouraged to use the think aloud approach while conducting the tests. According to (Nielsen, 1994), think aloud may be the single most valuable usability engineering method since it requires users to verbalize their thoughts as they move through the application. Each of the identified users was provided with a mobile device and requested to perform a series of tasks to evaluate the application. The researcher observed each user while executing the tasks and would record how long it would take each user to accomplish a particular task.

3.6.4 Tasks

The researcher identified the tasks to be used for evaluation based on the thematic areas raised by the users during the pre-study.

Task 1 - Register Farmer

1. Launch the mobile application by clicking on the application icon
2. Navigate to the farmer profile menu
3. Enter test farmer data: first name, last name and telephone number
4. Click the save button

Task 2 – access crop profile

1. Navigate to the planning menu on the application
2. Select the crop that you interested in growing

Task 3 – access training material

1. Navigate to the planning menu on the application
2. Select the crop that you are interested in learning more about
3. Access the list of training resources available
4. Select one of the training material

Task 4 – capture farming activity

1. Navigate to the production menu on the application
2. Enter the required data for the farming activity performed
3. Click on the save data

Task 5 – review best practices

1. Navigate to the planning menu on the application
2. Select the crop profile you are interested in
3. Access the list of best practices

3.6.5 Usability Testing Questionnaire

Each user was presented with a set of assessment questions once they had successfully completed all the tasks. The researcher read out a series of questions from a predefined questionnaire to the user to assess their level of satisfaction in interacting with the application.

The questionnaire was split into three broad sections.

1. Section 1: building background profiles of the end users
2. Section 2: evaluating the suitability of a smart mobile application as a means of disseminating best practices to end users
3. Section 3: functionality assessment

Chapter 4: Results and Analysis

4.1 Introduction

This chapter presents the results from the usability tests carried out. First phase of the usability testing was designed to measure users' relative performance on a given set of tasks. The second phase used a questionnaire based approach with a set of qualitative metrics.

4.2 Usability Test Results

The researcher analysed the average time it took a user to evaluate all the tasks and then the average time (in seconds) it took for all the users to complete a particular task.

User Type	**User ID**	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Average**
Researcher	User1	57	32	28	85	27	45.8
Researcher	User2	87	20	26	82	19	46.8
Extension Officer	User3	76	32	22	66	23	43.8
Extension Officer	User4	54	29	32	55	24	38.8
Contract Farmer	User5	89	24	25	81	28	49.4
Contract Farmer	User6	86	26	23	51	19	41
Contract Farmer	User7	69	42	22	83	18	46.8
Small-holder Farmer	User8	86	33	15	61	21	43.2
Small-holder Farmer	User9	86	26	16	55	20	40.6
Small-holder Farmer	User10	52	23	20	56	25	35.2
Small-holder Farmer	User11	56	26	18	81	29	42
Small-holder Farmer	User12	61	18	17	74	27	39.4
Small-holder Farmer	User13	62	27	28	63	26	41.2
Small-holder Farmer	User14	72	14	31	68	21	41.2
Small-holder Farmer	User15	54	20	29	69	21	38.6
Small-holder Farmer	User16	68	29	21	74	18	42
Small-holder Farmer	User17	69	33	27	58	34	44.2
Small-holder Farmer	User18	61	27	26	62	30	41.2
Small-holder Farmer	User19	67	29	31	61	31	43.8
Small-holder Farmer	User20	62	30	25	55	29	40.2
Average		68.7	27	24.1	67	24.5	

Table 7: Average application user timings

The figure above illustrates the average timings taken by the users in executing the provided tasks.

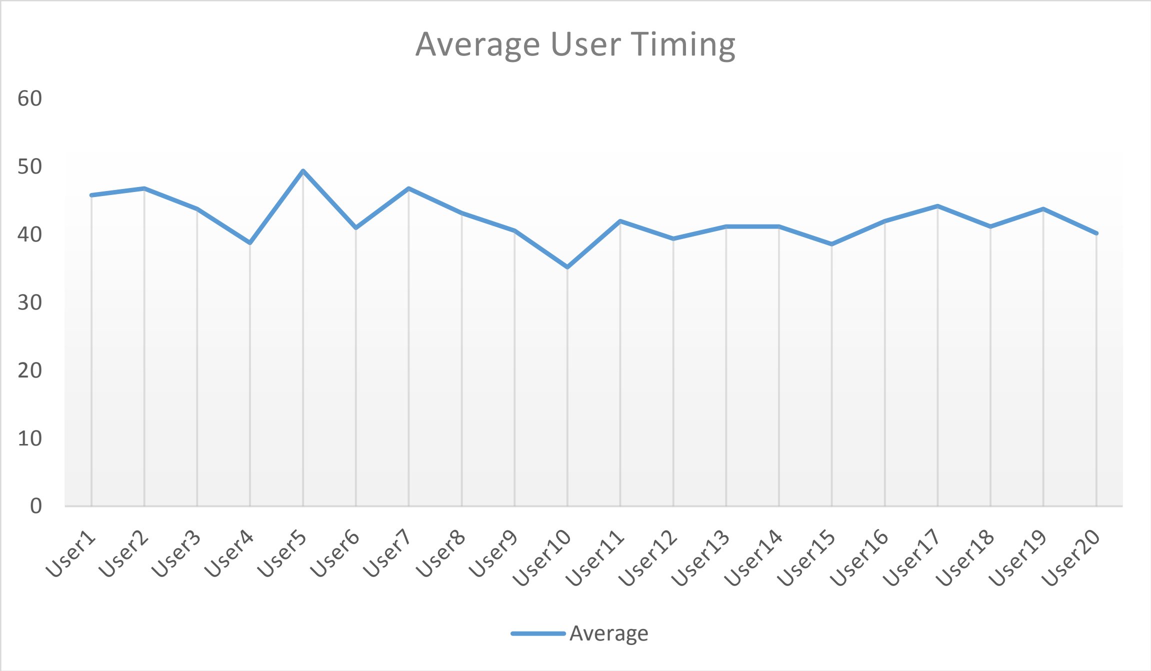


Figure 13 Average user timing

The figure above is a graphical representation of the average user timing presented in Table 7. From the graph we can see that the average time taken by the users was stable with a 15s difference between the fastest and slowest average times recorded.

It was noted that Task 1, where users were required to enter their profile information was the easiest to execute for small holder farmers. This is because the data required was already known and natural to the user and so not much thought went into it. There were however slight hesitations with the extension officers and researchers when the system asked them to provide their personal profile information. They wanted guarantee that this information would be private and not shared with other people.
Tasks 2 and 3 registered the slightest hesitations from all the users since they simply involved accessing existing data. Task 4 was the most challenging since for the small holder farmers since they needed to review the list of available farm activities to determine what they had done on a particular day. This was the stage where the language barrier was most evident, as some farmers could not understand the terminology used in reference to farming activities.

4.3 Questionnaire Results

Both qualitative and quantitative approaches were used in analysing the data from the questionnaire. Qualitative analysis was used for the open ended questions (5 and 6) where users were required to give semi-structured feedback. Quantitative analysis was used for the first set of questions where users were restricted to limited set of responses.

4.3.1 Quantitative Analysis

The final results were analysed using bar graphs to represent the distribution of the responses to the structured questions.

Question 1

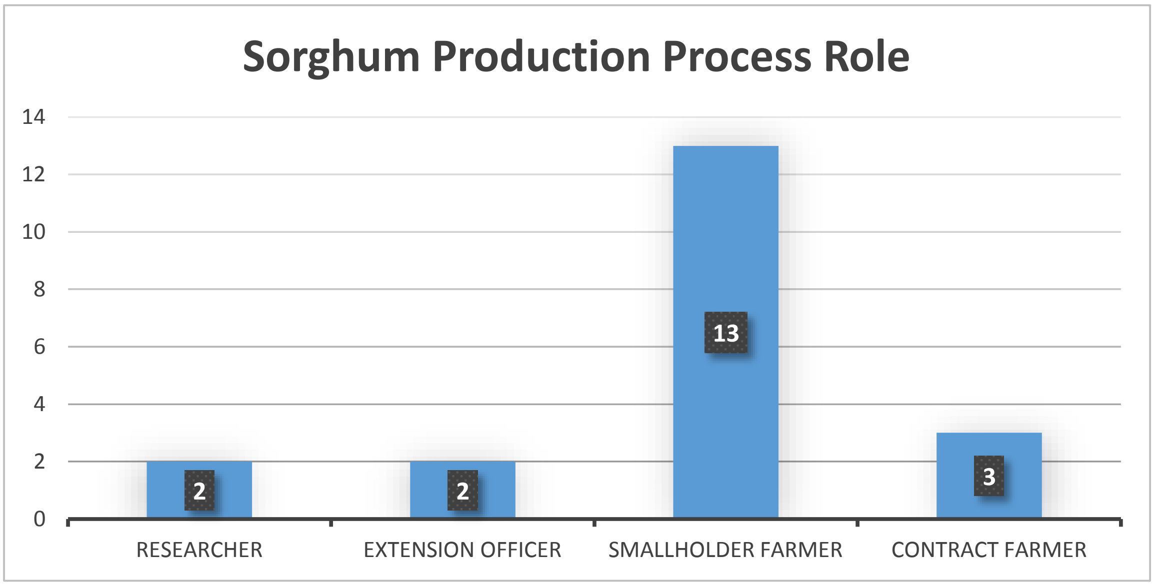


Figure 14: Usability Testing Question 1 Results

As illustrated in figure 14 above, majority of the test users were small holder farmers. The researcher intentionally did this because farmers will eventually be the largest user base for the application. They would also be the source of the data to be used for refining the tacit knowledge from the researchers and extension officers.

Question 2

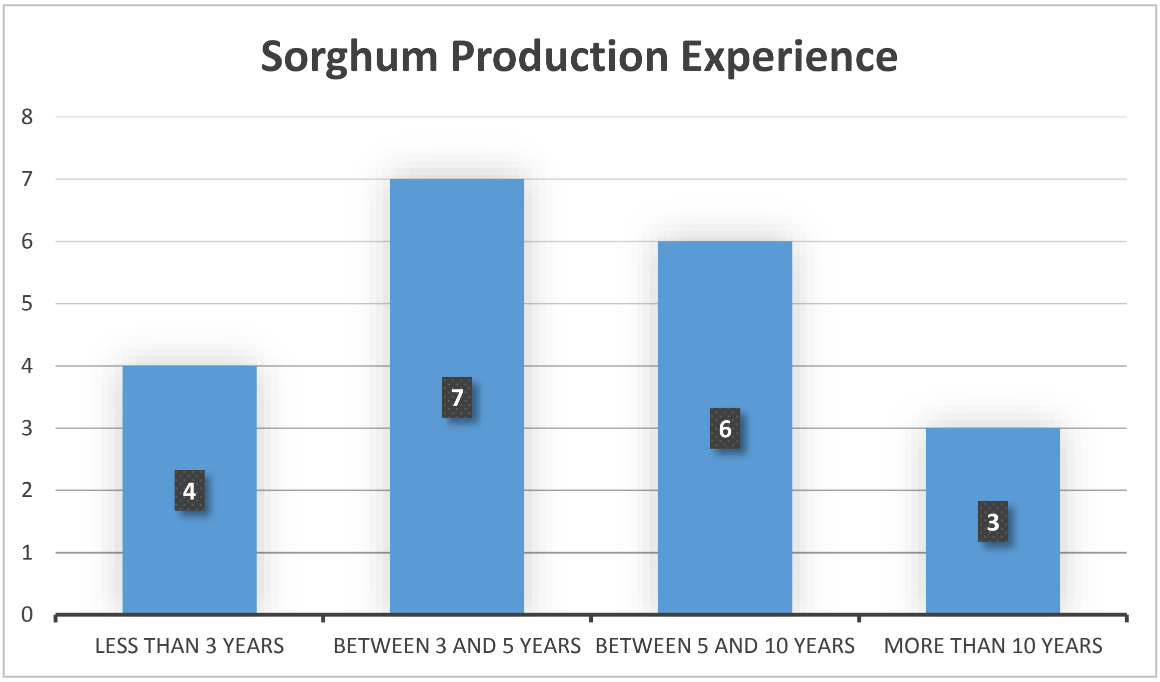


Figure 15: Usability Testing Question 2 Results

As illustrated in figure 15 above, only 15% of the test users had practiced sorghum farming for more than 10 years.

Question 3

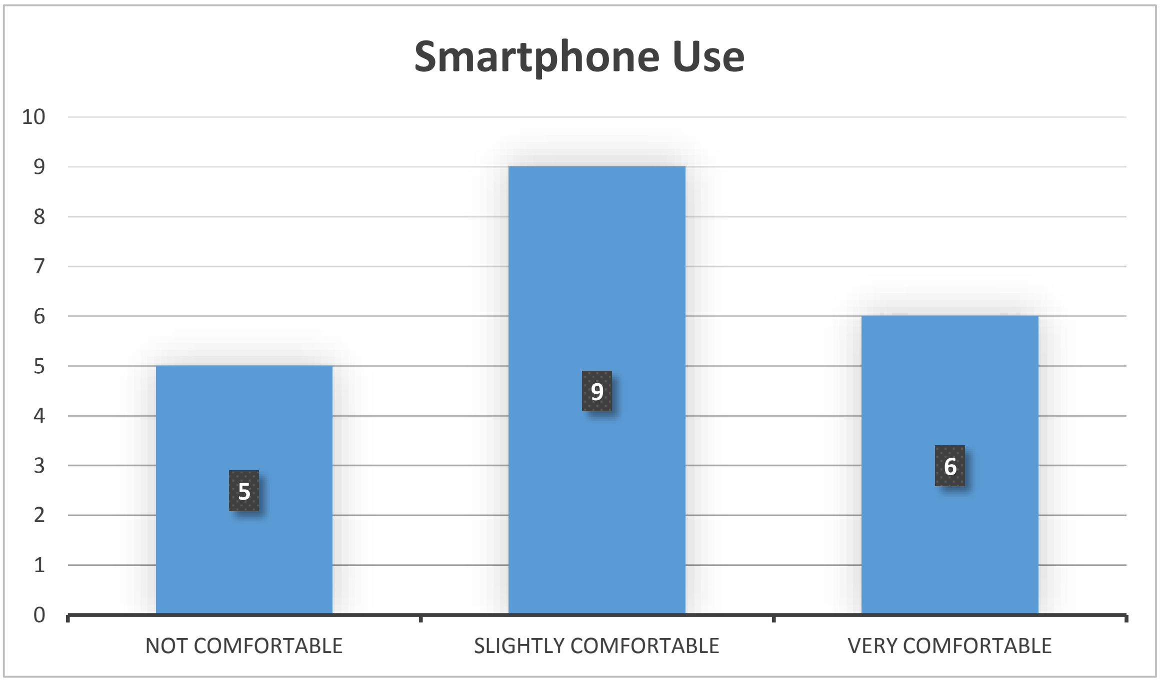


Figure 16: Usability Testing Question 3 Results

Question 4

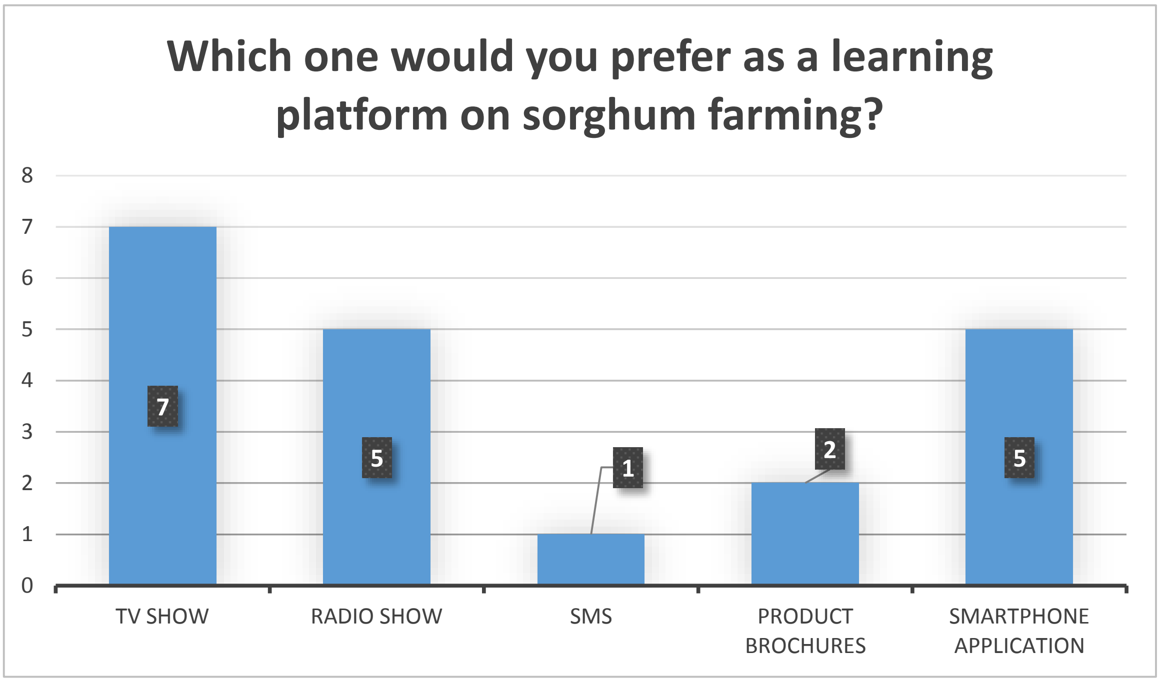


Figure 17: Usability Testing Question 4 Results

Question 5

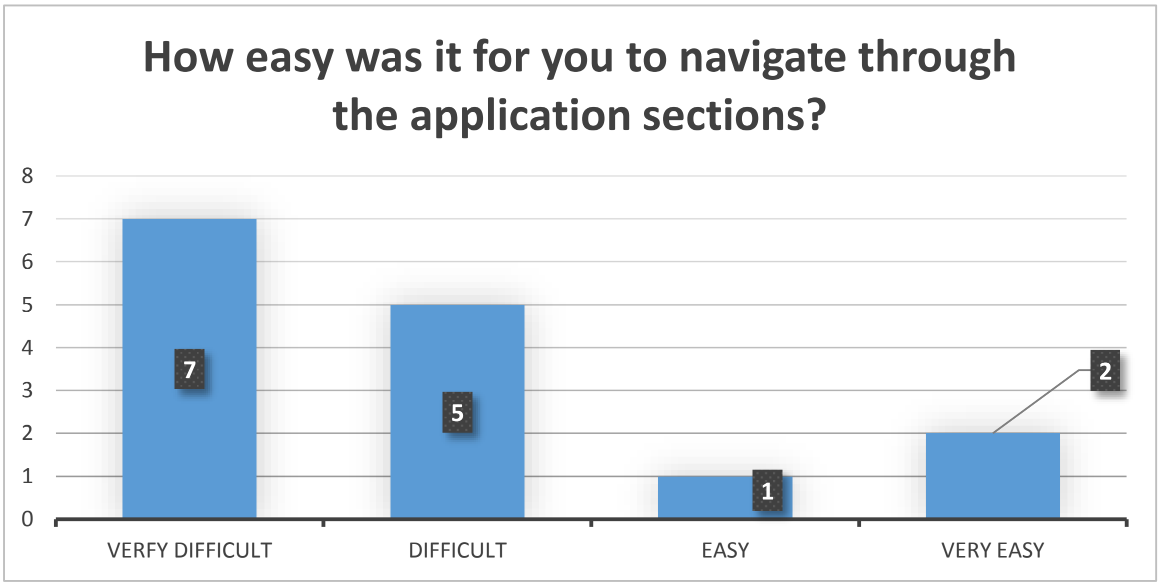


Figure 18: Usability Testing Question 5 Results

As illustrated in figure 18 above, 35% of the test users found the application very difficult to navigate. This can be attributed to the fact that 70% of the users were either not comfortable or slightly comfortable with using a smart phone as was illustrated in figure 16.

Question 6

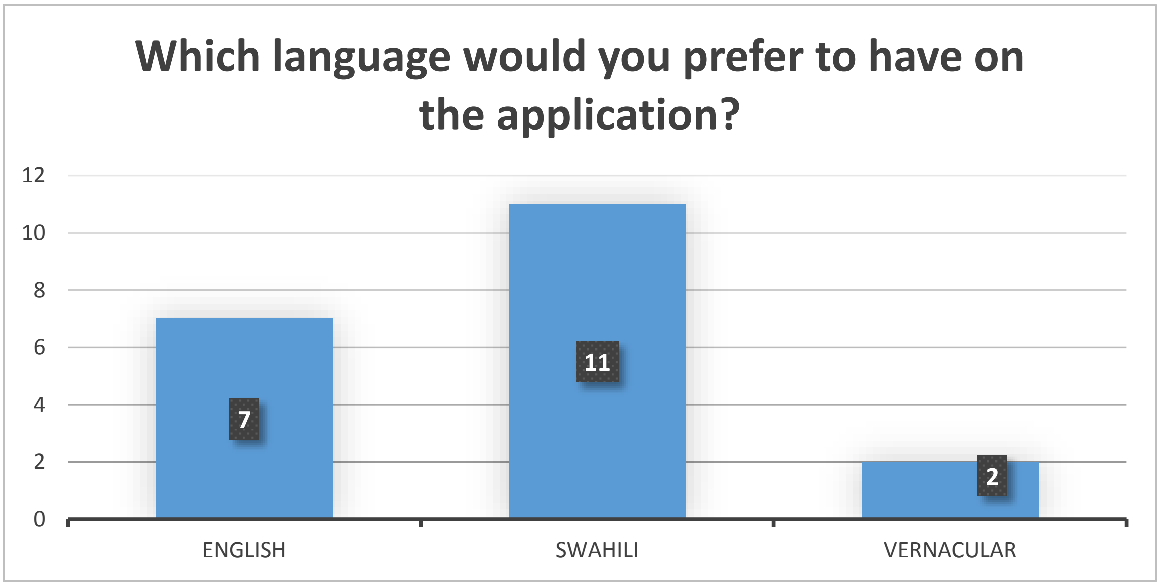


Figure 19: Usability Testing Question 6 Results

As illustrated in figure 19 above, 55% of the test users picked Swahili as the language of choice in using the application. This is also part of the reason why 35% of the users found the application very difficult to use and interact with.

Question 7

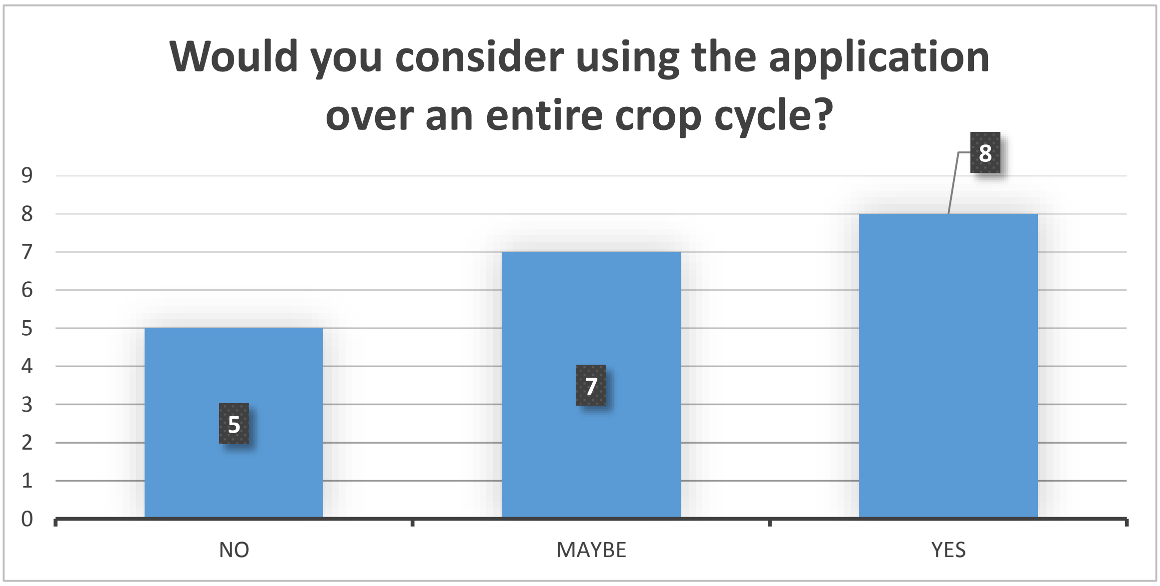


Figure 20: Usability Testing Question 7 Results

Overall, only 25% of the test users would not consider using the application over an entire crop cycle simply from the first interaction with the application.

Further work is required in building digital literacy and having the application in a language that users were more comfortable with to allow for a greater adoption rate.

4.3.2 Qualitative Analysis

The open ended questions were asked to help in improving the general functionality of the application. All of the 20 test users had general feedback on the open ended questions which the researcher noted down on the questionnaire template.
The following key themes were noted:

Application scope expansion

Most test users felt that the system should include other crops as well. Majority of the smallholder farmers in Tharaka South are exploring green grams contract farming already. The farmers felt that the application would go a long in accelerating the learning process for them. There was a general consensus that the system would be of even more value if it was expanded to include livestock farming as well. Majority of the smallholder farmers in Tharaka South were already rearing traditional chicken and cattle.

Access to market

This was the most prevalent theme among the farmers, both small holder and contract farmers. They felt that the system was only going half the journey in improving their productivity. One of the biggest challenges faced by all farmers is access to buyers and profitable markets. Farmers were keen on tracking market prices and interacting with principal buyers directly from the application. The researcher responded that this was beyond the scope of the research but would make recommendations for further work to integrate with existing market research platforms.

Chapter 5: Conclusion and Recommendations

5.1 Introduction

This chapter discusses the overall achievements from the research and prototype development based on the key objectives that were outlined at the beginning. It also highlights the challenges that encountered in the process of trying to achieve the key objectives. Finally, the researcher outlines suggestions for further to broaden and extend the research.

5.2 Achievements

The researcher's achievements against the stated objectives were as follows:

Objective1: To develop an approach for collecting best practices on sorghum farming in Tharaka from traditional farmers

An approach for identifying the best practices for production of sorghum was developed. An interface for disseminating these best practices, in a way that is easily understandable for the farmer was also developed. The provided best-practices dissemination mode moves away from traditional training approach to an event-assisted mode. This means that the application tracks the farmer throughout the production cycle and provides information relevant to the current level of the production process, making it easier for the farmer to implement the proposed practice.

Objective 2: To develop an approach for zone profiling to determine the ideal traditional crop for Tharaka

An approach for identifying the ideal crops for specific ecological zones was developed based on the agro-ecological profile of a zone, the soil-type categorization and historical production of indigenous crops in that area. Once a small holder farmer creates a profile on the system, the application picks the exact geo-coordinates of the farmer's location and continues to provide crop recommendations based on the ecological profile of the zone. The farmer in the case of this research is then presented with the ideal sorghum variant for production in that particular zone.

Objective 3: To build a knowledge management system prototype for indigenous crops production.

A knowledge management system for indigenous crops production was developed. The solution was developed based on the thematic analysis carried out on the pre-study responses. The prototyping approach is evolutionary in nature, allowing for continuous improvement of the prototype based on feedback and interaction with the end users.

Objective 4: To test the knowledge management system prototype

The researcher managed to present the developed prototype to potential end users for evaluation. The evaluation phase was primarily based on usability testing, to assess the general interactivity of the system by the users. Second level of testing was open ended, allowing the users to give feedback on whether the prototype had the functionality they needed.

5.3 Limitations

During the pre-study, it was quite difficult to identify the expert traditional farmers and to extract the knowledge that they had from them. Majority of the traditional crops farmers do not interact with extension officers who would have helped to easily identify these farmers. Traditional farmers tend to have a self-belief in their practice and for this reason rarely request for help from extension officers. As a result, the initial pre-study took longer than anticipated.

The prototype developed was only presented to a group of farmers and researchers who are involved in sorghum production. The long term goal of the research was to build a prototype that can be used by all categories of traditional farmers. This will mean extending the prototype to include other drought resistant crops defined as by the Ministry of Agriculture such as millet, green grams, cassava and sweet potatoes.

Small holder farmers typically do not keep farm records of any type, even in documented form in farm hand books provided by the Ministry of Agriculture via the agricultural extension officers. This meant that it was difficult for these farmers to trace historical information on previous crop cycles. At the most they would remember the most recent 2-3 crop cycles and then generalize the details for the previous cycles.

The mobile application developed was only made available on one platform, which is the windows mobile platform. In future, this will have to be ported to other platforms as well to allow more farmers to easily access the application.

5.4 Conclusion

Among the strategies being pursued towards Achieving food security is promotion of traditional crops production and utilisation. Sorghum has been identified by Kenya’s Ministry of Agriculture as one of the high value traditional crop that has enormous nutritional and industrial value. There is therefore need to scale these efforts and technology provides a platform to effectively grow awareness on improved production processes. The proposed solution also offers away of increasing interactivity between the different stakeholders on the sorghum production value chain and enhances cross-functional collaboration.

Most importantly, the solution provides a platform for supporting data driven decision making. The researchers will have access to data generated from hundreds of farms spread across different ecological zones helping them enhance the work that the do. These enhancements will then be translated to better production processes and approaches for the small holder sorghum farmers.

[This research brings to the fore the advancements made in introducing knowledge management systems for the production of exotic crops and investigates how to extend these advantages to indigenous crops farming.]

5.5 Recommendations

5.5.1 Improved Practice

The importance of ICT in any industrial production process, including agricultural production cannot be over-emphasised. There is great potential in the use of a knowledge management system for indigenous crops farming by small holder farmers. The first step in driving adoption of the solution is to have subsidizes for mobile devices for use in agriculture and specifically by small holder farmers. There is need for the policy makers to categorize mobile devices as essential farm inputs to allow for faster adoption of the application by small holder farmers.

There is also need for a strengthened push on agricultural e-extension, which will technologically empower extension officers and as a result they can act as agents of change to help drive adoption by the farmers they interact with.

Research institutions also need a renewed approach to research, especially in data aggregation beyond the controlled confines of the institutions themselves. The ability to collect, aggregate and analyse data from multiple farms on a real time basis can go a long way in improving current research work. It also provides decision makers with the ability to make informed, quick decisions on matters of crucial importance such as building national food reserves when there's the solution predicts drops in production.

5.5.2 Further Work

There is need to extend the solution to cover other indigenous crops. The scope should also be widened beyond drought resistance traditional crops to include crops which can grow in high-rainfall ecological zones such as traditional vegetables. This way the small holder farmers can have multiple options to choose from beyond sorghum to supplement the local diets. It also allows for a bigger push towards traditional crops which are less dependent on modern fertilizer and pesticides and can drive the push towards organic farming.

A lot of the farmers interviewed also expressed an interest to see the solution extended to cover market information as well. The scope of this research was however limited to the production process itself and therefore could not include market data. Future research should look at plugging the solution into existing market analysis solutions and pulling data deeds from these third-party platforms.

The long-term goal of the research is prove that IT supported traditional farming can help in the fight towards food insecurity in arid and semi-arid areas in Kenya. There is therefore need to carry out a long term evaluation of the system, to build enough data for supporting this assessment. This should preferably be driven by an agricultural research institution which will have the technical capacity to assess the data over a long period of time and continuously improve on the recommended production practices.

References

Alavi, M. & Leidner, D. E., 2001. Knowledge Management and Knowledge Management Systems: Conceptual Foundations. *MIS Quarterly,* 25(1), pp. 107-136.

Barbour, R. S., 2008. *Introducing Qualitative Research: A Student Guide to the Craft of Doing Qualitative Research.* London: Sage Publications Ltd.

Boer, H., 2015. *Continuous Improvement.* 10.1 ed. New York: John Wiley & Sons, Ltd..

Buschmann, F. et al., 1996. *Pattern-Oriented Software Architecture.* 1 ed. New York: Wiley Publishers.

Communications Authority of Kenya, 2015. *Quarterly Sector Statistics Report: SECOND QUARTER OF THE FINANCIAL YEAR 2014/15,* Nairobi: CAK.

Cong, X., Li-Hua, R. & Stonehouse, G., 2007. Knowledge management in the Chinese public sector: Empirical investigation. *Journal of Technology Management in China,,* 2(3), pp. 250-263.

Davenport, T. H. & Prusak, L., 2000. *Working Knowledge: How Organizations Handle What They Know. Harvard Business School Press.* 2nd ed. Massachusetts: Harvard Business Review Press.

Denscombe, M., 2007. *The Good Research Guide.* New York: McGraw-Hill Education.

Duhon, B., 1998. It's All in our Heads. *Inform,* Sep 12(8), pp. 8-13.

FAO, 1996. *World Food Summit 1996,* Rome: FAO.

FAO, 2015. *The State of Food Insecurity in the World 2015,* Rome: Food and Agriculture Organization of the United Nations.

Gallupe, R. B., 2000. *Knowledge Management Systems: Surveying the Landscape,* Kingston: Queen's University.

Glopolis, P. G. P. I., 2013. *Food Security and Agricultural Trade in Kenya,* Prague: Prague Global Policy Institute.

GoK, 2008. *Vision 2030, Popular Version,* Nairobi: Govertnment Press.

GoK, 2010. *Agricultural Sector Development Strategy,* Nairobi: Government Press.

Jacobson, I., Christerson, M., Jonsson, P. & Overgaard, G., 1992. *Object-Oriented Software Engineering: A Use Case Driven Approach.* 1 ed. New York: Addison-Wesley Professional.

Kamoni, N., Ombati, J. M. & Oywaya-Nkurumwa, A., 2013. Implementation of Njaa Marufuku Kenya intervention in Kajiado County and the implications for food security. *Academia Publishing,* 1(7), pp. 122-130.

KARI, 1999. *Towards Increased Use of Demand Driven Technology,* Nairobi: Kenya Agricultural Research Institute.

Kilongozi, N., Kengera, Z. & Leshongo, S., 2012. *The Utilization of Indigenous Knowledge in Range Management and Forage Plants for Improving Livestock Productivity and Food Security in the Maasai and Barbaig Communities,* Rome: FAO.

KNBS, AWSC, 2014. *Status Report on the Kenyan National Food Security,* Nairobi: University of Nairobi Press.

Kothari, C. R., 2006. *Research methodology: Methods & techniques.* New Delhi: New Age International Publishers.

McKenna, F., 2008. *A Knowledge Management System: A Discourse,* San Diego: KnowledgeOne Corporation.

Menoir, L., 2009. *ICT Update.* [Online]
Available at: http://ictupdate.cta.int/Feature-Articles/Farmers-teaching-farmers
[Accessed 05 07 2015].

Mitchell, R. & Boyle, B., 2010. Knowledge creation measurement methods. *Journal of Knowledge Management,* 14(1), pp. 67-82.

Nielsen, J., 1994. *Usability Engineering.* New York: Academic Press Inc.

Nonaka, I. & Takeuchi, H., 1995. *The Knowledge-creating Company.* New York: Oxford University Press.

Plummer, A. A., 2001. *Information systems methodology for building theory in health informatics: the argument for a structured approach to case study research.* Hawaii, 34th Hawaii International Conference on System Sciences.

Punch, K. F., 2005. *Introduction to Social Research–Quantitative & Qualitative Approaches.* London: Sage Publications Ltd.

Rajaonarison, H. M., 2014. Food and Human Security in Sub-Saharan Africa. *Procedia Environmental Sciences,* 20(1), pp. 377 - 385.

Rao, M., 2012. *Knowledge Management Tools and Techniques.* London: Routledge.

Ruggles, R., 1996. *Knowledge Management Tools.* 1st ed. London: Routledge.

Siew, S.-T., Alvin, W. Y. & Tariq, Z., 2013. *Participatory Action Research in Software Development.* 1st ed. s.l.:Springer Berlin Heidelberg.

Sommerville, I., 2010. *Software Engineering.* 9th ed. New York: Pearson.

Tiwana, A., 1999. *Knowledge Management Toolkit, The.* London: Prentice Hall.
UNDP, 2015. *UNDP in Kenya.* [Online]
Available at: http://www.ke.undp.org/content/kenya/en/home/countryinfo.html
[Accessed 10 06 2015].
Unhelkar, B. & Murugesan, S., 2010. The enterprise mobile applications development framework. *IT Professional,* 12(3), pp. 33-39.
WFP, 2015. *Kenya Food Security and Outcome Monitoring Report of May 2015,* Rome: World Food Programme.
World Bank, 1998. *World Development Report 1998/1999,* New York: Oxford University Press.
World Bank, 2012. *The Transformational Use of Information and Communication Technologies in Africa,* New York: World Bank.

Appendix

System Evaluation Questionnaire

Tick, mark or write as appropriate in the spaces provided.

Section A: Background Information

1. What is your role in the sorghum production process?
   Researcher [ ]
   Small holder farmer [ ]
   Contract farmer [ ]
   Extension Officer [ ]

2. How long have you been involved in the sorghum production process?
   Less than 3 years [ ]
   Between 3 and 5 years [ ]
   Between 5 and 10 years [ ]
   More than 10 years [ ]

Section B: Mobile Evaluation

1. How comfortable are you using a smartphone?
   Not comfortable [ ]
   Slightly comfortable [ ]
   Very comfortable [ ]

2. Which one would you prefer as a means of learning about sorghum farming?
   Radio Show [ ]
   TV Show [ ]
   SMS [ ]
   Product Brochure [ ]
   Smartphone Application [ ]

Section C: Functionality Evaluation

1. How easy was it for you to navigate through the application sections?
   Very difficult [ ]
   Difficult [ ]
   Easy [ ]
   Very Easy [ ]

2. Which language would you prefer to have on the application?
   English [ ]
   Swahili [ ]
   Vernacular [ ]

3. Would you consider using the application over an entire crop cycle?
   Yes [ ]
   No [ ]
   Maybe [ ]

4. Would you say the application has helped improve your level of understanding of sorghum farming?
   Not at all [ ]
   Slightly [ ]
   Very much [ ]

5. What functionality do you feel should be fixed or re-evaluated?

6. What information do you feel is missing and you would like to be added?

Code Samples

Getting a user's current location

```
private async void GetUserLocation2()
        {
            try
            {
                string bingMapsKey =
"Ap2PDL2GRAW8Ft4DxQ_30fUbeJk5Vvv4cIEt5qMNLNYRMHYt-3-8zhyjv3p4l7UJ";

                var geolocator = new Geolocator();
                geolocator.DesiredAccuracyInMeters = 100;
                Geoposition position = await geolocator.GetGeopositionAsync();

                string bingUrl = @"http://dev.virtualearth.net/REST/v1/Locations/" +
                    position.Coordinate.Latitude.ToString() + "," +
position.Coordinate.Longitude.ToString() + "?o=&key=" + bingMapsKey;

                var webClient = new HttpClient();
                var response = await webClient.GetAsync(bingUrl);
                var jsonResult = await response.Content.ReadAsStringAsync();

                CurrentUserLocation _userLocation =
JsonConvert.DeserializeObject<CurrentUserLocation>(jsonResult);

                /// here also it should be checked if there result isn't null and what
to do in such a case
                if (_userLocation != null)
                {
                    txtLocation.Text =
_userLocation.resourceSets[0].resources[0].address.locality + ", " +
_userLocation.resourceSets[0].resources[0].address.countryRegion.ToUpper();


Windows.Storage.ApplicationData.Current.LocalSettings.Values["Town"] =
_userLocation.resourceSets[0].resources[0].address.locality;

Windows.Storage.ApplicationData.Current.LocalSettings.Values["Country"] =
_userLocation.resourceSets[0].resources[0].address.countryRegion;
                }
                prgWeather.IsActive = false;
            }
            catch (Exception locEx)
            {
                string errMsg = locEx.Message;
            }
        }
```

Crop Information Base Class

```
namespace ProjectApp.Models
{
    public class CropInfo
    {
        public int Id { get; set; }
        public string Name { get; set; }

        public ObservableCollection<CropVariety> CropVarieties { get; set; }
        public ObservableCollection<TrainingContent> TrainingMaterial { get; set; }
```

```
    }
    public class CropVariety
    {
        public int Id { get; set; }
        public string CropId { get; set; }
        public string RefName { get; set; }
        public string Brief { get; set; }
        public string Description { get; set; }
        public string ImageUrl { get; set; }
        public ObservableCollection<CropCycle> CropCycles { get; set; }
    }
    public class CropCycle
    {
        public int Id { get; set; }
        public string Description { get; set; }
        public int Duration { get; set; }
        public ObservableCollection<CropCycleActivity> Activities { get; set; }
        public ObservableCollection<TrainingContent> TrainingMaterial { get; set; }
    }
    public class CropCycleActivity
    {
        public int Id { get; set; }
        public int CycleOrder { get; set; }
        public string Activity { get; set; }
        public string Description { get; set; }
        public CropCycle BaseCycle { get; set; }
    }
    public class TrainingContent
    {
        public int Id { get; set; }

        public string Type { get; set; }
        public string Category { get; set; }
        public string Title { get; set; }
        public string Description { get; set; }
        public string Url { get; set; }
    }
}
```

Daily Record Base Class

```
public class DailyRecord
    {
        public string id { get; set; }
        public DateTime recorddate { get; set; }
        public FarmTask task1 { get; set; }
        public FarmTask task2 { get; set; }
        public FarmTask task3 { get; set; }
        public string notes { get; set; }
    }
    public class FarmTask
    {
        public int id { get; set; }
        public string task { get; set; }
    }
```