School of Computing and Informatics

University of Nairobi

A TRACEABILITY SYSTEM FOR CONTRACTED OUTGROWER SCHEMES: THE CASE OF FRENCH BEAN SMALLHOLDER FARMERS IN KIRINYAGA COUNTY

STEPHEN EBICHONDO IMENJE

P56/71985/2008

SUPERVISOR

DR. ROBERT OBOKO

A research report submitted in partial fulfilment for the requirement of Master of Science in Degree Information Systems Degree of the University of Nairobi.

2015

ACKNOWLEDGEMENT

I would like to thank my wife Lucy, for her encouragement, her support and for sacrificing the countless evenings and weekends to enable me to complete this research.

I'd like to pay a special tribute to Dr. Robert Oboko, first for being willing to enter into detailed conversations about all kinds of topics while I was conceptualising my research topic around traceability systems, and second for critiquing all the initial research ideas and finally for agreeing to supervise this research. I couldn't have asked for a more knowledgeable and thorough supervisor, Dr. Oboko is an authority on matters ICT for development within the region and beyond.

I would also like to thank my boss, Mr. Jack Ngare, for the endless support accorded in the various stages of the project.

Finally to my parents Mr. and Mrs. Imenje without them it goes without saying, none of this would have been possible.

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.

Student Name:

Stephen Ebichondo Imenje Signature _____ Date _____

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

Dr. Robert Oboko Signature _____ Date _____

ABSTRACT

Many African countries have moved into the production of non-traditional agricultural products, in an effort to diversify their exports and increase foreign currency earnings. However, in order to access developed country markets and urban domestic markets, these products must meet food safety requirements, including protocols relating to pesticide residues, field and pack house operations, and traceability. Faced with stringent food safety requirements, companies that establish production centres in low-income countries might exclude smallholder farmers. For instance, export demand for Kenyan French bean recently dropped suddenly by 25 per cent when the World Trade Organization put Kenya on the watch list due to high pesticide residue levels. Due to this, exporters stopped buying from about 50,000 smallholder farmers.

This research proposed a mobile-phone based traceability system to make it easier for exporters to work with smallholder farmers in outgrower schemes to enable better quality control and avoid such disruptions in future. To do this, a pre study was conducted as a part of an exploratory study in order to understand the main issues of the overall traceability concept and the specifics of pesticide residue excesses detected in Kenyan fresh produce to the European Union (EU). From these findings, early requirements were derived and an initial functional prototype derived using Object Oriented Design (OOD) methodology. The Unified Modelling Language (UML) which is an object oriented language for specifying, visualising, constructing, and documenting the artefacts of software systems was used to develop a requirements model. After validation of the requirements, an end-to-end prototype application system that traces all the farming activities by using a mobile application to capture the information of farming operations was developed. The mobile application was deployed to six farmers from two different farmers' French bean grower groups in Kirinyaga. They were trained on how to use the system to capture data and interpret the results from the system. The results of the usability evaluation of the system show that tracing all activities involved in the growing cycle of horticultural crops and GlobalGAP related information is improved by simple and user friendly system.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

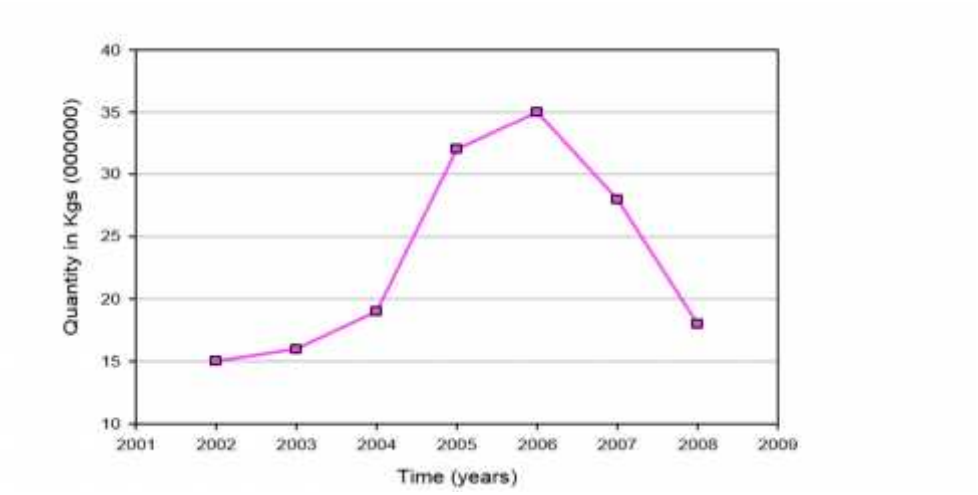
1.1 Background

Fruits and vegetables have some of the fastest growing agricultural markets in developing countries with production increasing by 3.6 and 5.5 percent per annum respectively over the 1980-2006 period (World Bank, 2008). During this period, China had the greatest increase of horticultural production (58%) followed by other developing countries (38%) and the remaining 4% came from developed countries. This shows that the boom in horticulture is mainly occurring in developing countries. In India, fruits and vegetables were the most important growth sector for crop production in the 1990's (World Bank, 2008).

Sub-Saharan African countries have not been left behind. To reduce poverty and achieve higher rates of growth, they have diversified their export portfolio away from primary commodities like coffee, tea and cocoa into non-traditional exports with more propitious market trends (Asfaw et al., 2007). Empirical literature pinpoints the success of horticulture in Kenya, Ghana, South Africa, Egypt and Morocco. In these countries, horticulture or high value crops have contributed to increased rural incomes and reduced rural poverty, through both direct production effects and linkage effects, as horticultural incomes are re-spent in rural areas (Muriithi, 2008).

The agricultural sector is crucial in the Kenyan economy as it provides a source of livelihood to majority of the population. The sector provides food, raw materials, employment, markets and foreign exchange. It accounts for 24% of Gross Domestic Product (GoK, 2009). The majority of the population resides in the rural areas and depends on agriculture as a source of livelihood directly through farming or indirectly through employment in agro-processing and rural industries. Hence the sector is essential for poverty reduction and increased food security which lead to development. Horticulture is the fastest growing agricultural sector in Kenya and is a major foreign exchange earner. It is the country's most important foreign exchange earner in the agricultural sector (GoK, 2009). The main export crops are cut flowers, fresh fruits and vegetables. Large-scale producers mainly grow the cut flowers while medium scale and smallholder farmers dominate in production of fresh fruits and vegetables. Frozen and fresh beans are one of the most important vegetable exports from Kenya. The quantity

of beans exported have been increasing over time but slowed down in 2006 when it was mandatory for all horticultural produce exported to the European market to be compliant with food safety standards in that market as evident in Figure 1 below.



Source: United Nations Trade Statistics

Figure 1 : Export quantities of Kenyan frozen French beans

Kenya has been one of the developing world's most successful exporters of fresh vegetables to the European Union. The country has a comparative advantage in horticulture production due to good rainfall, terrain, soils and cheap labour. This explains the highly acclaimed success of horticulture in Kenya (Minot and Ngigi, 2004). The country's location near the equator allows it to grow these crops all year round giving it a competitive advantage over other producing countries like Egypt, Zambia, Ghana and Morocco. This translates to a horticultural boom for Kenya given the horticulture revolution by consumers in developed countries markets.

French beans constitute the greatest majority of exported fresh vegetables. They are a highly asset specific vegetable mainly grown for export. They are grown by both large-scale and small scale farmers in various parts of the country. The dominant growing regions are Central and Eastern provinces. French beans are graded according to size and shape. Food safety standards (FSS) require that the beans are not infected by

insects. The beans are packed in boxes in extra-fine and fine grades and shipped by air mainly to Europe. Value addition to the beans involves washing, chopping, packing and labelling. The beans can be packed with other produce like carrots, baby corn, leeks broccoli and cauliflower to create a convenience ready to cook dish (Mbithi, 2008).

The major markets are European countries with the Netherlands and the UK being the dominant buyers. According to the Horticultural Crops Development Authority (2007), the country's exports of fine and extra fine beans were 13,668,330 and 9,635,128 kilograms respectively. These were mainly exported as fresh and canned French beans. Smallholders play an important role in production of French beans for export. Kenya's French bean industry started in the colonial era when colonialists exported this product to their home countries. The practice still continued post-independence and expanded rapidly in the 1970's and 1980's.

However, the expansion in trade plummeted in the 1990s due to imposition of international FSS in western countries. The industry has since recovered and even increased its volume of exports (McCulloch and Ota, 2006; Okello et al., 2008). However, due to the strict requirements of complying with the standards, some farmers have exited production of the crop while others prefer to grow without complying and sell in the local markets.

Food safety has become an issue of concern over the last few decades and this has resulted to major changes in the food and agriculture sector. The most prominent change has been the shift from traditional export crops to high value crops with stringent agronomic and processing practices. The increase in these high value crops is attributed to several reasons namely: agricultural reforms and liberalization of trade policies, increased market access, privatization and high prices which serve as a production incentive. In addition, there are changing consumer preferences due to increased incomes, health awareness and changes in dietary habits (Prema -Chandra et al., 2003; Dolan and Humphrey, 2004).

The increasing concern on food and environmental safety by European consumers led to the passing of the United Kingdom food safety Act in 1991, which obliged food retailers to demonstrate "due diligence" to ensure safety of food. Hence, the responsibility of assuring food safety shifted from the public sector to private food retailers and farmers (Okello, 2006).

Supermarkets have therefore become much more involved in imposing requirements on how food is to be produced throughout the commodity supply chain, even to the degree of monitoring and controlling horticultural production in developing countries like Kenya (Dolan et al., 2000,; Humphrey, 2008). They have put in place rigorous food production and handling rules which must be strictly adhered to throughout the food supply chain. The new regulations on product traceability and high standards of social and environmental compliance as detailed in the Global Good Agricultural Practice (GlobalGAP) standards have stimulated the reorganization and development of institutional framework to govern production and marketing of fresh fruits and vegetables.

The institutionalization of FSS especially in developed country markets is attributed to several reasons. First increased awareness of food safety risks particularly those associated with imports originating from developing countries has prompted food retailers to impose standards on food production and handling. This was evident when E.coli was detected in hamburger meat in the U.S, dioxin in poultry meat, Salmonella in eggs and cholera causing organisms in imported fish from East Africa (Spencer and Mitullah, 2004). Secondly, FSS are seen as a way of brand protection by firms. Compliance with FSS reassures consumers on the safety of the food they purchase thereby protecting the retailer's reputation. They also shield retailers from liability in the case of food risks. Thirdly, food retailing in the western countries is highly oligopolistic with a few retailers controlling a large part of the market share thereby giving them power to impose any requirements they want on suppliers and producers. Hence the highly buyer driven FSS witnessed in international food markets (Ignacio, 2007). Fourthly, there are major and increasing changes in governance and regulation of markets. This has led to reduced public control and increased private control of market operations which in turn has led to the amplification of private FSS. Lastly, intensified globalization and trade liberalization has escalated food diversity in global markets. Traceability of the origin of all the food stuffs, especially with food scares like mad cow and salmonella, therefore becomes problematic for the public sectors. Hence the private sector is accorded the duty of ensuring the safety of the food they vend. This is the so called "due diligence requirement" for food retailers (Eaton et al. 2008).

The GlobalGAP standards formerly known as the Euro Retailer Produce Working Group on Good Agricultural Practices (EurepGap) is the most widely known example of a common international food standard (McCulloch and Ota, 2006). Though a private and voluntary standard, it is regarded as a condition of entry to European markets and does not provide price premiums. It was originally initiated in 1997 by retailers belonging to the Euro-Retailer Produce Working Group (EUREP) and developed into an equal partnership of agricultural producers and their retail customers. The aim was to develop widely accepted standards and procedures for the global certification of Good Agricultural Practices (GAP). The development of GlobalGAP was driven by the desire by retailers and producers to reassure their consumers of food safety following scares such as mad cow diseases (BSE) and foot-and-mouth epidemic in the U.K (Frohberg et al., 2006). Other concerns include pesticide levels in food products and the rapid introduction of genetically modified foods (Minot and Ngigi, 2004; Asfaw et al., undated). The GlobalGAP protocol has 250 rules or control points. The goal of this protocol is to provide the tools that objectively verify best good agricultural practices to reduce the risk in agricultural production in a systematic and consistent way throughout the world (Spencer and
Loader, 1999).

Farmers have two options with which to comply with the standards: individually or in groups. They are required to observe hygiene in food handling and to strictly follow outlined agronomic and food processing practices. To be compliant, farmers are required to: adopt alternative ways of managing pests, implement safer ways of handling, storing and disposing pesticides, set up hygienic packing conditions, and establish a traceability system. These standards require that food products meet prescribed pesticide residue levels and care be taken by farmers to reduce exposure of farm workers and other non-target plant and animals to pesticides (Spencer and Jaffee, 2007). Emphasis is placed on consumer safety by using only approved (less toxic) pesticides and strict observance of the pre-harvest interval which prescribes the latest date for pesticide use for ensuring safe residue levels. Farm worker safety especially safe handling, storage of pesticides and disposal, and the use of protective devices and alternative pest management practices is also stressed. This implies switching to new and safer but more costly pesticides, investing in assets such as grading sheds, charcoal

coolers, pesticide disposal pits and pesticide storage area along with keeping technical records of pesticide use and application (Okello, 2006). Failure to comply with these set standards leads to loss of incomes for farmers hence compliance is necessary to ensure market access

1.2 Problem Statement

Kenya's fresh produce industry has been facing a series of challenges among them increased interceptions involving pesticide residue excesses detected in some of its exports to the EU, Kenya's leading market for fresh produce. Most of the fresh fruits and vegetables from Kenya target the European market. However, the high cost of implementation of the private-sector food-safety standards set by the European Union (EU) retailers, for example EurepGap, present a major challenge especially to smallholder exporters. The standards have increasingly become a major determinant of access to markets in the developed countries. Lack of implementation of these standards might lead to the exclusion of smallholder farmers from the international market and related market income-earning capabilities and hence worsening the welfare of rural households.

1.3 Objectives of the Research

1. To analyse and establish gaps in the current traceability systems among smallholder farmers in outgrower schemes within Kirinyaga.
2. To develop a prototype system for collecting information to enhance traceability along the value chain
3. To develop a mobile app that will allow for offline capture in areas without mobile network coverage and allow for synchronization of the same when a field staff gets to a network enabled area.
4. To incorporate GPS coordinates capture in the field to allow for accurate data capture in the respective farm blocks.
5. To simplify the audit process by allowing for digital capture of all the GLOBALG.A.P required production information with real-time alerts of non-compliant activities thereby saving time that would have been spent collating information from farmers' paper based records.
6. To evaluate the system in terms of speed, efficiency, usability, accuracy, and operator satisfaction.

1.4 Overall Research Question

1. What are the necessary requirements for the implementation of a traceability system for managing smallholder farmers in outgrower schemes?
2. Will the system developed provide a holistic pathway for tracing all activities involved in the growing cycle of French beans and GlobalGap related information via real-time monitoring and tracking system?

1.5 Significance of the Research

This system will make it easier for exporters to work with smallholder farmers. It will make certain that the exporters contracted by overseas chain stores to supply fresh fruits and vegetables are assured of consistent good quality produce, fair transaction costs and most importantly traceability by the smallholder farmers.

Through real-time monitoring and tracking, the proposed system will provide a holistic pathway for tracing all activities involved in the growing cycle of horticultural crops and GlobalGap related information. This will facilitate the connection of smallholder farmers to lucrative international markets, giving them an opportunity to earn a stable income. Using the platform it will be possible for small farmers to meet safety requisites, compliance, social and sustainability standards which many a times lock these smallholder farmers from external markets.

This system could be used by horticultural exporters such as Kenya Horticultural Exporters (KHE) who recruit smallholder farmers to produce for export. Whenever there is a problem such as contravention of Maximum Residue Levels (MRLs) the exporter then incurs losses, which are channelled down the whole export value chain.

This system will build the capacity of farmers and government agencies to adopt innovative technologies and traceability best practices while minimising the risk profile of Kenya as a source of safe high quality produce.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Food chain traceability refers to "the ability to follow a food component intended to be, or expected to be into a food product through all stages of food supply chain" (European Commission, 2002). The definition and implementation of a food traceability system depends on both the SC and the relationships between the various partners which collaborate in the production process. Manufacturers, distributors, authorities and consumers should be able to track and identify food and raw materials used for food production to comply with legislation and to meet the requirements of food safety and food quality (Ruiz-Garcia et al., 2010). This result can be conveniently achieved if each company along the SC is able to adopt a system of internal control and recording (internal traceability) and if the transitions between the actors involved are regulated and managed in a coherent and shared way. The food SC is a complex structure formed by different actors that contribute to the production, distribution, marketing and supply of a food product.

As defined by Gandino et al. (2009), a typical food SC consists of five basic entities: the producer, the processing company, the distributor, the retailer and the carrier. Each actor performs a specific task. The producer cultivates agricultural products and sells them to the processing company; the processing company transforms the raw materials; the distributor handles the food commodities; the retailer sells food directly to the consumer; the carrier moves the food products from a company to company. The presence of these actors highlights that the concept of food chain is extended both to the individuals upstream and downstream in the SC. In order to guarantee total food traceability, each actor must collaborate and share information in a coherent and shared form. In such a context it is possible to trace the path followed by a food product from "farm to fork". Compared to other supply chains, the time taken from manufacture of raw materials to consumption of the final products remains relatively shorter in food supply chain (Nishantha et al., 2010).

Food products, in fact, are extremely time critical and, by their nature, they characterized by a short shelf. Food products are perishable and their shelf life is conditioned by the harvesting means, transformation processes, transporting ways,

and storage conditions. This aspects, along with the wide variety of food products, contribute to making more difficult the design, implementation, and management of an efficient system of traceability (De Cindio et al., 2012).

2.2 Principles of traceability

Several published studies describing principles of traceability in the food industry and other industries have been found. In the below sections, different views of traceability are described.

According to Kim, Fox, and Gruninger (1995), traceable resource unit (TRU) is the name given to an entity that is traceable. TRUs are entities with similar characteristics that have gone through the same processes. Traceability is based on a clearly defined relationship between these units.

Moe (1998) follows this approach, but specifically points out that traceability is based on unique identification of the products. Identifying TRUs and activities is necessary in order to trace a product. TRUs can be described according to weight, volume, etc., and activities can be described according to type and time/duration, such as processing, transportation and storage.

Storey et al. (2008) take a similar view of traceability, but describe it in more detail. They state that trade units must be uniquely identified, that additional information must be linked to these units via the unique identification number, and that all transformations (split and joins) must be recorded. Trans- formations are points where the resources are mixed, transferred, added, and/or split up (Derrick & Dillon, 2004). The relationships between traceable units can be one-to-one, many-to-one, one-to- many or many-to-many. Identifying traceable units and trans- formation relationships is the key to tracing a product internally and/or in supply chains (Storey et al., 2008). Product information can be linked to the identification number of traceable units.

This is line with the TraceFish standards (CEN, 2003a, 2003b), ISO-12875:2011 (2011), ISO-12877:2011 (2011) and the TraceFood framework (2012): Prerequisites for achieving traceability are unique identification of traceable units and records of transformations. The TraceFish standards are specifications of the information to be recorded in captured fish and farmed fish distribution chains, and TraceFood is a

framework comprising principles, standards, and methods for implementing traceability in the food industry. The TraceFood framework (2012) divides traceable units into 1) batch, 2) trade unit (TU), and 3) logistic unit (LU): A batch is "...a quantity that has gone through the same process at a specific place and time period before moving to another place. A production batch is the traceable unit that raw materials and ingredients go into before they are transformed into products placed in new Trade Units and Logistic Units", a trade unit is "....the smallest traceable unit that is exchanged between two parties in the supply chain', and a logistic unit is "...the smallest traceable unit that is exchanged between two parties in the supply chain".

According to Opara (2003), traceability consists of six elements:

1. Product traceability - which determines the physical location of a product
2. Process traceability - which ascertains the type and sequences of activities that have affected the product
3. Genetic traceability - which determines the genetic constitution of the product
4. Input traceability - which determines the type and origin of inputs
5. Disease and pest traceability - which traces the epidemiology of pests and biotic hazards
6. Measurement traceability - which relates individual measurements results through an unbroken chain of calibrations to accepted reference standards). 'Process traceability' is to some degree similar to 'activity', as defined by Moe (1998).

Moe (1998) did not include input, hazards, or measurements in her model. Bianchi, Fasolino, and Visaggio (2000) have yet another view of traceability. They divide traceability into three dimensions:

1. Vertical and horizontal traceability - whether the interconnection between items is in the same software model or in different models
2. Explicit or implicit links - types of links between items and
3. Structural or cognitive links - more detail description of the implicit link.

The focus here is software maintenance and trace- ability model comprehension. It is clear that this view of trace- ability is quite different to the other descriptions of traceability. The similarity of these views, however, is that the links between the 'Zs' must

be traceable. 'Z' can, for example, be a product or a class in a Unified Modeling Language (UML) class diagram.

2.3 Related Works on Food Traceability

In recent years traceability has attracted the attention of industry, public authorities and researchers. The increasing interest of the scientific community in the research area about SC traceability is the result of many developments aimed at improving food quality and safety management (Opara, 2003).

The relevance of product tracing in both the external supply chain and inside the production system has been underlined by Stein (1990) and Ramesh et al. (1995). Fundamental concepts related to traceability have been well defined by Kim et al. (1995) and Moe, (1998). Kim et al. describe the fundamental and necessary core in ideal traceability systems as the ability to trace both products and activities. Products and activities are called core entities, an entity being what can be individually considered (European Committee for standardization, 1995). They use the Traceable Resource Unit (TRU) to identify production batch. Moe (1998) has introduced the concept of traceable resource unit (TRU) for batch processes as "unique unit, meaning that no other unit can have exactly the same, or comparable, characteristics from the point of view of traceability". Important concepts in food traceability are the "batch dispersion" (Dupuy et al., 2005) or also so called "transformation" (Ridden &Bollen, 2007) and the "risk transmission" (Hu et al., 2009).

A general method for modelling and optimizing traceability systems in food industry is proposed by Dupuy et al. (2002) and Dupuy et al. (2005). Bollen, Riden, and Cox (2007) and Riden and Bollen (2007) studied and analysed the traceability in fruit supply chains in order to improve the traceability control of the batches. The traceable information flow and risk transmission throughout food supply which contains raw material, process and distribution have been studied by Hu et al. (2009). They take into consideration the research work of Dupuy el al. (2002) and propose a graphical model to describe the risk transference problem, according to Gozinto graphs which proposed by Dorp (2003). In the recent past the development of traceability systems in the food Supply chain has interested several author (Jansen-Vullers et al. (2003); Regattieri et al.

(2007); Bechini et al. (2008); Takur and Hurburgh (2009); Thakur and Donnelly (2010); Thakur et al. (2011,a); Thakur et al. (2011, b); Bevilacqua et al. (2009); Ruiz- Garcia et al. (2010); Verdouw et al. (2010)). Some examples follow in the next lines. Jansen-Vullers et al. (2003) propose a reference-data model for tracking and tracing goods based on the Gozinto Graph, a tree-like graphical representation of raw materials parts, intermediates and subassemblies, in which a particular production process transforms into an end product through a sequence of operations.

The development of the reference data model is described by explaining the model-part of the bill of lots and/or batches, the model-part of operations and variables and the integration of these two model-parts. The bill of lots is designed analogous to the bill of materials and registers each relation between a sub-ordinate entity and super-ordinate entity via the concept of aggregation. Aggregation is an abstract concept for building composite objects from their component objects (Elmasri & Navathe, 2000). Regattieri et al. (2007) developed a traceability system for Parmigiano Reggiano, the famous Italian cheese, and introduced a general framework based on the integration of alphanumeric codes and RFID. The product characteristics are identified in their different aspects along the entire supply chain, from the bovine farm, the dairy, the seasoning warehouse, and lastly the packaging factory. The complete supply chain of Parmigiano Reggiano is traced by an RFID system using an alphanumerical code. Technically the system developed is based on a central database that collects data from bovine farms and from dairies. Manufacturers can check the progress made in production at any time and if some problem occurs in the market place they can re-trace the development of the portion and introduce effective re-call strategies. Bechini et al. (2008) introduce a data model for identifying assets and actors and show a formal description of the lot behaviour throughout the supply chain.

The lot behaviour has been modelled by six activity patterns (integration, division, alteration, movement, acquisition, providing) using a UML activity diagram. The standard Unified Modelling Language (UML) notation is adopted to formally describe the different aspects of the modelled system. The model of a simply cheese supply chain with a UML communication diagram is presented in the paper. An independent, private data-sharing network (PDSNs) is proposed as proper infrastructure for business process integration and Enterprise Service Bus (ESB) as architectural scheme for

connecting third party applications. The ebXML Message Service (ebMS) is used to transport business documents in a secure, reliable, and recoverable way in the inter-enterprise business collaboration scenario. In case one of the business partners cannot manage ebMS messages (for instance, in the case of legacy systems), the communication is handled via ESB. A model for implementing internal traceability system for a grain elevator has been developed by Takur and Harburg (2009) and extended by Thakur et al. (2011,a). In the first reference a UML sequence diagram shows the information while the UML (Unified Model language) Use Case diagram technique defines the usage requirements of the traceability system. The internal traceability system is developed using the Integrated Definition Modelling (IDEF0) and the lot information is recorded in a RDBMS (Relational Database Management System) form presented in Thakur et al. (2011,a). Thakur and Donnelly (2010) present a new model for information capturing in the soybean SC and develop a UML class diagram for modelling products, processes, quality and transformed information. The UML state charts and EPCIS framework are presented by Thakur et al. (2011, b) as a new methodology for modelling traceability information. EPCIS is an EPC global standard designed to enable EPC-related data sharing within and across enterprises. The model presented is used for mapping of food production processes to provide improved description and integration of traceability information. The method follows the approach of defining states and transitions in food production. A generic state charts for food production is presented and applied to two supply chains; pelagic fish and grain. A state- transition model with emphasis on identifying both traceability transitions and food safety and quality data is developed.

The application of current EPCIS framework for managing food traceability information is presented by mapping the transitions identified in two product chains to the EPCIS events: Object Event and Aggregation Event. The corresponding states where the quality parameters are recorded are also identified and linked to these EPCIS events. The review of the previous references shows that although many authors have been interested in the traceability issue, at the present time there are no works that completely integrate the process flow chart model of the SC with the data model for managing the data required for traceability and automatically generate a web application useful for data track and trace. Moreover, those papers where a web model

is presented are limited. Bevilacqua et al. (2009) use the business process reengineering (BPR) approach to create a computer-based system for the management of the supply chain traceability information flows. They present a computer-based system for the traceability of fourth range vegetables. They use the Event-Driven Process Chains (EPCs) technique to model the business processes. To ensure the traceability, each single unit or lot of the food products has been uniquely identified combining global trade item number GTIN (GS1 traceability, 2006) and the lot code. The business processes database generate follows the Entity Relationship Model (ERM). In the paper, moreover, the data model is not presented, and the front-and generated using the software ARIS is only discussed. Ruiz-Garcia et al. (2010) present a web-based system to process, save and transfer data for tracking and tracing agricultural batch products along the supply chain. The development of the prototype involved the integration of several information technologies and protocols. The tracking system is based on a service- oriented architecture (SOA) and the communication is through messages in XML. Moreover, the work not deals with the problem of process and data modelling. In addition, there are only few authors who use the BPMN standard for process modelling. Referring to the food sector, only Verdouw et al. (2010) modelled the SC of fresh fruit using the BPMN standard to model the business process diagrams.

2.6 The Gap

In general, the following are the two approaches to building systems to achieve traceability in the supply chain Leopoulos D. et al. (2006) and Z. Panian (2005):

1. Centralized traceability systems

   In this case, traceability information is centrally managed in a shared database. Also, each firm and involved person performs tasks -- such as adding, updating and searching history information --primarily via the internet, based on fixed rules (e.g. Access privileges). One example of this type is the search service for central management of traceability information (register) relating to individual identification of cattle throughout Japan.
2. Distributed traceability systems

In this case, traceability information is saved or managed in a distributed fashion as the responsibility of each company, and needed data is transferred or exchanged primarily using EDI systems. As a rule, firms use the "one step forward, one step backward" system where each company positioned in a supply chain provides traceability information one step forward from itself, and can track information one step backward from itself. This approach is typically seen in industries such as household appliances and processed food. In particular, the latter distributed type is expected to expand in the future as the mainstream type of traceability system. In this sense, it is expected that there will be a growing role for EDI systems, which have previously developed as the technological infrastructure for sharing information between companies.

However, with either type of system, small and medium enterprises are faced with a large cost burden for adopting/operating a traceability system, and it is also difficult for them to secure adequate staff with the requisite technical capabilities. Yasuo Uchida et al. (2005).

Smallholder farmers face a number of issues such as bearing the costs of adopting and operating a traceability system, and securing staff having the applicable skills.

2.7 The Proposed Solution

This research proposes a system which holds down adoption costs and reduces the burden of operation and management by building the system on foundation of open source software and hosting the database on the Microsoft Azure Cloud. The rise of mobile phone technology provides potential for narrowing of digital divide among farmers. Data is always available for easy access through mobile devices. With the advent of the low-cost 3G Android smart phones and netbooks with mobile data capabilities, farmers can have access to state-of-the art infrastructure. Greater use of technology should result in a reduction in environmental impact due to reduction in external input. The system will make it easier for exporters to work with smallholder farmers by making sure that the exporters contracted by overseas chain stores to supply fresh fruits and vegetables are assured of consistent good quality produce, fair transaction costs and most importantly traceability by the smallholder famers.

Android smart phones will enable real-time monitoring and tracking which will provide a holistic pathway for tracing all activities involved in the growing cycle of horticultural crops and GlobalGAP related information. The mobile app shall capture data on disease, pest detection, the prescribed chemicals and comparison of inputs used against warehouse stock levels. In addition to the maximum dose per hectare, application date, pre-harvest interval (PHI), spray application interval, target pests, yield forecast, environmental hazards, clearance dates for each of the farmer's block, the specific sprayer and personnel for each operation.

The data in the field will be captured using mobile device and then synchronised and posted to the hosted online database which will be accessible by all actors in the supply chain. The mobile application will be used to capture data will work both offline and online. Data will be captured even in areas without mobile network coverage and when one gets in a network enabled area, they will be able to synchronize the captured information as show in Figure 2.

There is also a common problem in the industry of field officers avoiding going to the field thus giving wrong information and non-existent farmers to show they have been working. With the proposed system, there will be no room for this as all the stakeholders will be able to look at the website and immediately see which information is being captured for which farmers and with the exact location of where the farm is located using GPS functionality of the mobile device. With the captured farmers' profiles, exporters will be better placed to manage the smallholder.

2.8 The Proposed Architecture

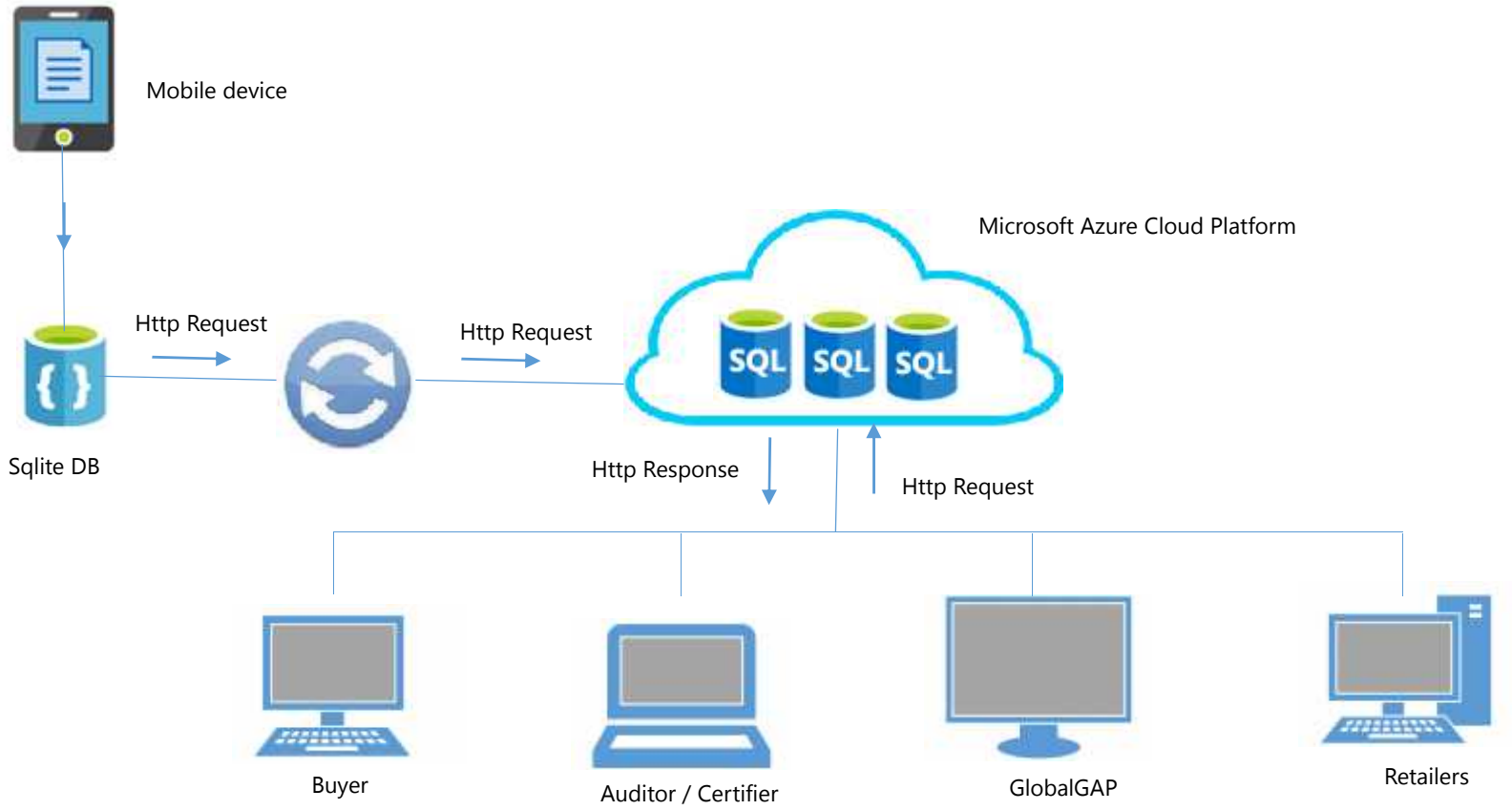


Figure 2: The proposed architecture

CHAPTER THREE: METHODOLOGY

3.1 Introduction

The goal of research methodology was to provide a standard method and guidelines to ensure that project was completed on time and conducted in a disciplined, well-managed, and consistent manner that promotes the delivery of quality product and results. This section presents an overview of the methods used in the study, to begin with the researcher elaborates how the pre-study was conducted and explains how interviews were conducted and data collected.

3.2 Research Approach

A pre-study was carried out with the intention of doing an exploratory study on the first research question RQ1 (What are the necessary requirements for the implementation of a traceability system for managing smallholder farmers in outgrower schemes?). The researcher had to understand the main issues of the overall traceability concept and the specifics of the pesticide residue excesses detected in Kenyan fresh produce export to the EU. The pre-study gathered first insights into the field and identified problems and peculiarities around traceability. From these findings, early requirements were derived and an initial functional prototype proposed. The pre-study is based on participatory action research and encompasses participatory observation and note taking, informal as well as semi structured interviews and video analyses. Notes taken from memory supplemented the insitu. In this case, semi structured interviews were used to collect the information needed. In this particular study, the main thrust of the research consisted of interviews with the various stakeholders to ensure that fresh produce producers capacity to meet the market and regulatory food safety requirements and traceability in Kenya.

3.3 Qualitative Research

Qualitative research is concerned with depth rather than breath of information and "the exploration of complex and subtle phenomena" (Denscombe, 2007 p.174; Punch, 2005). It is concerned with the who, the why and the how: the processes the occur within the context of people's everyday lives and the lived experiences of the research participants. 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). In this research project, the researcher opted to use semi-structured interviews in gathering the data required. The researcher identified key informant through purposive typical case selection with the aim of diversity across the value chain. 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). According to Punch, purposive sampling is "sampling in a deliberate way, with some purpose function in mind" (2005, p.187). Participants are deliberately chosen because of the data they will be able to produce. It was felt that these participants could add valuable insights and contribute to a greater understanding of this complex phenomenon.

3.4 Interview Design

The researcher opted to use 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 allows 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).

Interviews were conducted one-on-one. This format was chosen over group interviews as the research topic was quite sensitive and personal one for some participants and the researcher felt that participants were more likely to speak openly and frankly if they were not in a group setting. Questions tended to be more open-ended in nature to

allow the participant to speak freely about his/her experiences. According to Descombe, open-ended questions produce answers that are more likely to "reflect the richness and complexity of the views held by the respondent" (2007, p.166).

3.5 Sampling

Using a stratified purposive approach the researcher identified the key informants. Stratified Purposeful Sampling is a method that involves the division of a population into smaller groups known as strata. The strata are formed based on the attributes or characteristics of the members as shown table 1 below. The purpose of a stratified purposeful sample is to capture major variations rather than to identify a common core, although the latter may also emerge in the analysis. Each of the strata would constitute a fairly homogeneous sample. This strategy differs from stratified random sampling in that the sample sizes are likely to be too small for generalization or statistical (Patton, M., 1990).

Table 1: Sampling and sample size of the traceability stakeholders

Stratum	Stakeholder Type	Total Members
1	Exporters	30
2	Auditors	3
3	Smallholder farmer groups	5
4	Industry Regulatory Agencies	5
5	Government Regulatory Agencies	4
6	Government bodies	4
7	Researchers	8
8	Traceability System Vendors	3

The selection of key informants was purposive by targeting the different heads of departments that deal with traceability issues directly. Table 2 below shows the key informants that were selected purposively.

Table 2: Key Informant Information

Stakeholder type	Institution	Informant	Role
Exporters	Kenya Horticultural Exporters (KHE)	Mwangi	Operations Manager
Auditors	AfriCert	Ram Amunga	Auditor
Smallholder farmer groups	Romwa Ventures	Kariuki	Farmer
Industry Regulatory Agencies	Fresh Produce Exporters Association of Kenya (FPEAK)	Dr Stephen Mbithi	CEO
Government Regulatory Agencies	Kenya Plant Health Inspectorate Service (KEPHIS)	John Kigwama	Chief Inspector
Government Regulatory Agencies	Horticulture Crops Development Authority (HCDA)	Zachayo Magara	Acting Director
Researchers	Jomoo Kenyattta University of Agriculture and Technology (JKUAT)	Dr. Florence Mwaura	Deputy Director
Traceability System Vendors	FarmForce	George Osure	Program Director

3.6 Interview Procedure

The interview was semi-structured in nature. The venue for the interview changed according to who as being interviewed. Key informants were interviewed at their place of work, as this was the most convenient for them.

The participants were informed well in advance that the researcher would take notes during the interview and they could choose not to answer any questions if they did not want, in addition to stopping the interview at any time.

The interviews lasted between 45 and 60 minutes each depending on the communication skills and receptivity of the informants. The interview consisted of open-ended questions, questions containing exploring traceability concepts and structured questions identified from previous research around traceability systems.

3.7 Data Analysis

The Analyses of the resultant data were undertaken via a specially designed two stage process. The first stage of the analytic process initially involved the researcher familiarising with the data. This was done by reviewing the notes of the interviews several times, and carrying out a full transcription of this substantial body of material on to paper. The researcher also sent out e-mail correspondence to the informants seeking clarifications on any areas that weren't clear.

The next phase within this first stage can be characterised as a qualitative content analysis (Bryman 2001; Priest et al 2002) which produced emergent themes. This shares some similarities with the approach taken by the researcher to preform interview analysis.

In the second stage the researcher came up with "core relevant narrative formed from the interview". The purpose of this approach was to create a distillation of the parts of the interview with most relevance to the enquiry, and to present these in a logically sequenced narrative. The use of formulated meaning statements was adapted from the phenomenological data analysis techniques of Colaizzi (cited in Tuck 1995) who derived "formulated meaning statements" from primary textual material. In

phenomenological studies these are used to convey the core meaning or essence of an interviewee's experiences, and the researcher found these useful in a previous study (Macduff 1998). In the context of these key informant interviews, however, the technique was being applied in a looser, less intense way to summarise core content that could help structure and link an interview narrative. There are themes which the researcher saw as emerging from within each interview. These themes relate to the primary subject matter of the enquiry and can be termed "endogenous" in the sense that their genesis is from within the interview dialogue. Although the researcher necessarily abstracted them to some extent through subsequent interpretation, the aim has been to reflect the interviewee's own ideas and use of words whenever possible.

3.8 Prototype System Development

This was done using Object Oriented Design (OOD) methodology. This involved identification of functional requirements from which use case artefacts is developed. Thereafter the dynamic and static behaviour of the system is analysed and modelled. The modelling of static behaviours is done through identification of objects and classes which are represented using Unified Modelling Language (UML) diagrams. The dynamic aspects of the system are modelled using sequence, interactive, state diagrams and collaboration diagrams.

As regards to implementation prototyping technique was followed. The prototype development followed the four steps model proposed by Floyd, C. et al. (1984) this consists of

1. Functional selection: refers to the functionality chosen for the prototype. In general, the chosen functionality should be a subset of the functionality one would expect to exist in the final product. Within functional selection Floyd identifies two differing ways of prototyping: vertical prototyping, where the implemented functionality is presented in its intended final form, but only a small subset of the total functionality is included. Alternatively horizontal prototyping can be employed, where the entire functionality is functions are

not implemented in detail. This research shall follow vertical prototyping approach.

2. Construction: refers to the actual implementation of the prototype. The effort involved constructing a prototype should be much smaller than that involved in building the final product. Integrated Development Environment (IDE) namely Android Studio shall be used for mobile application development and Visual Studio shall be used for Web Application development.
3. Evaluation: this is the phase where the implemented prototype is tested and evaluated in order to inform the development process of the final product. This will be done through Use case testing.
4. Further use: this may vary depending on the kind of prototype being developed. In some projects the prototype is used exclusively for learning purpose, and is thus thrown away after prototyping. Other prototypes may be matured and then used fully or partially as a component in the final product. For this research the prototype will be developed with the intention of having final product that will serve to enhance the efficiency of traceability among smallholder farmers.

CHAPTER FOUR: PRE STUDY - RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the major findings of the study under two major themes: the main drivers of traceability. These themes are presented using data collected from key informants. These themes are presented under various sub-themes these drivers may factor into the stakeholders decision to pursue traceability. In presenting the results of the interviews, the researcher anonymised the participants in order to respect their privacy.

4.2 Themes and Sub-themes

The themes and sub-themes that emerged from the research findings are presented in the table 3 below, and they flow systematically.

Table 3: Themes and sub-themes

Theme	Sub-theme
Value and efficiencies	1. Reducing risk 2. Operation efficiencies and process consistency 3. Securing supply 4. Reputational benefits
Regulation	5. Meeting local regulatory legal requirements 6. Meeting global safety requirements

4.3 Value and Effectiveness

The findings below are based on the extent to which the various stakeholder stand to benefit from implementing a traceability system. The data collected from the KII are presented under five sub themes:

1. Reducing risk
2. Operation efficiencies and process consistency
3. Securing supply
4. Supplier selection and supplier relationships
5. Reputational benefits

4.3.1 Reducing Risk

The research findings reveal some of the risks that the horticulture industry has had to deal with due to lack of a reliable traceability system which include:

1. Increase in Physical checks at EU control points.
2. Increased interceptions.
3. Negative Market Perception on capacity to manage risks.
4. Traceability rules not fully implemented.
5. Reduction in Export volumes/sales.
6. Produce lack Origin & history information.
7. Future participation of Smallholder farmers in the export market is at risk.
8. Rapid growth of the industry has led to reduced controls.

One informant commented on pesticide application, the situation currently is as follows:

1. Big growers/exporters of vegetables are very serious in their use of pesticides regardless of price. They also have their own training programs and or use someone to do the training and dictate to their out-growers what to use and when.
2. Medium size growers/exporters are also very serious on choice and use of chemicals, but the price issue seems more relevant for this group. They dictate to out-growers what to use and when, but they often have less control over usage.
3. For small farmers and out-growers without a contract with an exporter, the control is much less. They normally know or have directives of what to use and when, but there are very little control of what is happening. These growers sell often to brokers. This sector represents a real risk, because traceability is often lost and it is expected that MRLs cannot be controlled in this market sector.

Another key informant commented on the general problems of pesticide use in Kenya:

1. The wide range of chemical products available in Kenya makes it difficult for small to medium size farmers to choose the correct product. The big producers/exporters have sufficient technical expertise to make the selection and apply the product properly. There is also little understanding of the classification of a product in Kenya. This results in a situation where a producer believes that he is using the correct chemical while it is in a class that is not allowed.
2. Pesticides are considered to be the only solution to a specific problem regardless of available other means. The big producers/exporters' knowledge of alternative measures are company secrets and not available to the sector as a whole.
3. The application technology is underdeveloped in Kenya, especially among small to medium size farmers, and leaking tanks, booms etc., inadequate coverage while spraying, spraying at the wrong time, poor or wrong nozzles etc. are frequent problems resulting in over use of chemicals and/or inadequate effects of the application.
4. There is a general lack of measuring the chemicals properly when mixing spraying solutions. This results in both over/under supplying chemicals and also the risks of creating an immunity and/or exceeding MRLs. MRLs tolerance for imports to the EU will most probably be at a level of detection which means a zero tolerance from July 2001 and onwards.
5. Most flower farms have a centralized spraying system, which has to be rinsed after each spraying. There are concerns about what to do with the rinsed solution and also the risks of forgetting to rinse which will harm the environment as well as harm the crop

What is emerging is that Kenya's fresh produce industry has been facing a series of challenges among them increased interceptions involving pesticide residue excesses detected in some of its exports to the EU, Kenya's leading market for fresh produce which may put the whole sector at risk within the next few years unless they are successfully negotiated.

4.3.2 Operation Efficiencies and Process Consistency

The findings below are based on the implementation of GlobalGAP which requires considerable changes for an African small-scale farmer. In most cases farm infrastructure must be upgraded to include a field toilet, hand washing facilities, a pesticide store and permanent plot markers for every field. Record keeping and traceability systems have to be introduced, and the farmer and any farm workers need training in hygiene, good agricultural practice, safe and effective use of pesticides and farm management. The farmer must also undergo a shift in attitude away from subsistence farming towards modern professional techniques that stress detailed farm management. One of the key informant working with contracted small holder farmers noted:

> The exporters also require that farmers keep records of the type and quality of inputs used. Each farmer must keep records relating to crop movement, pesticide stock movement and pesticide applicator's spraying records. These records accompany green beans to the exporter's pack house with duplicate copies, which are available to the exporter. Keeping majority of these records requires special skills and functional literacy, and therefore drives off farmers that find record-keeping difficult (especially the illiterate and low-skilled).

It emerged that Good agricultural practice had been seen to improve efficiency and profitability of farming operations, as yields and product quality had increased and wastage of chemicals had been reduced due to following proper crop protocols. GlobalGAP compliant record keeping enabled farmers to evaluate the profitability of farming as a business and reduce theft of inputs by farm workers. Creation of traceable plots with coded markers linked to records enabled many farmers to calculate the cost of production per plot and hence to obtain a further measure of profitability. Introduction of proper crop rotation had improved soil fertility and reduced the number of pests seen in the crop. Using proper harvest containers exclusively for produce has improved product quality and income.

A key informant from the government regulatory body also noted that:

> HCDA (Export) Order No 190 of December 2011 replaced the previous Order of 1995. It empowers the Authority to facilitate and enforce standards for all horticulture produce. The provisions include requirements for the safe use of

pesticides and for traceability (detailed rules for traceability have yet to be adopted). Exporters have to be registered annually, and must have own production schemes or contracted growers. Exporters must keep records of their transactions and submit quarterly returns to HCDA. The Order also provides for sanctions.

1.3.3 Securing Supply

The findings below are based on the fact that in 2011 fresh produce exports worth Sh20 billion were denied entry into the EU after unsafe residue of Dimethoate were detected. This led the Kenyan government to ban the use of the product. The challenge had always been identifying the produce once it had been intercepted and this now has been mitigated as explained a key informant from Horticultural Crops Development Authority (HCDA):

> Horticulture exporters must now identify farms where they source their fresh produce from or risk losing their licences, as the industry regulator tightens the noose in a bid to comply with European Union standards.
>
> Horticultural Crops Development Authority (HCDA) will also make it compulsory for brokers and middlemen to register with one exporter.
>
> The new measures by the Horticultural Crops Development Authority (HCDA) will also make it compulsory for brokers and middlemen to register with one exporter.
>
> These measures have become necessary to address standards compliance and traceability. No export licenses or export certificates will be issued to firms that have not submitted this data.

It emerged from these government regulators that traceability of food crops makes it easier for quality gatekeepers to ensure that horticultural exports meet health, safety and ecological standards as a key informant went further to explain:

> Middlemen are buying from multiple farms despite existing export supply contracts. This is making it very difficult to trace the origin of products.

4.3.4 Reputation Benefits

The benefits of traceability system will be to enhance the market access for farmers and protect the brand reputation of Kenya and its exporters. One of the respondents during the key informant interviews stated that:

> Kenya and other horticultural exporters face serious challenges related to changes in the structure of consumer demand in Europe and the transformation of food retailing there due to the rise of supermarkets: The share of fresh fruits and vegetables sold by supermarkets in the UK rose from 33% in 1989 to 70% by 1997. Increasingly, supermarket chains bypass wholesalers and buy directly from exporters in Kenya and other countries. To protect their reputations, the chains impose new restrictions and even organize production in developing countries.
>
> Maintaining Kenya's leading position and good reputation is key to continued export growth to the EU. Compliance with maximum residue levels (MRL) is crucial to continued growth of the industry. With Kenya having seen an increased number of interceptions in 2011, there is need to enforce regulatory systems on agrochemical use in horticulture. The ban of dimethoate use on fruits and vegetables will contribute significantly to adherence to MRL requirements.
>
> In Kenya and in Europe there is a perceived disconnect between the increasingly stringent regulations on paper and the actual capacities of most member states to enforce these rules. This implies that enforcement will continue to be done by inspection and testing of samples, drawn either randomly or, more likely, purposively. This means that the reputation of a country and of particular products will probably be a significant factor in how intensively one's supplies are subjected to official inspection. Kenya needs to protect its seemingly high reputation for 'clean', high-quality produce. Exporters are uncertain regarding the official penalties for infractions of emerging EU or Member State regulations.
>
> In the UK, the pesticide monitoring program is also not used for direct enforcement action (no seizures; no follow-up samples). Instead, the results of the program are published quarterly on the PSD's website providing a powerful

incentive for firms to take their own precautionary measures. The published results include a detailed analysis, explicitly mentioning the names of the brands, retail outlets, packers, country sources, etc. of individual samples. If there are apparent violations of MRL tolerances the affected companies are notified and they typically issue their comments (explanations; statements of actions taken) on the PSD website. In cases where an infringement concerns a product from another country, the official outcome is simply a letter issued by the PSD to the embassy of that country requesting action. The private action taken may be more severe, depending upon the supplier, the reason for the problem, and whether or not that supplier has been in violation of MRL tolerances before. Essentially, the UK policy of naming names provides a relatively powerful deterrent by affecting the reputations of individual retailers and thus leading the latter to carefully monitor their suppliers and crackdown on those suppliers who cannot meet their standards. This process has led several of the UK's major supermarkets to put in place strict requirements for their suppliers—whether local growers or importer/distributors—to carry and document MRL tests, plus to carry out MRL tests of their own.

4.4 Regulation

This study established a number of regulatory frameworks, in principal, the standards and grade requirements of horticultural products are set by the importing country. There are standards in Kenya for seed and packaging, but it is the contacts with the markets that regulate these issues. This section will present the findings of this study in two sub-themes: meeting local regulatory legal requirements and global safety requirements.

4.4.1 Local Legal Requirements

Exporters in Kenya require an export license to be able to export, and the cost of such a license as well as the performance level of the applicant will increase in the future. This certificate is issued by HCDA, the license has been quite easy to obtain at a cost of Ksh 5.000 for a three-year license. However, the Horticultural Bill, which

many exporters in Kenya sees as an even larger threat than the import duty to the EU due to the fact that the Bill has a much closer time perspective than the import duty, and also because many exporters expect that the import duty will never be implemented, whereas the Bill can be implemented on short term.

The Horticultural Bill contains a significant expanded power for HCDA in the regions of technical assistance, research and control functions, which will be paid by the private sector according to the costs of the operations. The private sector claims in principal that these activities to be undertaken by HCDA are already undertaken by the private sector. The private sector can manage these functions better than HCDA, that they don't require these services, and that it will only increase their costs and not result in increased export earnings to pay for the costs.

At the same time, HCDA is launching an out-grower scheme, with the assistance of Japanese funding, in order to collect, handle and sell produce from out-growers to the export and/or canning sector. HCDA is also empowered to act as an exporter for the produce. Initially HCDA has contracted some 400 out-growers of beans into this project. The joint reaction from the private sector is that HCDA cannot function both as a regulatory body and as a competitor. None of the issues of the bill seems to be acceptable for the private sector. Furthermore, the bill has triggered a suspicion that this is the first step towards increased government control of the sector.

Other concerns from the private sector are:

1. That there will be too many label systems implemented in the EU markets, which the exporters will have to join, which will increase the costs rather significantly. Most of these label systems also introduce regulations, which only have to be followed by Kenyan (and other non-EU suppliers), and which will burden the exporters with costs that are not experienced by the European growers. The EU will launch a new, joint code of practice, EUREGAP, in September 2001. Hopefully, the EU will impose that this is the only label required, and that its regulations are required also from the European growers, as well as accept that the Kenya CoP is conform to the requirements of the EUREGAP.
2. EU will impose stricter quarantine inspections, which may result in disinfecting of shipments with methyl bromide, and which will have a

negative effect on quality and vase life but also may delay clearance of the shipment significantly. It may also involve increased testing of vegetable- and fruit shipments. The cost for the new system will be imposed on the exports directly. It is estimated to cost the flower export sector 300.000 Euro per year in additional costs, and possibly the same for the vegetable/fruit sector. The cost will be invoiced in Europe, but the cost will reflect on the sales price and hence, be returned to the exporter's price. The market price as such is unlikely to change because of this new cost.

In principal, the standards and basic minimum grades of horticultural products exported from Kenya are set by the importing countries in the EU and by the customers. The supermarket chains in the UK have been spearheading the development of very strict regulations for vegetable/fruit imports, and they monitor the implementation of those regulations closely through control visits to the exporters audited for their systems. There are standards set for imports of horticultural products into the EU. A National Code of Practice has been developed in Kenya, which is being implemented, and which is harmonized to most label systems in Europe. Accreditation to the CoP will become a necessary instrument to obtain an export license in Kenya in the future. It is of utmost importance that the CoP will be accepted by the various label systems in Europe, especially the new EUREGAP, in order for the Kenyan exporter to abide by only the CoP and not have to join a large number of label systems.

KEBS has set standards for certain fruits and vegetables through its technical committee but there is no evidence that these are being implemented and there is doubt whether there should be such standards. The only important issue for the exporter is that his exported quality is conform to his customer's requirements without taking any local regulations into consideration. The standards set for the local market are mainly according to size and that seems to be adequate according to local demand. The current practical standards and grades are described below.

1. Phytosanitary standards and grades: These are set by the importing country and are mandatory and there will be a more stringent application of these regulations in the future by the EU quarantine inspection. This is still under negotiation, but the new regulations are likely to be imposed in 2002, and

which will increase the costs of importation from non-EU countries. The MRLs regulations are mandatory for the whole sector and will require an upgrading of analysing facilities in Kenya at KEPHIS for small to medium size exporters to follow up on these issues.

2. Quality: Grades and standards that relate to quality, such as size, colour, taste, appearance etc. are set by the buyer and vary from buyer to buyer and over time. These standards are mandatory for each individual exporter and depend on market preferences and trading practices.
3. Code of Practice and Code of Conduct: Standards that relate to social and environment issues as well as business ethics are becoming increasingly important. These standards have been voluntary in the past but are becoming mandatory, and will be mandatory in Kenya in the near future through the implementation of the National CoP. This will probably result in preventing some small exporters from operating.
4. Organically Produced Fruits/Vegetables: There is an increasing demand for these products in the EU, and there are certifying bodies, such as IFOAM, that will inspect and certify an individual grower/exporter. The criteria for certification are totally controlled by the importing countries.
5. An exporter in Kenya will require an export license, which is issued by HCDA. The license has been quite easy to obtain at a cost of Ksh 5.000 for a three-year license. HCDA is proposing increase he fee to Ksh 25.000 for a one year license and they will also follow up on the exporter's compliance with the Code of Conduct and may, in the future, refuse to give an export license to exporters that do not comply with these conditions. The sector is strongly opposed to the increased fee, and considers this to be another instrument to collect more funds for HCDA. They would prefer the existing charge and a simple register of exporters instead of a license and which could be maintained at the existing fee. The increased market demands will automatically exclude non-serious exporters from exporting.

There are standards set for seed, but the reality is that the grower will depend totally on his connection with the seed supplier. Attempts to claim from the supplier on the

grounds that the seed did not conform to Kenyan standards will be very lengthy and most probably fruitless. The standards set concern purity of the seed, max. weed content, min. germination capacity, max. moisture content.

In general, these issues are a solved between the seed supplier and the client, since it is impractical to conduct tests prior to the actual sowing of the seed for practical purposes.

There are also standards of packaging. Kenya has an intrinsic advantage over neighbouring countries that it has a paper and board manufacturing industry, based largely on trees grown locally on a renewable basis. There are also several packaging factories in Kenya, a situation which has created a competitive situation and which has resulted in declining packaging prices over the last few years.

However, the packaging industry in Kenya is protected by a 45% import duty and packaging material in Kenya is still quite expensive. Packaging has been a very big issue for Kenyan exporters of horticulture produce. There was a rather big study made by Price Waterhouse Coopers in 1999, which stated that most of the problems related to Kenyan cartons were to be found in the airport handling system and not caused by the quality of the packaging. The standards for Kenyan packaging are to be found in the directives from Kenya Bureau of Standards, KS 03-948 of Jan. 1991. The EU regulations covering the basic cartons etc. state that:

1. The materials used should be clean, new and harmless to food.
2. There should be no print on the internal surfaces in contact with food.
3. The packaging should provide adequate protection for the content
4. No straw should be used as packaging material on phytosanitary grounds
5. The heavy metal content of the cardboard should not exceed certain specified levels (this is rarely a problem)
6. Re-cycling of packaging is mandatory in the EU, and cartons should be possible to recycle without extra cost. There are extra charges for re-cycling waxed or plastic filmed cartons.

A major complaint is labelling, where many exporters fail. The minimum legal requirements for export into the EU include

1. Quality grade and size

2. Nature of product (such as beans) and variety
3. Name and address of packer and/or exporter
4. Country of origin
5. Net weight

Supermarket buyers often have additional demands such as

1. Supplier/traceability code
2. 'Sell by', 'Use by', Best before' or 'display until' dates
3. A bar code for stock control in the supermarket depots
4. The name of the supermarket

Often pricing is also done prior to shipping the products

Often the inner labels will contain information concerning storage and cooking instructions, serving suggestions, nutritional information etc. Some pre-packs are very stylish and quite expensive but the main pre-packs used include poly-bags and over-wrapped trays.

Pests and diseases are one of the most important factors in the production and exports of flowers, fruits and vegetables and often account for significant losses in the field as well as during post-harvest handling.

All legislation is under the mandate of the Pest Control Products Board.

1. The introductions of pesticides to Kenya: All pesticides introduced from outside the country will have to be approved of the Board. To get an approval from the Board, the applicant will have to bring in experimental samples, and to submit data supporting efficacy, toxicological and environmental data on the product. The procedure may take up to 2 years.
2. Immediately after approval comes a testing phase, which is obligatory carried out at the agricultural centers of the Kenya Agricultural Research Institutes. However, there is a more open and practical approach to these issues and private companies as well as consultants can carry out the tests and provide results to KARI. Generally, the procedure will take 6-12 months
3. Registration: There are three types of registration, temporary, provisional and full.

There are general complaints that a registration in Kenya is a longer process than in neighbouring countries in the region, since they have less strict regulations on these matters.

For pesticide application, the situations, in general, is as follows:

1. Big growers/exporters of vegetables are very serious in their use of pesticides regardless of price. They also have their own training programs and or use someone to do the training and dictate to their out-growers what to use and when.
2. Medium size growers/exporters are also very serious on choice and use of chemicals, but the price issue seems more relevant for this group. They dictate to out-growers what to use and when, but they often have less control over usage.
3. For small farmers and out-growers without a contract with an exporter, the control is much less. They normally know or have directives of what to use and when, but there are very little control of what is happening. These growers sell often to brokers. This sector represents a real risk, because traceability is often lost and it is expected that MRLs cannot be controlled in this market sector.

General Problems of Pesticide Use in Kenya.

1. The wide range of chemical products available in Kenya makes it difficult for small to medium size farmers to choose the correct product. The big producers/exporters have sufficient technical expertise to make the selection and apply the product properly. There is also little understanding of the classification of a product in Kenya. This results in a situation where a producer believes that he is using the correct chemical while it is in a class that is not allowed.
2. Pesticides are considered to be the only solution to a specific problem regardless of available other means. The big producers/exporters' knowledge

of alternative measures are company secrets and not available to the sector as a whole.

3. The application technology is underdeveloped in Kenya, especially among small to medium size farmers, and leaking tanks, booms etc., inadequate coverage while spraying, spraying at the wrong time, poor or wrong nozzles etc. are frequent problems resulting in over use of chemicals and/or inadequate effects of the application.
4. There is a general lack of measuring the chemicals properly when mixing spraying solutions. This results in both over/under supplying chemicals and also the risks of creating an immunity and/or exceeding MRLs. MRLs tolerance for imports to the EU will most probably be at a level of detection which means a zero tolerance from July 2001 and onwards.
5. Most flower farms have a centralized spraying system, which has to be rinsed after each spraying. There are concerns about what to do with the rinsed solution and also the risks of forgetting to rinse which will harm the environment as well as harm the crop.

There is obviously a lack of a single organization with the capacity to take the overall responsibility of the management of pesticides. The Pest Control Board is a regulatory organization. The Board:

1. Does not have a laboratory facility to undertake quality checks for products. KEPHIS is doing this on request and at a rather high fee, and which weakens the Board's position when in controversy with a company on quality.
2. Label recommendations on the use of chemicals in pre-harvest intervals are based on trials made outside the country, and it would be necessary to determine the PHIs relevant for the local conditions in Kenya. However, the big producers/exporters are doing this but that knowledge is not available for smaller to medium size producers/exporters in Kenya.
3. Basic chemical and physical tests on pesticides including quality control of formulations(suitability of solvents and filler materials for pesticides, emulsifiability of EC formulations, suspendability etc.) are not carried out, and which affect the suitability of a product for a certain purpose.

4. Does not have the facilities to assess the use of buffers, wetters, spreaders etc. in order to improve the effectiveness of a specific product. The Board does not have the capacity or even the procedures to register biological pesticides. A few pest control alternatives have been developed locally, but the Board is not able to assess them and make recommendations on their use.
5. There is no surveillance and monitoring to assess the status of residues in fresh and processed food.

There is a lack of national capacity to analyze for pesticide residues. The Kenya Plant Health Inspectorate Service is the only organization with a reasonable capacity to analyze some categories of pesticides. The major problems being:

1. They have a capacity of 70 samples per week, but a larger number would be required for a realistic assessment of the export situation.
2. Lack of a complete range of standards.
3. The methodologies used are not developed for all the pesticides.
4. The issue of metabolites of residues has not been addressed at all, and the tests are done mostly for parent compounds only.
5. The analysis are quite expensive or ranging from US$ 25-100, and also quite lengthy, which has forced the private sector to invest in their own analyzing facilities. It seems that the private sector has no need for an official analyzing capacity at present.

There has been a lot of discussing of training in the country and. The Global Protection Federation also sponsored some training for the last 5-6 years as well as other organization such as USAID, Care etc. However, the emphasis was on safety and not on economical and environmental basis of the use of chemicals. It is quite clear that an improved knowledge of the use of pesticides and also on alternative methods would reduce the total use of chemicals significantly.

Issues such as MRLs, correct measurement of chemicals, correct application, both from a timing point of view as well as coverage, delay before harvest etc. present a real problem to the MRLs issue and also to the over use of chemicals. The big producers/exporters handle these issues very well, but the small to medium size

exporters, without their own production and/or depending on brokers for their supply, may have a problem to address these problems properly.

The present regulations that burial of waste should be done 250 m away from any water source are not viable since many farms are of 1-2 acres or even less. There should be a stricter manufacturer responsibility of taking back chemical packaging and destroying them.

Suggestions for improving the use of Pesticides in Kenya.

1. The cost of pesticides is quite high in Kenya, and a product under international registered labels seems often higher priced in Kenya than on the international markets.
2. Increase the capacity of PCPB to evaluate and approve of products in time.
3. Training input to especially out-growers supplying the vegetable/fruit export trade.
4. The introduction of special spraying teams/companies, which would do the pesticide application for the farmers.
5. Monitoring the residue levels through an improved analysis capacity in export commodities.
6. More specific research has to be done for introducing alternative methods of pest control, especially biological control or repellent plant function.
7. There is a need for capacity building in the PCPB in the area of registering and evaluating biological treatments.
8. Increased and accredited laboratory capacity for determining MRLs and with much more rapid results, which would require very sophisticated equipment to serve the industry. At present, most exporters rely on analysis results from the import country. The cost for local analysis is too high and not competitive, mainly due to poor equipment and lack of staff. This is an issue of great importance for the future of Kenya as a major horticulture exporting country.

4.4.2 Global Safety Requirements

The EU is the largest market in the world for imported fresh produce. In 1999, imports to the EU from non-EU countries of fresh vegetables exceeded US$ 1bn while imports

of fresh fruits reached US$ 5.5bn. Imports of floricultural products from non-EU countries were almost US$ 1 bn.

Unification of the member states into the EU has had a significant effect on the fresh horticultural trade. In particular:

1. The customs union means that imports are only controlled at the point of entry to the EU and are thereafter free to circulate
2. Freedom of movement of goods allows perishable products to move within the EU without unnecessary border delays.
3. The monetary union will have important implications for the business system in the EU and exporters must be prepared for the Euro.
4. External relations, support for the ACP countries for example, is common to all EU members in preferential tariffs for import duties (present situation).
5. In legislation the progression of harmonization has led to a reduction of national trade barriers so that individual member economies can no longer distinguish between locally produced and imported goods. However, the process of harmonization of legislation is leading to a new generation of food regulation covering a diversity of aspects from standards, through hygiene to labelling and packaging waste.

Exporters of fresh produce to the EU should be aware of changing legislation in the application and permitted residue of pesticides. Two initiatives are important here:

1. The EC is reviewing the active ingredients authorized for sale in the EU and intends to draw up a list of accepted substances by 2003. Any active substance not defended, reviewed and authorized by 2003 will no longer be permitted for use within the EU. Although overseas use cannot be controlled, there will be "zero tolerance" of residues from pesticides for which EU approvals has been revoked.
2. Maximum Residue Levels (MRLs) are the permitted residue levels of any pesticide on a fruit or vegetable product. Since 1976 a number of directives have modified the legislation to incorporate a number of crop/pesticide combinations. At present, over 17,000 MRLs have been set for various commodities for 133 pesticides.

CHAPTER FIVE: REQUIREMENTS SPECIFICATION

5.1 Introduction

This chapter presents primary business requirements based on the thematic analysis from the previous chapter. These can be deduced as:

1. A platform that will help isolate the source and extent of food safety or quality control problems
2. Protect brand reputation - the system will help reduce the potential for bad publicity, wastage, spoilage, and loss of income. Keeping precise records allows farmers / companies to quickly identify and recall only unsafe produce thereby reducing the number of recalled produce, demonstrating a high level concern of public health and limiting negative media exposure.
3. Diagnose problems in production and determine the agent at fault. The system can help resolve production and process problems and determine third-party responsibility if records show that a supplier was the source of the contamination, e.g. contaminated or poor quality fertilizers and seedlings.
4. Security features, making sure user data is not compromised.

5.2 Use Cases

The target market will be exporter who work with smallholder farmers in outgrower schemes. The solution will makes certain that the exporters contracted by overseas chain stores to supply fresh fruits and vegetables are assured of consistent good quality produce, fair transaction costs and most importantly traceability by the smallholders farmers. Through real-time monitoring and tracking, the solution will provide a holistic pathway for tracing all activities involved in the growing cycle of horticultural crops and GlobalGAP related information.

The high-level business requirements deduced from the analysis are as illustrated in figure 3.

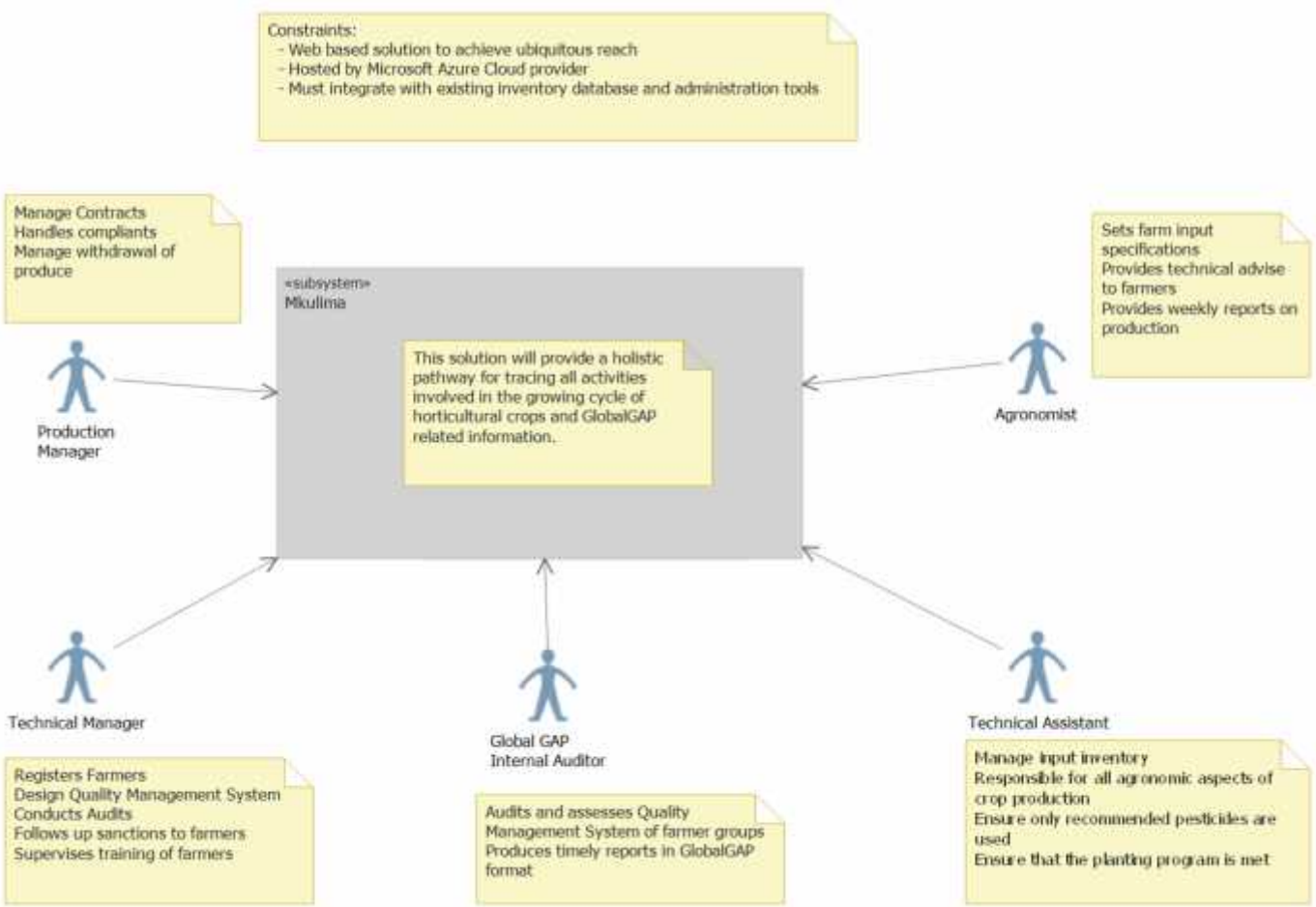


Figure 3: High-level business requirements

The use cases defined in this specification relate to functions within the application. Note that specification addresses functions / roles should be planned for system, even if the functionality is not part of this deliverable.

5.3 Technical Assistant Roles

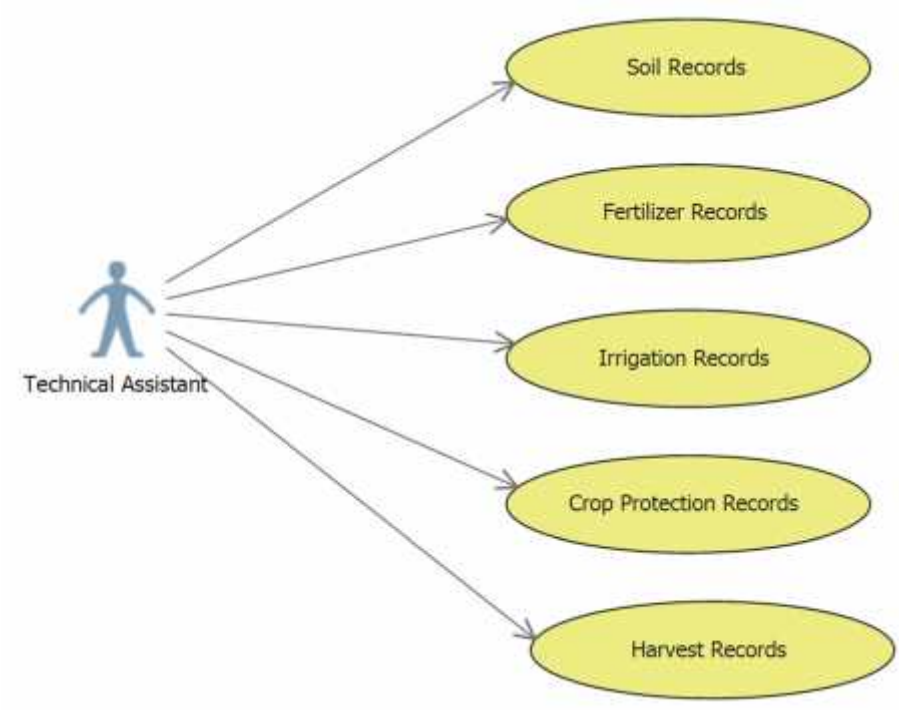


Figure 4: Technical Assistant Roles

5.3.1 Soil Management

Soil is the basis of all agricultural production; the conservation and improvement of this valuable resource is essential. Good soil husbandry ensures long-term fertility of soil, aids yield and contributes to profitability.

The system will enable the technical assistant to capture the types of soil identified for each site, based on a soil profile or soil analysis or local (regional) cartographic soil-type map.

5.3.1.1 Use Case 1- Add New Soil Profile

Use Case Id	UC01
Description	The main purpose of this use case is to capture new soil profile
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	This use case is triggered when the actor requests to capture new soil profile information
Measurable Result	Soil profile information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the soil profile, such as soil type, nutrient name, nutrient level and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new soil profile is captured in the system and the list of soil profiles that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture soil profile information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Soil profile information saved successfully

5.3.1.2 Use Case 2 - Modify Soil Profile

Use Case Id	UC02
Description	The main purpose of this use case is to modify existing soil profile
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing soil profiles
Measurable Result	The existing soil profile information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing soil profiles and the system presents the information. The actor makes a request to edit all the information except the list of soil profiles. The actor can either save the changes or return to the list of soil profiles without any changes being saved. If the actor chooses to save the changes, the edited soil profile is saved and the list of soil profiles is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify soil profile information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Soil profile information updated successfully

5.3.1.3 Use Case 3 - Delete Soil Profile

Use Case Id	UC03
Description	The main purpose of this use case is to remove existing soil profile
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing soil profiles
Measurable Result	The existing soil profile information is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of soil profiles. The actor then requests to delete a soil profile. If the soil profile has been used for fertilizer or irrigation recommendation the actor will be advised of this by the application and the delete will not be allowed. However, if the soil profile information has not been used to make fertilizer or irrigation recommendations then actor is prompted to accept or cancel the operation. If the actor accepts the operation the soil profile is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete soil profile information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Soil profile information deleted successfully

5.3.2 Fertilizer Management

Fertilizers are natural or synthetic substances that are added to the soil or plants to provide them with nutrients necessary for plant development. The use of fertilizers is a common practice to increase soil fertility and consequently the quantity and quality of fruits and vegetables.

The type of fertilizer used will influence the uptake of the nutrient, firstly because of the chemical composition and secondly the influence of the final broken down chemical, on the soil composition. For example, three different Nitrogen fertilizers could have different characteristics. The fertilizer Urea will be negatively charged and not adhere to soil particles when applied to the soil. Urea Ammonium Nitrate will be positively charged and therefore be more suitable to soil types with low clay percentages. Ammonium sulphate will influence the soil pH by causing a lower pH.

The system will enable the technical assistant to capture:

1. Field identification number
2. Application date
3. Type of fertilizer
4. Amount of fertilizer applied
5. Method of application
6. Name of the operator who applied the fertilizer

5.3.2.1 Use Case 4 - Add New Fertilizer Details

Use Case Id	UC04
Description	The main purpose of this use case is to capture new fertilizer details
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	This use case is triggered when the actor requests to capture fertilizer details
Measurable Result	Fertilizer information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the fertilizer, such as type, trade name, concentrations and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new fertilizer details are captured in the system and the list of fertilizers that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture fertilizer information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Soil profile information saved successfully

5.3.2.2 Use Case 5 - Modify Fertilizer Details

Use Case Id	UC05
Description	The main purpose of this use case is to modify existing fertilizer information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing fertilizers
Measurable Result	The existing fertilizer information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing fertilizer details and the system presents the information. The actor makes a request to edit all the information except the list of fertilizers. The actor can either save the changes or return to the list of fertilizers without any changes being saved. If the actor chooses to save the changes, the edited fertilizer information is saved and the list of fertilizers is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify fertilizer information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Fertilizer information updated successfully

5.3.2.3 Use Case 6 - Delete Fertilizer Details

Use Case Id	UC06
Description	The main purpose of this use case is to remove existing fertilizer information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing fertilizers
Measurable Result	The existing fertilizer information is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of fertilizers. The actor then requests to delete a fertilizer profile. If the fertilizer has been used for crop planting activities the actor will be advised of this by the application and the delete will not be allowed. However, if the fertilizer has not been used in crop planting cycle then actor is prompted to accept or cancel the operation. If the actor accepts the operation the fertilizer is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete fertilizer information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Fertilizer information deleted successfully

5.3.2.4 Use Case 7 - Add New Fertilizer Application

Use Case Id	UC07
Description	The main purpose of this use case is to capture new fertilizer application
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	This use case is triggered when the actor requests to capture fertilizer application information
Measurable Result	Fertilizer application information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the field identification number, fertilizer type, application date and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new fertilizer application details are captured in the system and the list of fertilizer applications that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture fertilizer application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Fertilizer application information saved successfully

5.3.2.5 Use Case 8 - Modify Fertilizer Application Information

Use Case Id	UC08
Description	The main purpose of this use case is to modify existing fertilizer application information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing fertilizer application information
Measurable Result	The existing fertilizer application information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing fertilizer application details and the system presents the information. The actor makes a request to edit all the information related to fertilizer application. The actor can either save the changes or return to the list of fertilizer application without any changes being saved. If the actor chooses to save the changes, the edited fertilizer application information is saved and the list of fertilizers is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify fertilizer application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Fertilizer application information updated successfully

5.3.2.6 Use Case 9 - Delete Fertilizer Application Details

Use Case Id	UC09
Description	The main purpose of this use case is to remove existing fertilizer application information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing fertilizer application information
Measurable Result	The existing fertilizer application information is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of fertilizer application. The actor then requests to delete a fertilizer application record. If the fertilizer application has not been used in crop planting cycle then actor is prompted to accept or cancel the operation. If the actor accepts the operation the fertilizer application is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete fertilizer application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Fertilizer application information deleted successfully

5.3.3 Irrigation Management

To guarantee reliable and economically viable crop yields, application of irrigation water to supplement natural rainfall is frequently needed. However, water is a costly input, often in short supply and not always of the desired quality. Hence, particularly with resource-poor smallholder farmers, it is essential that sustainable and cost-effective methods of applying and managing irrigation water are adopted, and that the quality of the water applied and its impact on soil and crop water balances is carefully monitored.

The system should be able to capture irrigation records which indicate the date and volume per water meter or per irrigation unit. If the producer works with irrigation programs, the calculated duration of irrigation and actual quantity of irrigated water should be recorded.

5.3.3.1 Use Case 10 - Add New Irrigation Application

Use Case Id	UC10
Description	The main purpose of this use case is to capture new irrigation application
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	This use case is triggered when the actor requests to capture irrigation application information
Measurable Result	Irrigation application information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the field identification number, volume per water meter, application date and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new irrigation application details are captured in the system and the list of irrigation applications that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture irrigation application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Irrigation application information saved successfully

5.3.3.2 Use Case 11 - Modify Irrigation Application

Use Case Id	UC11
Description	The main purpose of this use case is to modify existing irrigation application information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing irrigation application information
Measurable Result	The existing irrigation application information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing irrigation application details and the system presents the information. The actor makes a request to edit all the information related to irrigation application. The actor can either save the changes or return to the list of irrigation application without any changes being saved.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify irrigation application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Irrigation application information updated successfully

5.3.3.3 Use Case 12 - Delete Irrigation Application Details

Use Case Id	UC12
Description	The main purpose of this use case is to remove existing irrigation application information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing irrigation application information
Measurable Result	The existing irrigation application information is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of irrigation applications. The actor then requests to delete a irrigation application record. If the irrigation application has not been used in crop planting cycle then actor is prompted to accept or cancel the operation. If the actor accepts the operation the irrigation application is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete fertilizer application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Irrigation application information deleted successfully

5.3.4 Integrated Pest Management

Pest management is part of the more general framework of GAP, and for optimum crop protection, specific control methods must be used in association with the complete range of available cultural techniques (rotation, crop staggering, soil tillage, integrated fertilizing and so on), emphasizing the role and impact of agronomical and ecological factors. The term "pesticides" can be defined as "a substance or association of substances". That is intended to repel, destroy or combat undesirable species of plants or animals causing damage or otherwise harming the production processing, storage, transport or marketing of foodstuffs, agricultural products, wood and wood products, or animal feed. Pesticides are used to

1. Limit losses in crop yields
2. Protect stored food stuff
3. Limit the development of pathogens for humans and animals
4. Destroy undesirable plants (herbicides, algaecides, moss killers);
5. Destroy parts of plants, slow down or prevent undesirable growth of plants (haulm destroyers, anti-sprouting agents, etc.).

The system should be able to capture the following information about each application:

1. Date of application
2. The product used (full name, supplier, formulation, batch number, and so on.);
3. The dose actually used (measurement made);
4. The volume of mix (per ha);
5. The type of application (apparatus, nozzle, volume per ha, spray width [swath], speed) and spraying conditions (rain, wind, and so on.).

This traceability is more important, as it is sought to ensure for the exporter that the product harvested is in conformity with phytosanitary quality standards and, in particular, respects the MRL authorized for the product(s) on the foodstuff concerned.

5.3.4.1 Use Case 13 - Add New Pesticide Application

Use Case Id	UC13
Description	The main purpose of this use case is to capture new pesticide application
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	This use case is triggered when the actor requests to capture pesticide application information
Measurable Result	Pesticide application information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the field identification number, product used, application date and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new pesticide application details are captured in the system and the list of pesticide applications that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture pesticide application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Pesticide application information saved successfully

5.3.4.2 Use Case 14 - Modify Pesticide Application

Use Case Id	UC14
Description	The main purpose of this use case is to modify existing pesticide application information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing pesticide application information
Measurable Result	The existing pesticide application information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing pesticide application details and the system presents the information. The actor makes a request to edit all the information related to pesticide application. The actor can either save the changes or return to the list of pesticide applications without any changes being saved.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify pesticide application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Pesticide application information updated successfully

5.3.4.3 Use Case 15 - Delete Pesticide Application Details

Use Case Id	UC15
Description	The main purpose of this use case is to remove existing pesticide application information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing pesticide application information
Measurable Result	The existing pesticide application information is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of pesticides applications. The actor then requests to delete a pesticide application record. If the pesticide application has not been used in crop planting cycle then actor is prompted to accept or cancel the operation. If the actor accepts the operation the pesticide application is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete pesticide application information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Pesticide application information deleted successfully

5.3.5 Harvest Information Management

Fresh produce must be harvested at the correct stage of maturity if it is to maintain its quality attributes throughout its post-harvest life.

The system should allow for registered product to be traced back to the registered farm or, in a farmer group, to the registered farms of the group, and tracked forward to the immediate customer (One step up, one step down). Harvest information must link a batch to the production records or the farms of specific producers.

The unique field block identification label is maintained for as long as the farm(er) is contracted by the farmer group. To achieve this the system will assign a lot number to harvested products. Lot numbers are a series of numbers or letters representing various parts of the farm's production. Harvested products should be identified according to

1. The date of harvest,
2. The quantity of harvest
3. The particular crop harvested and
4. The field where the crop was grown.

Each marketable unit of product harvested from the farm- whether it is a box, pallet, sack, bin, and so on must have a corresponding lot number to accompany the product all the way through the various steps of the production/processing chain. An example of a phrase to remember how to set up the lot number would be as follows: "On date and year, I harvested crop from field number." The sequence of numbers to make a lot number would look like this:

000000-00-00

Example: On June 25 2012, I harvested cabbage from the Jones Farm. Your lot number might look like this: 20120612-08-04

Date - 000000

Using the format "yyyymmdd" digits of the harvest year will allow product date labeling for crops including those that may be carried over from year to year. Example, potatoes, onions.

Crop- 00

Crops produced on the farm or in the greenhouse should have a two digit number assigned to each crop or sub-type. Growers should plan and develop their crop code list with care as there can be impacts beyond assigning just a lot number. Should a product recall occur, the crop code may help to separate product so that an entire field or crop could avoid being quarantined. The economic impact of a recall procedure might determine a farm's ability to continue to be profitable.

Field- 00

Each growing location on the farm or in the greenhouse must have an assigned two digit number.

5.3.5.1 Use Case 16 - Add New Harvest Information

Use Case Id	UC16
Description	The main purpose of this use case is to capture new harvest information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	This use case is triggered when the actor requests to capture harvest information
Measurable Result	Harvest information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the harvest such as field identification number, date of harvest and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new harvest details are captured in the system and the list of harvests that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture harvest information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Harvest information saved successfully

5.3.5.2 Use Case 17 - Modify Harvest Information

Use Case Id	UC14
Description	The main purpose of this use case is to modify existing harvest information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing harvest information
Measurable Result	The existing harvest information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing harvest details and the system presents the information. The actor makes a request to edit all the information related to harvest. The actor can either save the changes or return to the list of harvests without any changes being saved.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify harvest information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Harvest information updated successfully

5.3.4.3 Use Case 15 - Delete Harvest Details

Use Case Id	UC15
Description	The main purpose of this use case is to remove existing harvest information
Primary Actors	Technical Assistant
Secondary Actors	Agronomist
Trigger	The actor MUST have displayed a list of existing harvest information
Measurable Result	The existing harvest information is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of harvests. The actor then requests to delete a harvest record. If the harvest has not been sent to the pack house then actor is prompted to accept or cancel the operation. If the actor accepts the operation the harvest is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete harvest information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Harvest information deleted successfully

5.4 Agronomist Roles

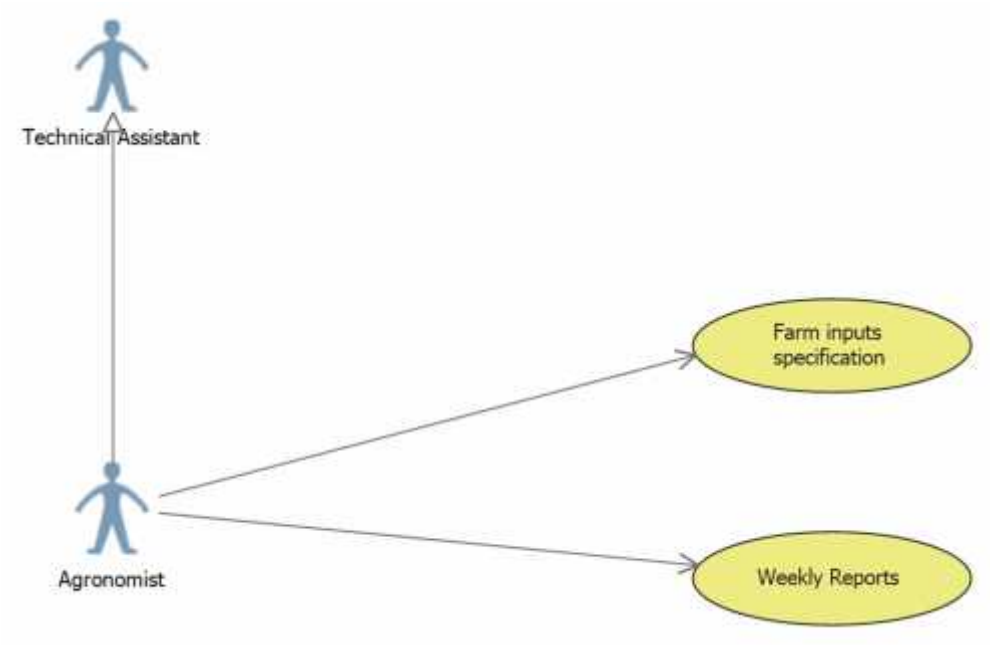


Figure 5: Agronomist Roles

5.4.1 Farm Inputs Management

According to Eaton and Shepherd (2001), contract farming can be defined as: "an agreement between farmers and processing and/or marketing companies for the production and supply of agricultural produce under forward agreements, frequently at predetermined prices". The arrangement also invariably involves the provision of a degree of production support by the purchasing company, through, for example, the supply of inputs and the provision of technical advice to the farmers.

The basis of such arrangements is a commitment on the part of the farmer to provide a specific commodity in quantities and at quality standards determined by the company and a commitment on the part of the company to support the farmer's production and to purchase the commodity.

Contract farming schemes typically involve the provision of inputs (seeds, fertilizers and pesticides) on credit by the company, often with extension advice, usually provide by the company's agronomist.

5.4.1.1 Use Case 16 - Add New Farm Input

Use Case Id	UC16
Description	The main purpose of this use case is to capture new farm input
Primary Actors	Agronomist
Secondary Actors	Technical Manager
Trigger	This use case is triggered when the actor requests to capture new farm input
Measurable Result	Farm input information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the farm input, such as input type, quantity, supplier and so on. The actor can choose to save the information or cancel the operation.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture farm input information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Farm input information saved successfully

5.4.1.2 Use Case 17 - Modify Farm Input

Use Case Id	UC17
Description	The main purpose of this use case is to modify existing farm input information
Primary Actors	Agronomist
Secondary Actors	Technical Manager
Trigger	The actor MUST have displayed a list of existing farm inputs
Measurable Result	The existing farm input information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing farm inputs and the system presents the information. The actor makes a request to edit all the information except the list of farm inputs. The actor can either save the changes or return to the list of farm inputs without any changes being saved. If the actor chooses to save the changes, the edited farm input is saved and the list of farm inputs is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify farm input information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Farm input information updated successfully

5.4.1.3 Use Case 18 - Delete Farm Input Details

Use Case Id	UC18
Description	The main purpose of this use case is to remove existing farm input
Primary Actors	Agronomist
Secondary Actors	Technical Manager
Trigger	The actor MUST have displayed a list of existing farm inputs
Measurable Result	The existing farm inputs information is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of farm inputs. The actor then requests to delete a particular farm input. If the farm input has been used during the cropping season the actor will be advised of this by the application and the delete will not be allowed. However, if the farm input has not been used then actor is prompted to accept or cancel the operation. If the actor accepts the operation the farm input is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete farm input information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Farm input information deleted successfully

5.4.1.4 Use Case 19 - Generate Weekly Reports

Use Case Id	UC19
Description	The main purpose of this use case is to create, view, manipulate or otherwise work with weekly reports
Primary Actors	Agronomist
Secondary Actors	Technical Manager
Trigger	The actor needs to run a report or data extract
Measurable Result	The weekly report creation is either cancelled or completed
Main Flow	This use case begins when the actor requests to create the desired report. The system presents the actor with a list of report's configurable parameters. The actor makes the necessary selections specific for the selected report type. The system validates the input parameters and upon success renders the report in a report viewer where the actor can then choose to export the same to a different file type including CSV, PDF, TTF, Word, Excel and so on.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to generate the report due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Report generated successfully

5.5 Technical Manager Roles

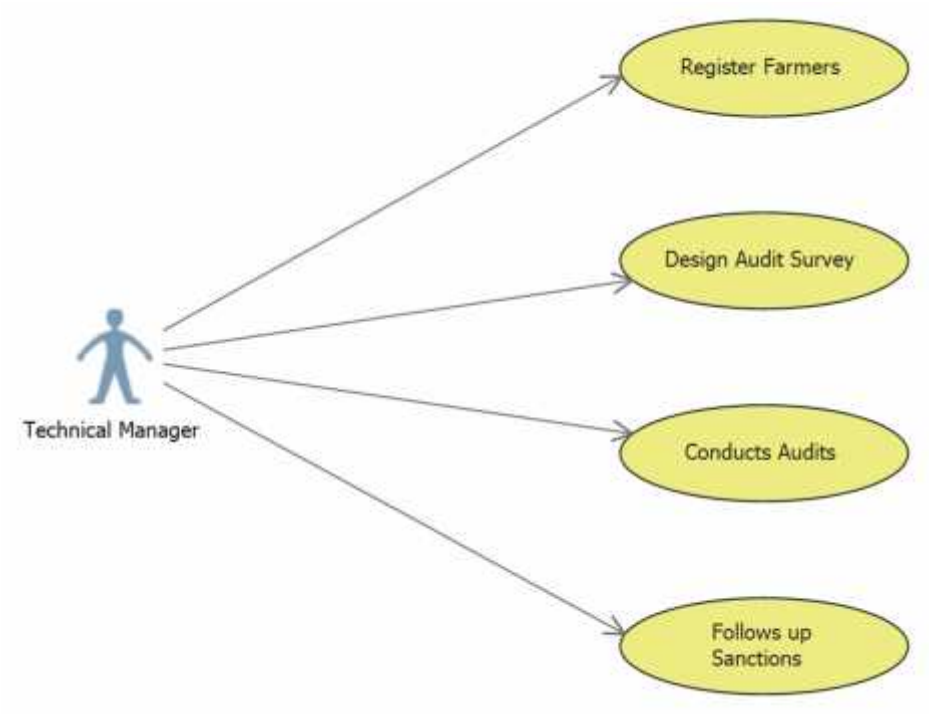


Figure 6: Technical Manager Roles

5.5.1 Farmer Registration

The system will ensure that all produce can be traced back to the farmer level and also the individual block where the crop was grown. Specific records concerning particular block production activities should also be available to be used to identify possible sources of problems at farm level.

Exporters usually deal with groups that are registered officially with the government registrar of societies. The legal status could be farmers association, cooperative or any other. The important part is that the group needs to have the legal right to produce or trade agricultural products.

The system should be able to capture the following information about the group:

1. Name of group
2. Contact person

3. Address
4. Telephone, fax and email
5. Product (the entire crop, not variety)
6. Total production area

Once the group had been registered, the members have been identified, the following details are captured as farmer register.

1. Name of farmer
2. Block Number
3. Address
4. Telephone, fax and email if available
5. Crop variety
6. Planting date
7. Expected harvesting date
8. Production area (e.g. 2 acres)
9. Production quantity (e.g. 1,000 tonnes)

5.5.1.1 Use Case 20 - Add New Farmer to Register

Use Case Id	UC20
Description	The main purpose of this use case is to capture new farmer details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	This use case is triggered when the actor requests to capture new farmer's details
Measurable Result	Farmer's information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the farmer, such as farmer's group information, names, size of land and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new farmer details are captured in the system and the list of farmers that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture farmer's information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Farmer's information saved successfully

5.5.1.2 Use Case 21 - Modify Farmer Details

Use Case Id	UC21
Description	The main purpose of this use case is to modify existing farmer's details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing farmers
Measurable Result	The existing farmers information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing farmers and the system presents the information. The actor makes a request to edit all the information except the list of farmers. The actor can either save the changes or return to the list of farmers without any changes being saved. If the actor chooses to save the changes, the edited farmer details is saved and the list of farmers is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify farmer's details due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Farmer's details updated successfully

5.5.1.3 Use Case 22 - Delete Farmer Details

Use Case Id	UC22
Description	The main purpose of this use case is to remove existing farmer's details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing farmers
Measurable Result	The existing farmer's details is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of farmers. The actor then requests to delete a particular farmer's details. If the farmer has registered for the current cropping season the actor will be advised of this by the application and the delete will not be allowed. However, if the farmer has not been registered for the current cropping season, then actor is prompted to accept or cancel the operation. If the actor accepts the operation the farmer is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete farmer due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Farmer deleted successfully

5.5.2 Design and Implementation of Quality Management System

The system will provide for capturing the process of internal audit in order to verify the implementation of the quality management system and compliance to third party audit (EUREPGAP / GlobalGAP) requirements.

The actor prepares the annual program of audit to be conducted. Internal audit shall be conducted to determine the effectiveness of the quality management system. They are done against the EUREPGAP / GlobalGAP checklists to determine the farmers' compliance. The actor prepares an audit plan indicating the areas of QMS and farmer group/farms to be audited, purpose, scope, audit criteria and the auditors.

The audit plan form shall capture the following details:

1. Date
2. Audit objective
3. Audit criteria
4. Auditor
5. Farm to be audited
6. Time of audit

Should there be any non-conformance the actor shall prepare corrective action plan that shall capture the following details:

1. Date
2. Farm code
3. Description
4. Root cause
5. Corrective action and date
6. Name of the farmer to carry out the corrective action

5.5.2.1 Use Case 23 - Add New Audit Plan

Use Case Id	UC23
Description	The main purpose of this use case is to capture new audit plan details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	This use case is triggered when the actor requests to capture new audit plan details
Measurable Result	Audit plan information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the audit plan, such as objective, date, criteria and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new audit plan details are captured in the system and the list of audit plans that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture audit plan information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Audit plan information saved successfully

5.5.2.2 Use Case 24 - Modify Audit Plan Details

Use Case Id	UC24
Description	The main purpose of this use case is to modify existing audit plan details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing audit plans
Measurable Result	The existing audit plans information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing audit plan and the system presents the information. The actor makes a request to edit all the information except the list of audit plans. The actor can either save the changes or return to the list of audit plans without any changes being saved. If the actor chooses to save the changes, the edited audit plan details is saved and the list of audit plans is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify audit plan details due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Audit plan details updated successfully

5.5.2.3 Use Case 25 - Delete Audit Plan Details

Use Case Id	UC25
Description	The main purpose of this use case is to remove existing audit plan details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing audit plans
Measurable Result	The existing audit plan details is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of audit plans. The actor then requests to delete a particular audit plan details. If the audit has used for carrying out an audit report, the actor will be advised of this by the application and the delete will not be allowed. However, if the audit plan has not been executed for the current cropping season, then actor is prompted to accept or cancel the operation. If the actor accepts the operation the audit plan is deleted from the system.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete audit plan due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Audit plan deleted successfully

5.5.2.4 Use Case 26 - Add New Corrective Action Plan

Use Case Id	UC26
Description	The main purpose of this use case is to capture new corrective action plan details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	This use case is triggered when the actor requests to capture new corrective action plan details
Measurable Result	Corrective action plan information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the corrective action plan, such as farmer code, date, non-conformance description, corrective action and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new corrective plan details are captured in the system and the list of corrective action plans that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture corrective action plan information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Corrective action plan information saved successfully

5.5.2.5 Use Case 27 - Modify Corrective Action Plan Details

Use Case Id	UC27
Description	The main purpose of this use case is to modify existing corrective action plan details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing corrective action plans
Measurable Result	The existing corrective action plans information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing corrective action plan and the system presents the information. The actor makes a request to edit all the information except the list of corrective action plans. The actor can either save the changes or return to the list of corrective action plans without any changes being saved.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify corrective action plan details due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Corrective action plan details updated successfully

5.5.2.6 Use Case 28 - Delete Corrective Action Plan Details

Use Case Id	UC28
Description	The main purpose of this use case is to remove existing corrective action plan details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing corrective action plans
Measurable Result	The existing corrective action plan details is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of corrective action plans. The actor then requests to delete a particular corrective action plan details. If the corrective action has been raised during an audit report, the actor will be advised of this by the application and the delete will not be allowed.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete corrective action plan due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Corrective action plan deleted successfully

5.5.3 Follow up Sanction to Farmers

The system will provide for capturing sanctions followed in effecting actions to ensure farmers and farmer group, farmer group and exporting companies, farmer group and service provider adhere to their contractual obligations as stipulated in their respective contracts, for the effective operation of the quality management system. The sanctions procedure is applicable to farmer and farmer group, farmer group and service providers and exporters contract with the farmer groups.

During routine inspections by group management, internal audits / inspections and external audits any failure noted as not complying with the agreed standard is a non-compliance and may result in sanctions which are meant to correct these failures. Different types of sanctions are imposed by the disciplinary committee of the farmer group, or the Service provider depending on the type of failure and party involved; the individual farmer or the farmer group as a whole, service provider or the export company. The affected party is informed as per the contract clauses. Sanctions, subsequent corrective actions and decision making processes are recorded as per the contract agreement. Any other arising defaults, commercial or otherwise, on other clauses in the terms of contracts will also lead to imposition of sanctions as per the contract clauses.

Farmer vs Farmer Group

Any farmer, who joins a farmer group in the farmer group's scheme, must sign a contract with the farmer group. The contract has by-laws and a constitution which governs the running of the day to day activities of the group and disciplinary measures taken when a member fails to adhere to the by-laws and the constitution.

The contract sets out disciplinary measures, which are taken in case of breach of this contract by either party. The disciplinary measures that may be taken cover:

Warning;

EUREPGAP non-compliances of minor issues agreed in this contract will lead to a Warning. The maximum time allowed for correction will be 28 calendar days. If the cause of the warning remains unresolved on expiry of this period, a complete

suspension will be imposed. EUREPGAP non-compliances will involves a written caution to the offending farmer, the nature of the offence, the corrective actions expected, monitoring of the corrective actions to verify they have been implemented and the likely consequences of not complying. Suspension; warnings are of two types; deferred and immediate

Deferred Suspension

EUREPGAP non-compliance of any minor must control point will lead to deferred suspension. The farmer will be given up to 28 calendar days for resolution of the problems the suspension originated from. Once this period has elapsed without resolution, the sanction imposed will be an immediate suspension.

Immediate suspension

Immediate suspensions result in a removal of the farmer from the farmer register for a limited period (maximum 6 months). Suspensions will be lifted once there is written / visual evidence that its causes do not longer exist. Non-compliance of any major must control point will lead to immediate suspension. The extent of the suspension can be limited to a clearly identified, traceable part of a registered crop (field or batch). Non-compliance with any of the agreements signed in this contract or any issue found during the inspection that leads to doubts about the farmer's way of proceeding will lead to an immediate complete suspension of the farmer.

Expulsion/cancellation If there is no written / visual evidence during the period of suspension that the farmer has put in place suitable corrective actions to avoid the re-occurrence of non-compliances, the farmer group or service provider shall cancel its contract with the farmer or farmer group and exclude him/her from the farmer register.

Farmer Group vs Customer/Exporter Company

A farmer group signs a contract with the exporter company(s)/customer(s) to whom they sell their produce. This contract stipulates the customer requirements on type of product, quality, quantity and prices offered for the produce. It also stipulates mode of payment to the group and other financial arrangement, the roles and obligations of

each party, the rules and regulations and the disciplinary actions taken should either party violate the terms of the agreement. The disciplinary measures that may be taken cover:

Warning:

This involves a written caution to the offending party, the nature of the offence, the corrective actions expected, monitoring of the corrective actions to verify they have been implemented and the likely consequences of not complying.

Suspension:

This involves formal documented a temporarily suspension of the contract for a certain duration of time. The nature of contractual default is clearly explained, the expected remedial action and accompanying monitoring actions spelt out and the consequences of not complying explained.

Termination:

This involves a complete withdrawal of either party from the contractual arrangement. This occurs when either party defaults on the contractual requirement that attracts this measure. The decision is written and communicated to the concerned party. The termination may not be permanent and can be reinstated depending on how willing both parties are to work to resolve the points of departure.

Appeals.

Either party has the opportunity to appeal against any of the above decision according to the laid down contract.

5.5.3.1 Use Case 29 - Add New Sanction Details

Use Case Id	UC29
Description	The main purpose of this use case is to capture new sanction details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	This use case is triggered when the actor requests to capture new sanction details
Measurable Result	Sanction information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the sanction, such as farmer code, date, reason for action and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new sanction details are captured in the system and the list of sanctions that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture sanction information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Sanction information saved successfully

5.5.3.2 Use Case 30 - Modify Sanction Details

Use Case Id	UC30
Description	The main purpose of this use case is to modify existing sanction details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing sanctions
Measurable Result	The existing sanctions information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing sanction and the system presents the information. The actor makes a request to edit all the information except the list of sanctions. The actor can either save the changes or return to the list of sanctions without any changes being saved.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify sanction details due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Sanction details updated successfully

5.5.3.3 Use Case 31 - Delete Sanction Details

Use Case Id	UC31
Description	The main purpose of this use case is to remove existing sanction details
Primary Actors	Technical Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing sanctions
Measurable Result	The existing sanction details is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of sanctions. The actor then requests to delete a particular sanction details. If the corrective action has been raised during an audit report, the actor will be advised of this by the application and the delete will not be allowed.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete sanction due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Sanction details deleted successfully

5.6 Production Manager Roles

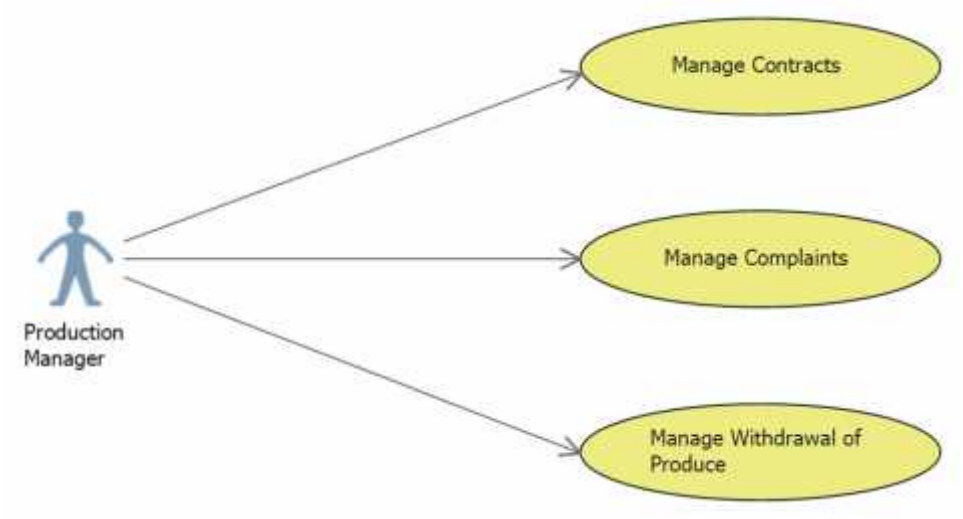


Figure 7: Production Manager Roles

5.6.1 Contract Management

The system will ensure contracts are captured at two levels:

1. Farmer vs Farmer Group

   This will include a list of members name with their signatures, a general map of the farmer group indicating where each farm is located, farm identification code and block registration and so on.

2. Farmer Group vs Exporter Company

   This will contain the organizational and management structure and how it relates to the farmer group, payment modalities, price structure particularly during the low and high seasons, shared risk on the rejects levels of produce, production and planting programmes, volumes and types of produce, technical quality specifications of produce involved, inputs to be provided and terms of provision and so on

5.6.1.1 Use Case 32 - Add New Contract Details

Use Case Id	UC32
Description	The main purpose of this use case is to capture new contract details
Primary Actors	Production Manager
Secondary Actors	None
Trigger	This use case is triggered when the actor requests to capture new contract details
Measurable Result	Contract information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the contract, such as list of members, contact persons, commercial details and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new contract details are captured in the system and the list of contracts that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture contract information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Contract information saved successfully

5.6.1.2 Use Case 33 - Modify Contract Details

Use Case Id	UC33
Description	The main purpose of this use case is to modify existing contract details
Primary Actors	Production Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing contracts
Measurable Result	The existing contract information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing contract and the system presents the information. The actor makes a request to edit all the information except the list of contracts. The actor can either save the changes or return to the list of contracts without any changes being saved.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify contract details due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Contract details updated successfully

5.6.1.3 Use Case 34 - Delete Contract Details

Use Case Id	UC34
Description	The main purpose of this use case is to remove existing sanction details
Primary Actors	Production Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing contracts
Measurable Result	The existing contract details is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of contracts. The actor then requests to delete a particular contract details. If the contract is effected in the current growing season, the actor will be advised of this by the application and the delete will not be allowed.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete contract due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Contract details deleted successfully

5.6.2 Complaints Handling

The ability to effectively manage customer complaints is considered essential to the success of farmers' group. If a buyer has reason to complain, for example on the presence of a pesticide residue above set MRL, this may have serious consequences for individual farmers, such as the withdrawal (recall) of products, cancellation of individual registrations etc. Depending on the circumstances, such events may also result in a loss of credibility of the entire Farmer Group. For this reason complaints are handled by the Production Manager him/herself in order to find out whether the problem is a singular event or reveals a general lapse in the system. The system should ensure that customer complaints are thoroughly recorded, investigated and followed up. In addition, the records associated with the complaints and corrective actions need to be captured and maintained in the system as follows:

1. Date the complaint is received
2. Complaint reference number
3. Complaint description
4. Root cause
5. Corrective action
6. By whom
7. By when
8. Action status

5.6.2.1 Use Case 35 - Add New Complaint Details

Use Case Id	UC35
Description	The main purpose of this use case is to capture new complaint details
Primary Actors	Production Manager
Secondary Actors	None
Trigger	This use case is triggered when the actor requests to capture new complaint details
Measurable Result	Complaint information is captured successfully in the system
Main Flow	The actor is prompted to enter information that defines the complaint, such as date the complaint is received, complaints reference number, root cause, corrective action and so on. The actor can choose to save the information or cancel the operation. If the actor decides to Save the information the new complaint details are captured in the system and the list of complaints that was presented earlier is updated.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to capture complaint information due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Complaint information saved successfully

5.6.2.2 Use Case 36 - Modify Complaint Details

Use Case Id	UC36
Description	The main purpose of this use case is to modify existing complaint details
Primary Actors	Production Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing complaints
Measurable Result	The existing complaints information modification is either cancelled or completed
Main Flow	This use case begins when the actor requests to review an existing complaint and the system presents the information. The actor makes a request to edit all the information except the list of complaints. The actor can either save the changes or return to the list of complaints without any changes being saved.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to modify complaint details due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Complaint details updated successfully

5.6.1.3 Use Case 37 - Delete Complaint Details

Use Case Id	UC37
Description	The main purpose of this use case is to remove existing complaint details
Primary Actors	Production Manager
Secondary Actors	None
Trigger	The actor MUST have displayed a list of existing complaints
Measurable Result	The existing contract details is either deleted or the delete cancelled by the system
Main Flow	This use case is started when the actor requests for a listing of complaints. The actor then requests to delete a particular contract details. If the complaint is effected in the current growing season, the actor will be advised of this by the application and the delete will not be allowed.
Alternate Flow	1. The actor enters an improper value for one of the fields. The system will not allow the update until a proper value for the field is entered. 2. Should for any reason, the application fail to delete complaint due to system problems, network issues and so on. This message will be shown: "<<Problem Description Occurred>>, please contact your administrator" and the application module will close down gracefully.
Post condition	Complaint details deleted successfully

5.6.3 Withdrawal of Certified Produce

The system should be able to capture the operating plan which will be executed in the event that a product problem is discovered which has the potential to affect the health of consumer, violates food safety regulations of the importing country, or could cause adverse public consequences for the exporter. The procedure will be tested annually in order to make sure that it can be effectively operated at any time should that be required.

In order to recall the correct batch of produce, the list of produce dispatched to the customer is used to trace which batch was sent to the customer (and when). In order to get to the root cause of the problem, the recall produce batch is traced back to the field block and seed. The seed lot number linked back to record of seed receipt and issue and seed delivery notes. Corresponding sowing and harvesting records will also be investigated and stock reconciled.

5.7 External Auditor Roles

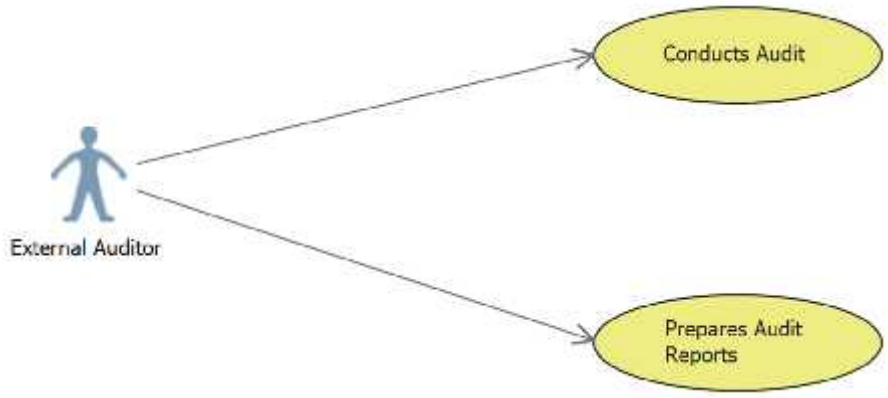


Figure 8: External Auditor Roles

5.7.1 External Audit and Reports

The system will ensure third party auditors (GlobalGAP, EUREPGAP and so on) are able to audit and assess the Quality Management System of farmer groups for compliance with the respective standard.

The system should enable the third party auditors to produce timely and accurate reports on such audits in accordance with the report format of the respective auditing body.

CHAPTER SIX: ANALYSIS AND DESIGN

6.1 Introduction

In this chapter converts use cases specified during requirement specification in chapter five of this document into analysis and design models. This is achieved through use-case analysis and design approach as proposed by Jacobson et al. (1994). This entailed.

1. Identification of classes which perform a use case's flow of events.
2. Distribution of use case behaviour to those classes, using use-case realizations.
3. Identification of responsibilities, attributes and associations of the classes.
4. Identification of usage of architectural mechanisms.

6.2 Domain Model

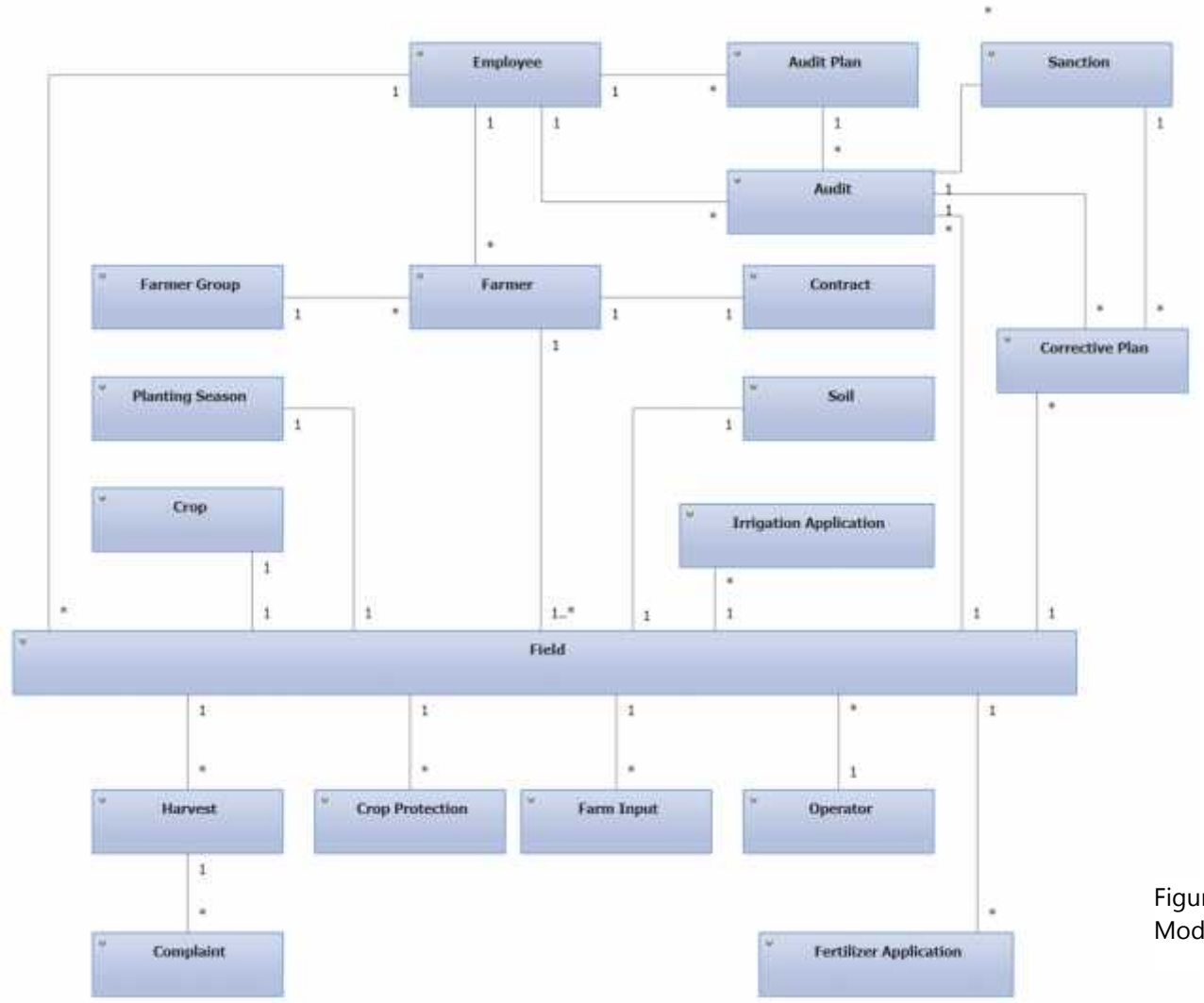


Figure 9: Domain Model

6.3 Farm Production Process Flow

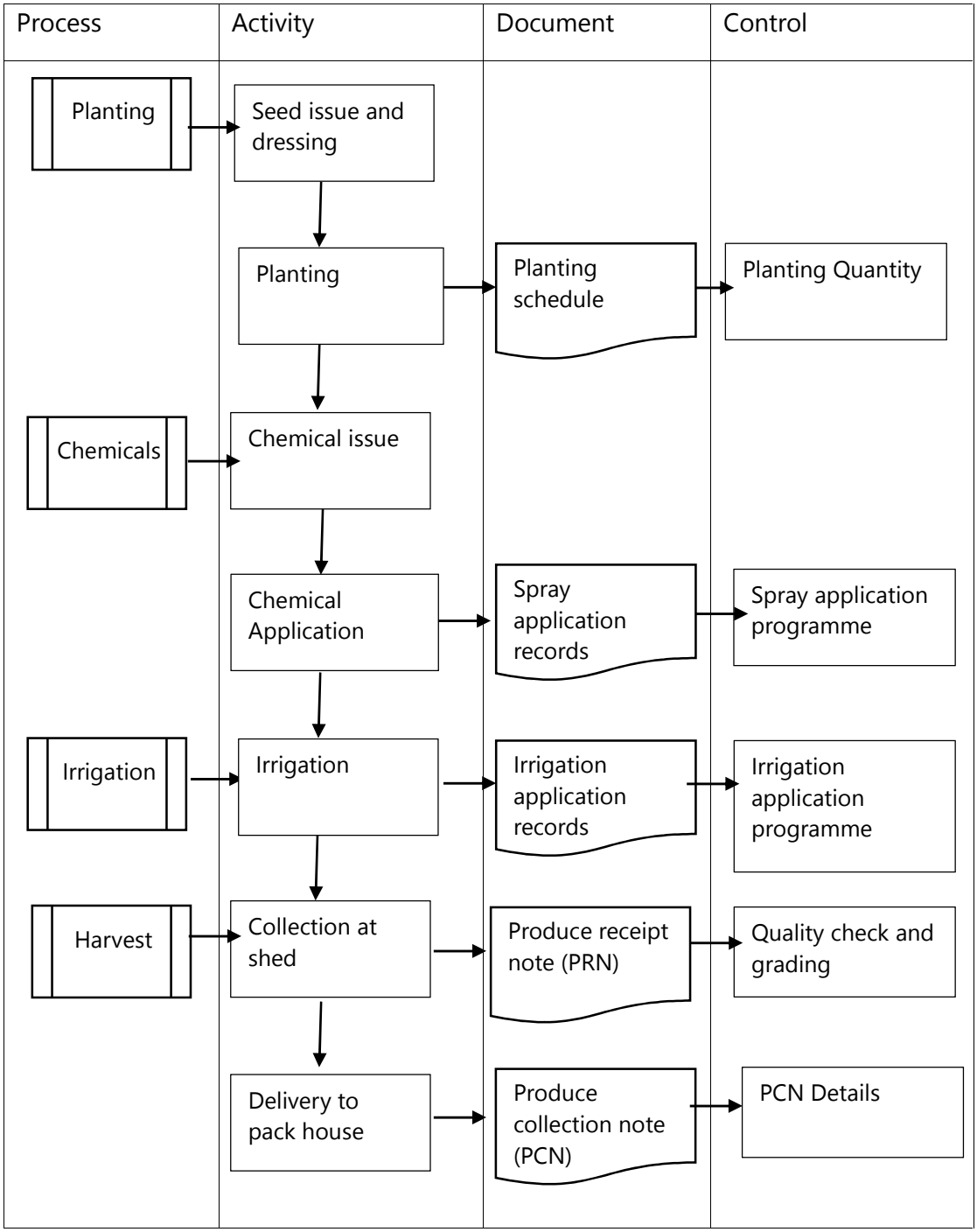


Figure 10: Farm production process flow

6.4 Traceability Process Flow

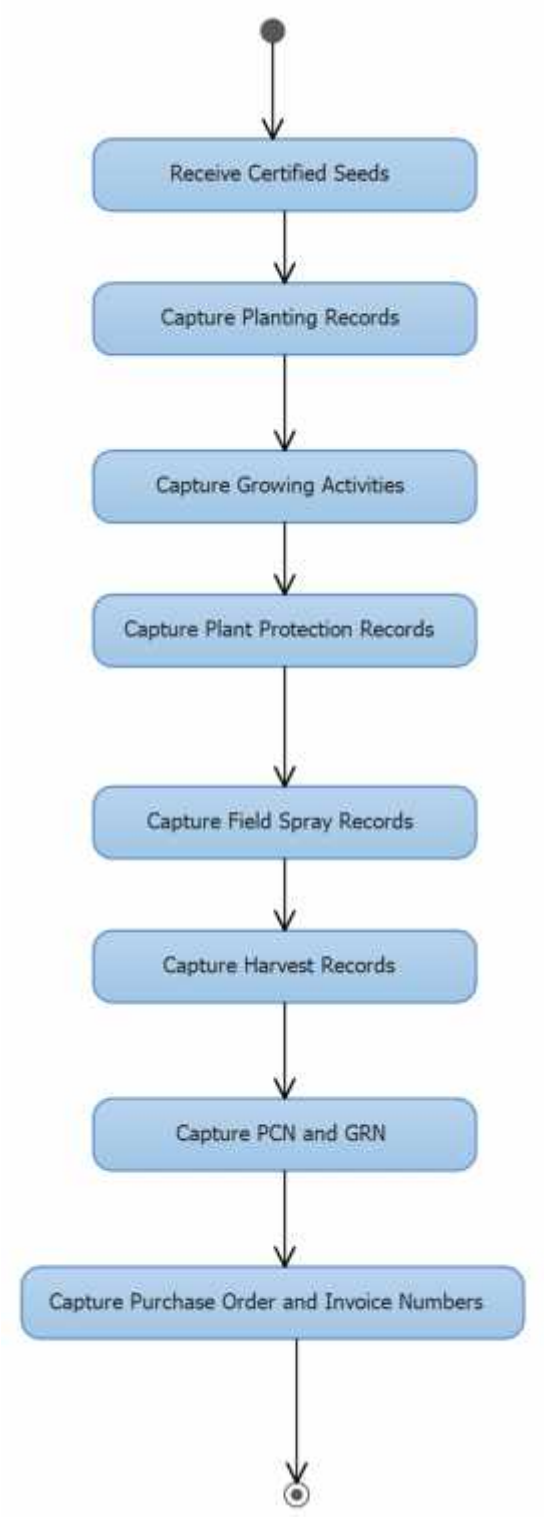


Figure 11: Traceability process flow

6.5 Class Diagrams

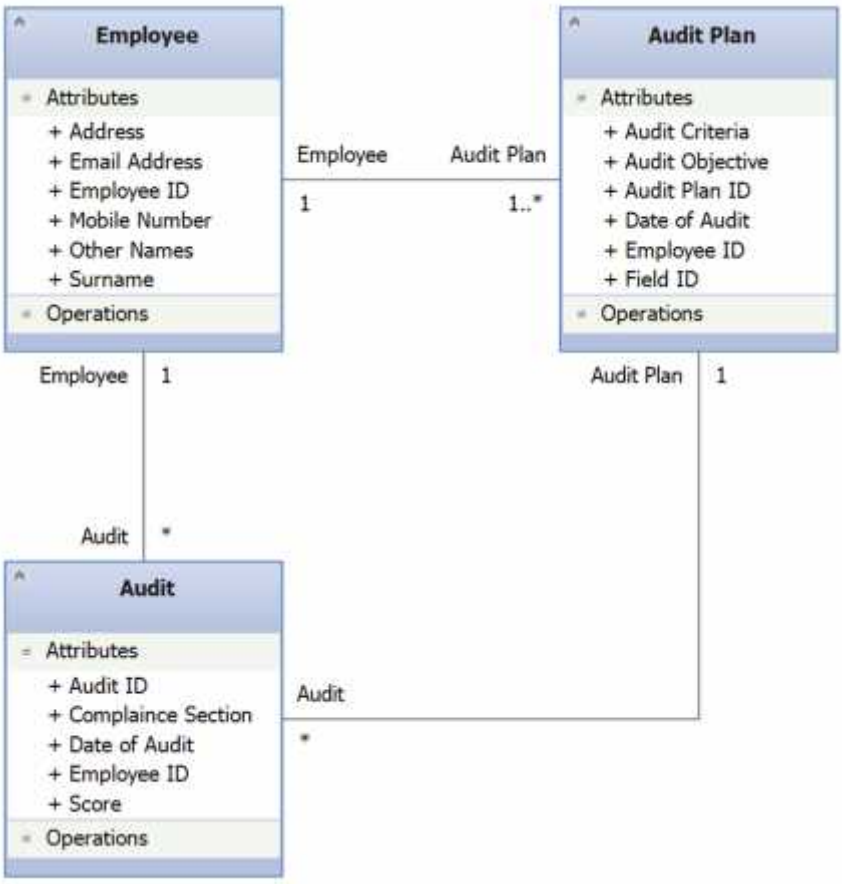


Figure 12: Employee model class diagram

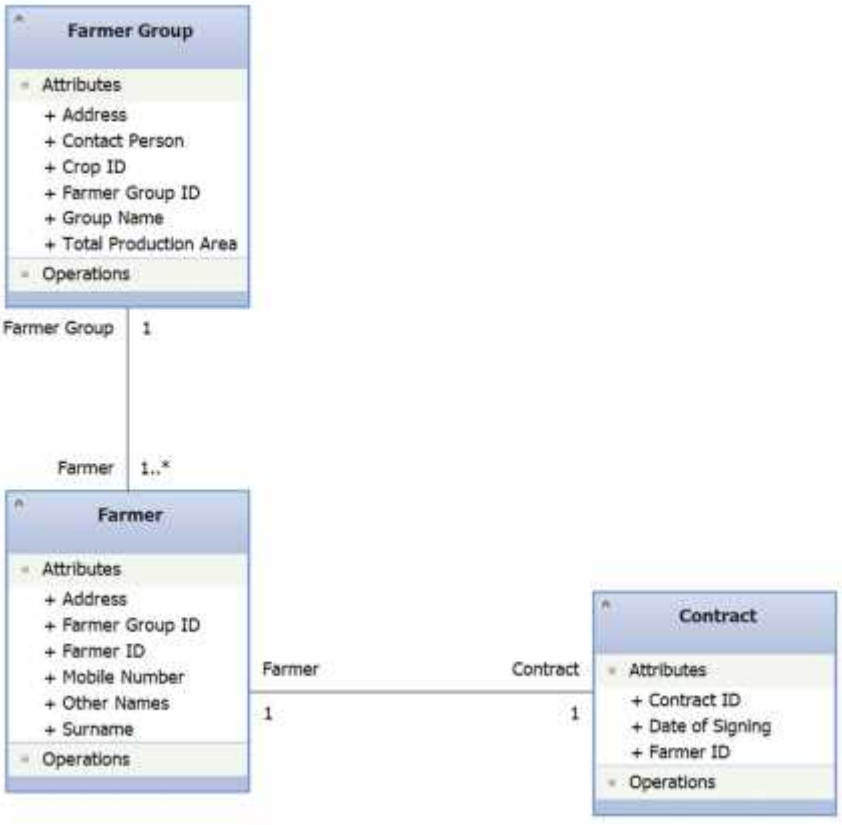


Figure 13: Farmer model class diagram

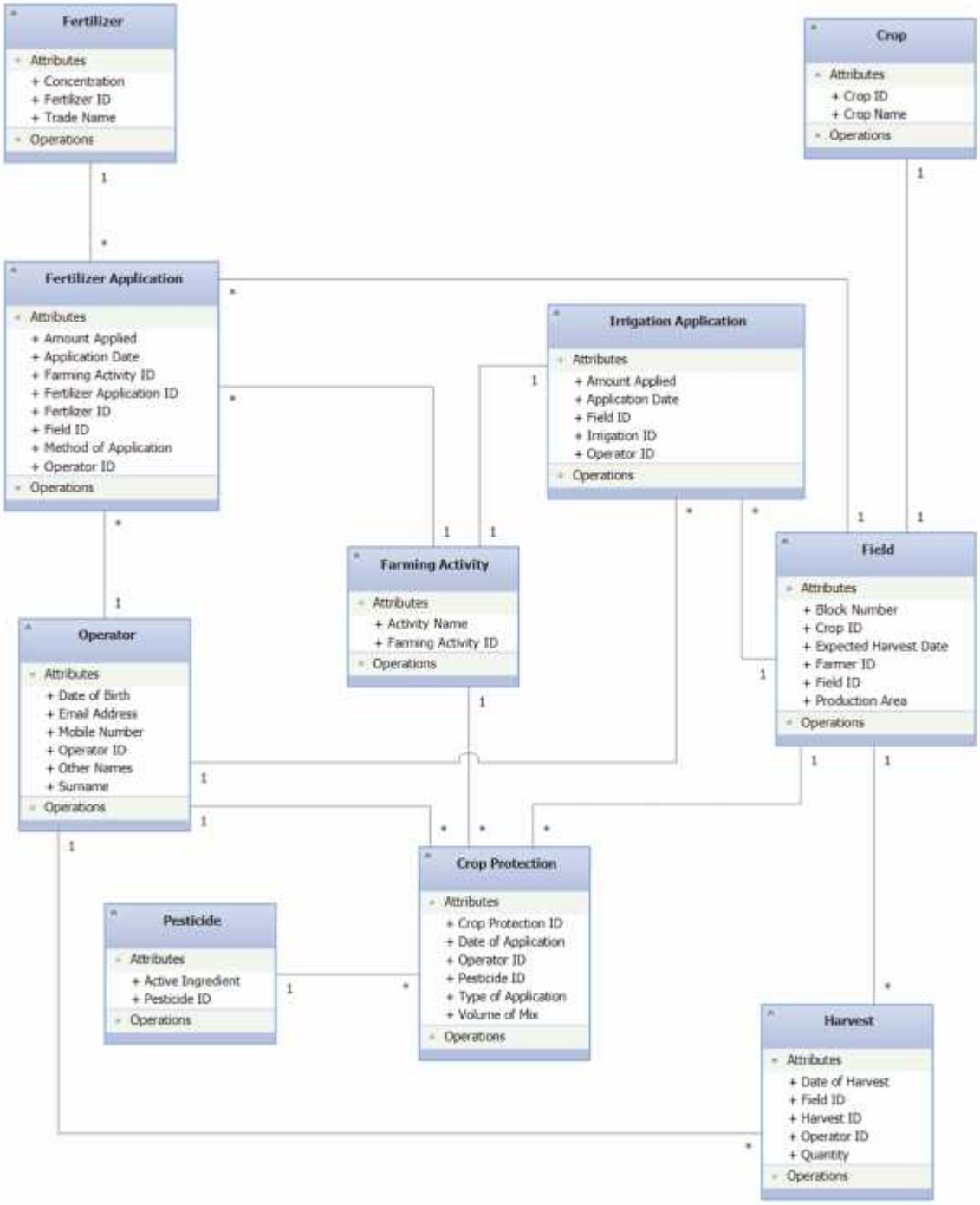


Figure 14: Field model class diagram

6.6 Sequence Diagrams

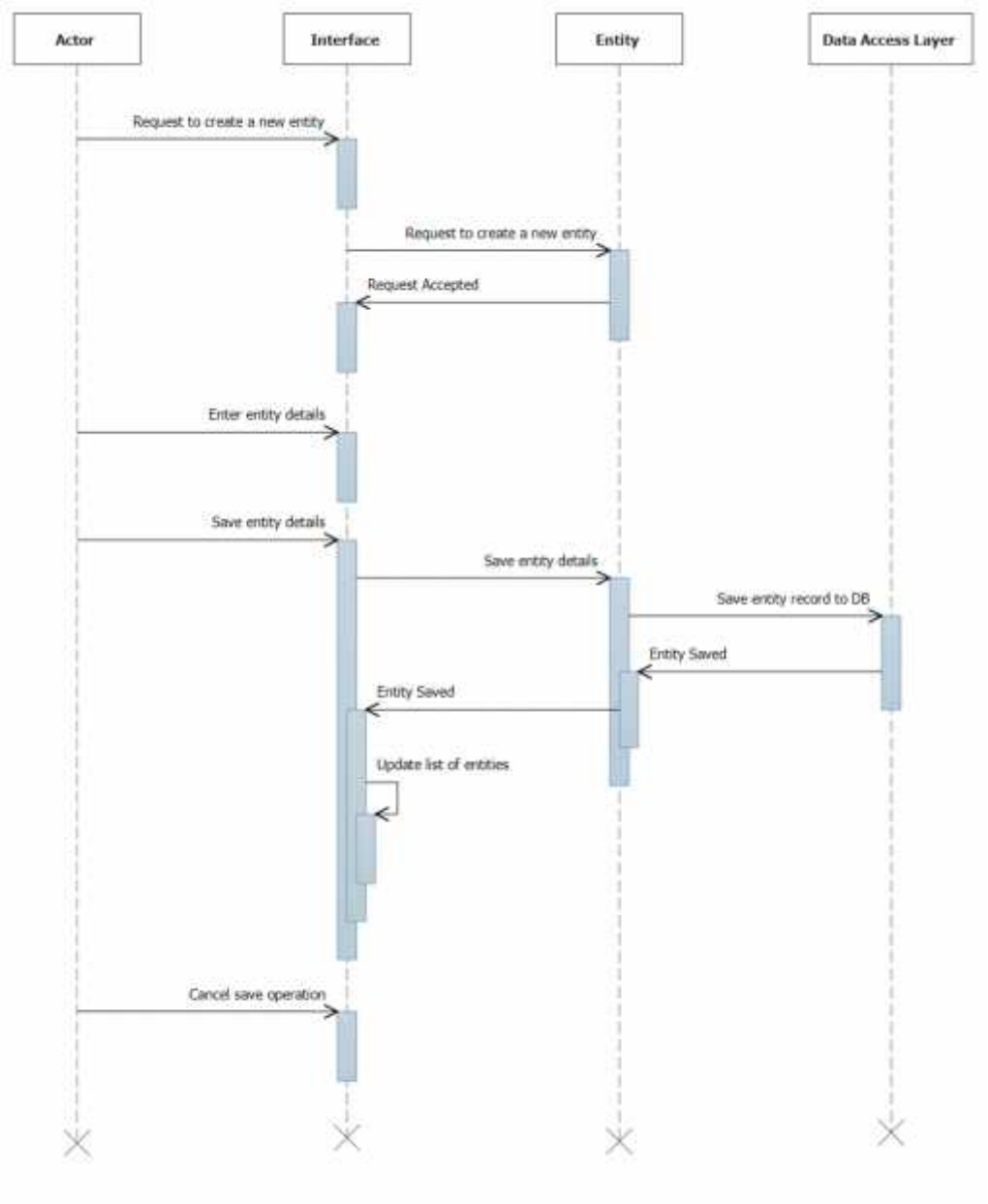


Figure 15: Add entity sequence diagram

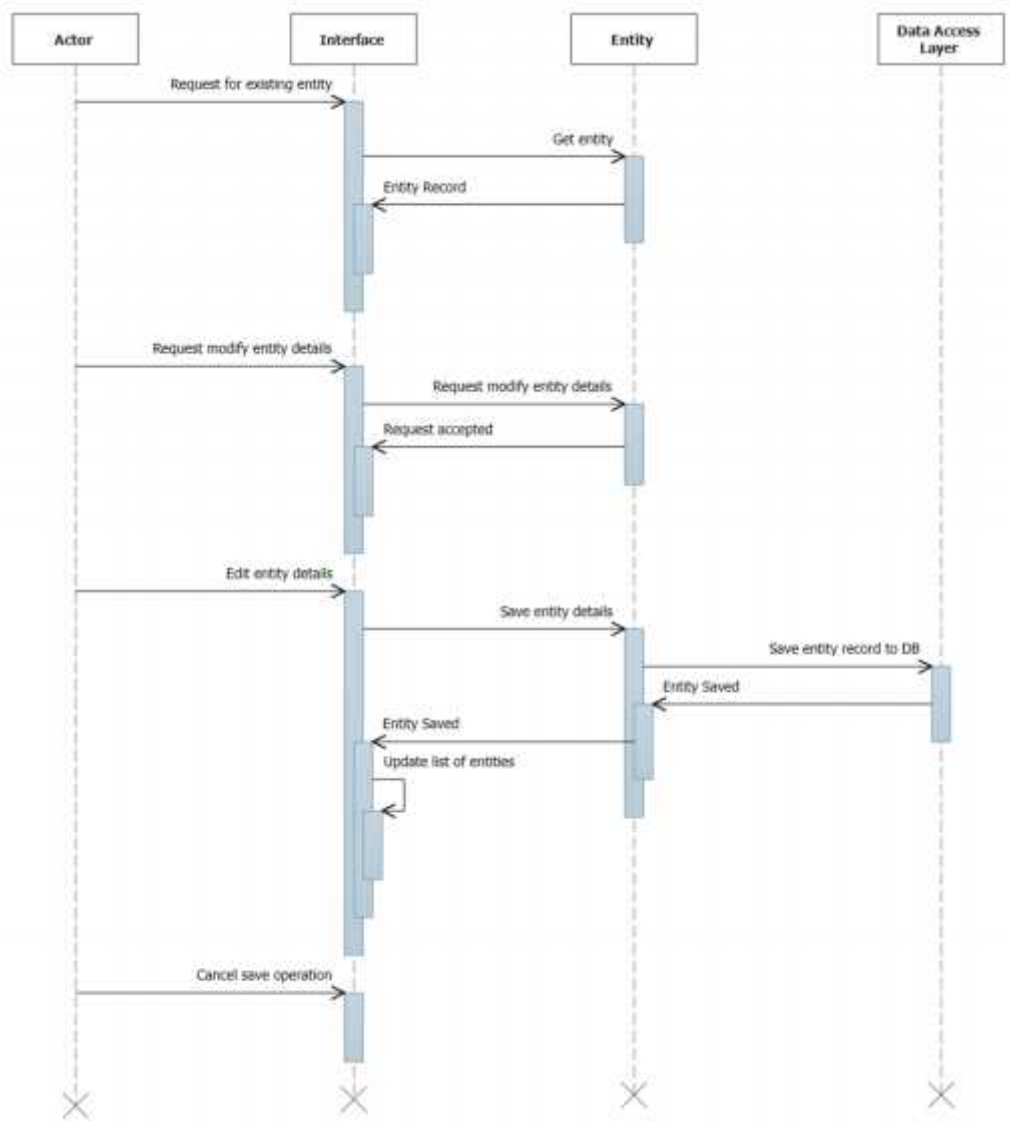


Figure 16: Edit entity sequence diagram

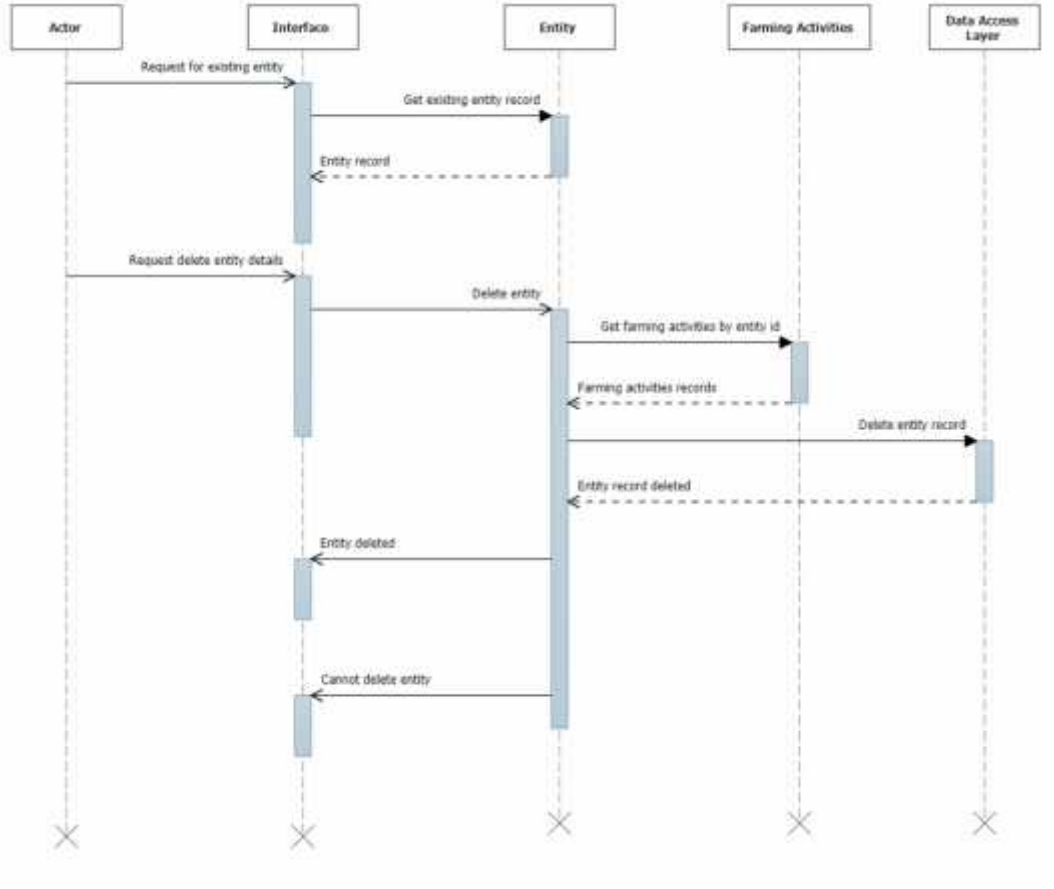


Figure 17: Delete entity sequence diagram

6.7 Overall Application Architectural Design

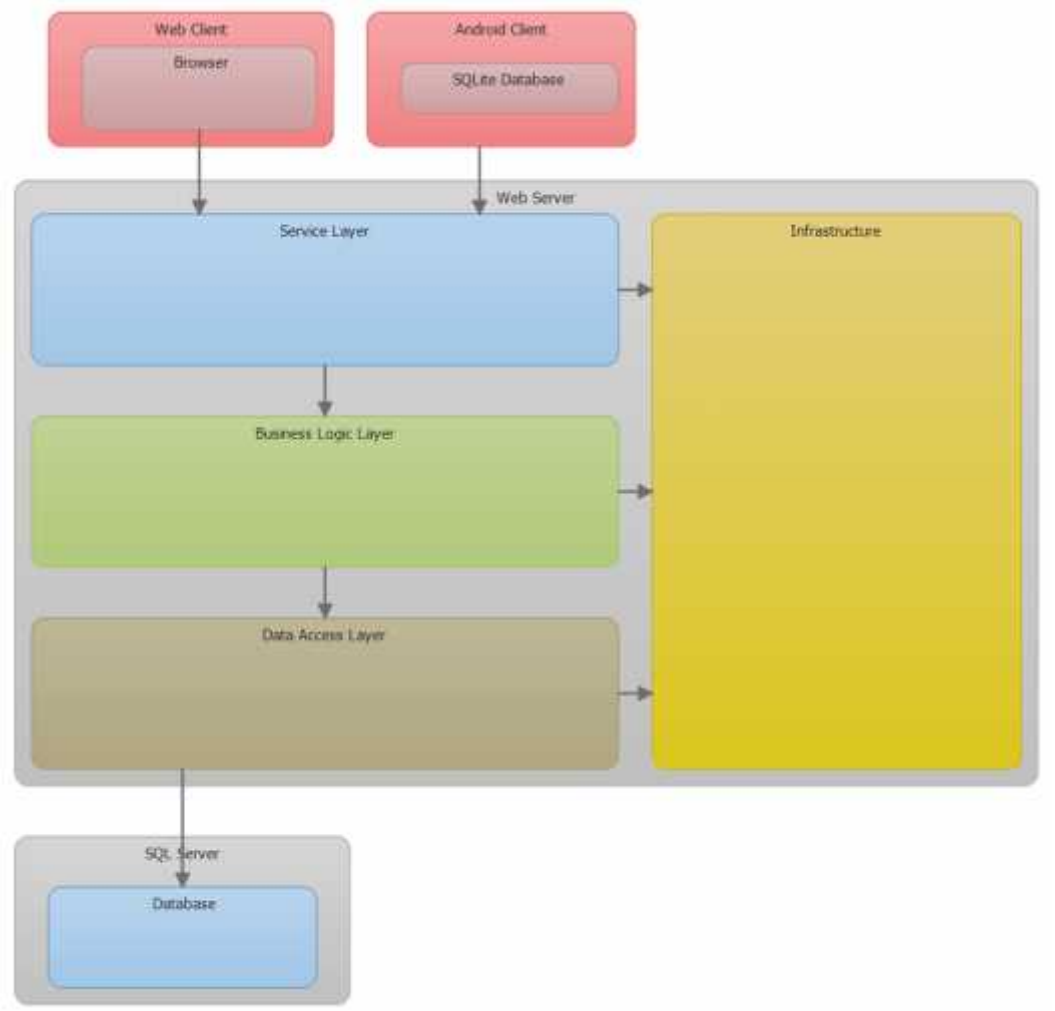


Figure 18: Overall Application architectural design

Presentation Layer

For modern MVC web applications, the presentation layer (server-side) consists of a Controllers who's only tasks are to render an HTML page, CSS, Javascript, HTML templates, images, etc. Very little server-side code, if any, is responsible for any UI rendering responsibilities. Once the page is rendered in the browser client-side components (the browser or user agent that executes scripts and displays the HTML). With client-side techniques such as AJAX and with rich client-side frameworks, it is possible to execute logic on the client, for nice fluid user experiences. Implementing a Single Page Application, can greatly increase the user experience by, reducing or eliminating post backs and refreshes.

Business Logic Layer

Using a separate business layer that implements the business logic and workflows will improve the maintainability and testability of the application, and allow you to centralize and reuse common business logic functions between the web application and android client.

Data Layer

This layer will abstract the logic necessary to access the database. This can be achieved with implementing the Repository pattern, the Repository pattern is often implemented with the Unit of Work pattern. Entity Framework already implements the Unit of Work Pattern with the DbContext. Using a separate data layer makes the application easier to configure and maintain, and hides the details of the database from other layers of the application.

Your business entities, usually shared between the layers of your application e.g. Business and Data Layer should be POCO entities.

Services Layer

This business logic will be exposed via a separate service layer given that the plan to expose your business logic using an API. Web API has become integral part of the web development now and most of the services now are exposed via Web API as against Web Services. Web API mainly returns light weight JSON formatted data (it can also return XML) that can be easily converted into object and easily understood by JavaScript to manipulate and iterate. Web API is based on HTTP is very light weight and perform much better than Web Services where SOAP

is used to transfer the data and convert back to request - response. This approach offers developers the ability to fully harness the richness of HTTP as an application layer protocol to communicate with a broad set of clients, including browsers, mobile devices, desktop applications, or backend services. The architecture is designed to support applications built with REST, but it does not force new applications to use a REST-style architecture.

Infrastructure Layer

Infrastructure is the foundation of an application. This term broadly to refers to any of the core cross-cutting functionalities that are required for scalable applications. This includes:

- Logging
- Exception handling
- Application settings
- Inversion of control (IOC)/dependency injection
- Object-relational mapping (ORM)
- Caching

6.8 Android Application Architectural Design

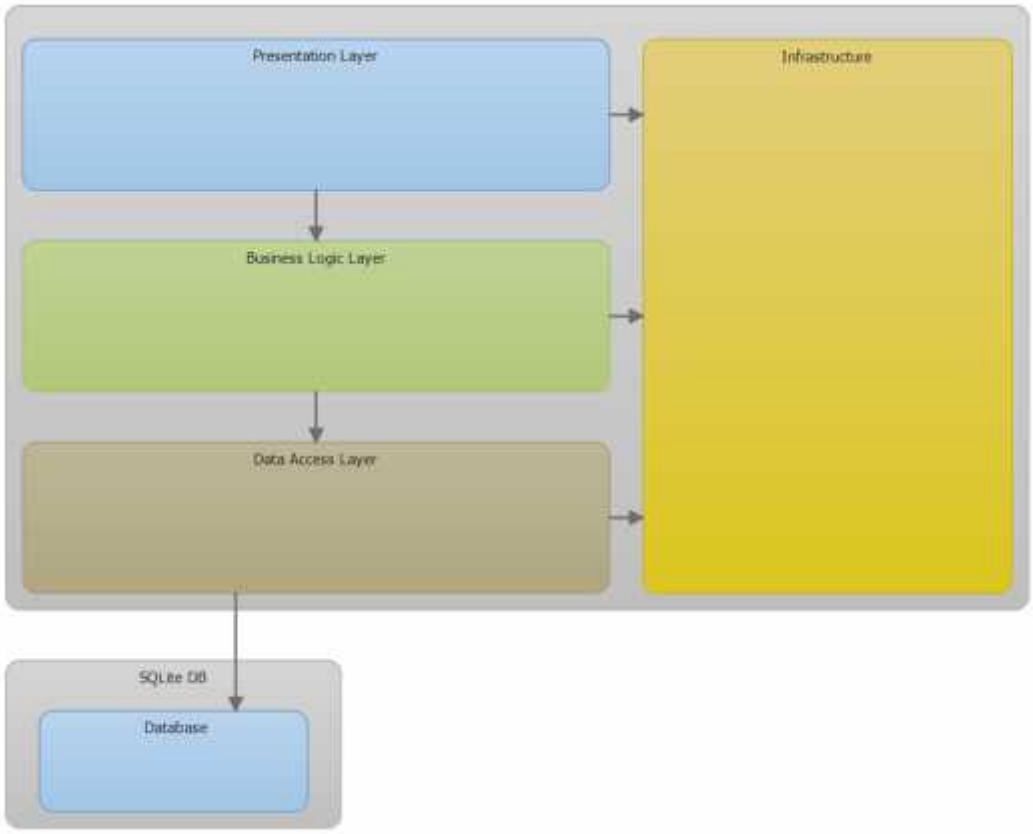


Figure 19: Android Application architectural design

Presentation Layer

this is where the logic related with views and animations happens. It uses no more than a Model View Presenter. Android fragments and activities are only views, there is no logic inside them other than UI logic, and this is where all the rendering takes place. Presenters in this layer are composed with interactors (use cases) that perform the job in a new thread outside the android UI thread, and come back using a callback with the data that will be rendered in the view.

Business Logic Layer

All the business logic happens here, this layer is a pure java module without any Android dependencies.

Data Access Layer

All the data needed for the application comes from this layer through repository pattern implementation. The idea behind that is that the data origin is transparent to the client, which does not care where the data is coming from.

6.9 Application Component Design

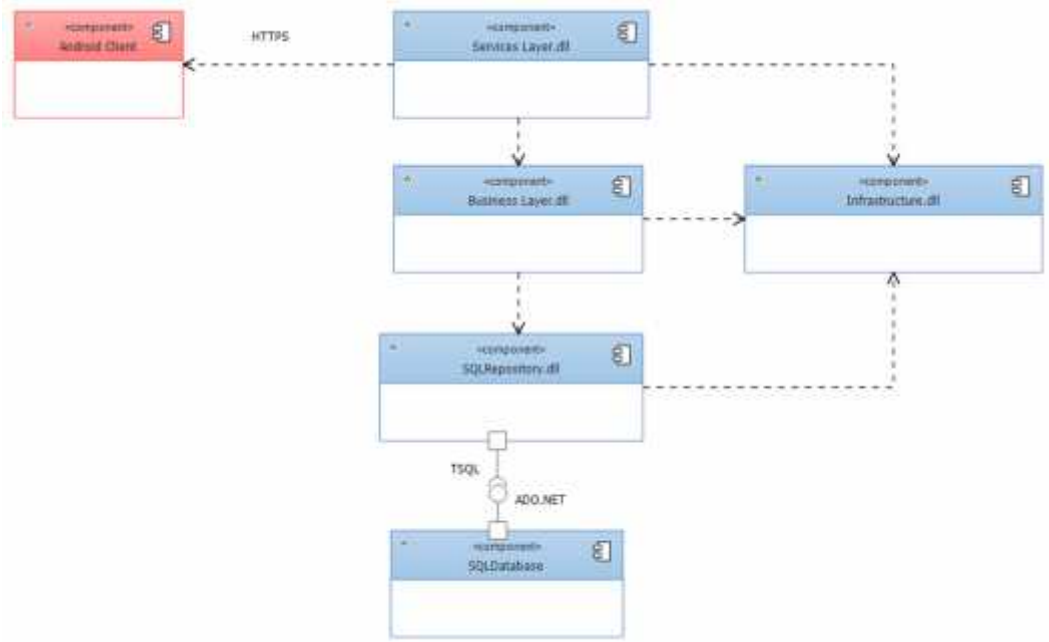


Figure 20: Application component design

CHAPTER SEVEN: PROTOTYPE IMPLEMENTATION AND TESTING

7.1 Introduction

This chapter presents a detailed description of how the various artefacts from chapter six were implemented. It describes the implementation and integration of both the web and android client as the resulting product thus effectively meeting the objectives of the study.

7.2 Implementation Environment

The web client was built as a Single Page Application (SPA) using AngularJS, WebAPI and Entity Framework as shown in figure 19 below.

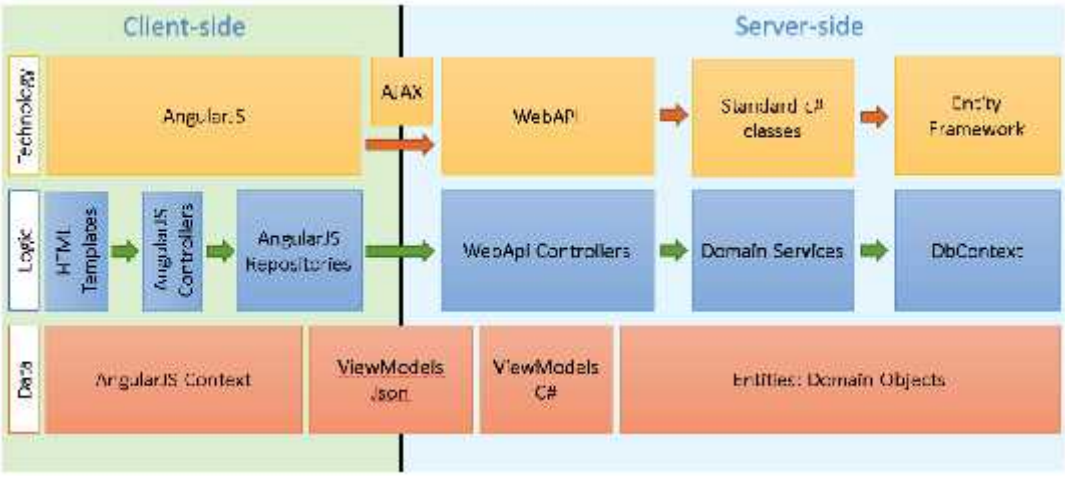


Figure 21: Client and server-side implementation environment

From figure 21 above, the first row is the communication between the different technologies. The middle row represents the logic of the application and the last the data containers used on these classes.

The mobile client was implemented on Android 5 (Lollipop) and integrated to the web client using Retrofit which is a modern type-safe REST client library for Android and

Java created by Square Inc. It provides a convenient way for authenticating and interacting with various APIs and allows for sending network requests with OkHttp or HttpUrlConnection. The library was used for fetching JSON data from the WebAPI and parsing the response once it's received into Plain Old Java Objects (POJO).

7.3 Justification of Development Stack

1. The choice to build a native Android mobile app was informed by the fact that the app would need to work offline due to lack of network coverage in some of the fields. The field officers have also caused a lot of problems in the industry by avoiding going to the fields thus giving wrong reports and non-existent farmers to show that they have been working. The app enables company management to look on the Web Application and immediately see which Technical Assistants have been capturing what data, where, and for which farmers or blocks. With the farmers' profiles, exporters are better placed to manage the smallholders. For this implementation the app required to take advantage of the device's features such as the camera, compass, device geolocation and so on.
2. The Microsoft Azure cloud was chosen to allow for real-time reporting from the field to the head-office management to monitor all field operations from the head office. It allows for more efficient diagnoses of field issues, and faster remedial action to be taken. This was achieved by synchronizing data from the mobile app to the SQL Azure database in the cloud making the data available to all users across the world.
3. AngularJS was chosen to build the web client as a Single Page Application since it gives the greatest return on workload as an application gets closer to the single-page model. Single-page applications take a different approach. An initial HTML document is sent to the browser, but user interactions lead to Ajax requests for small fragments of HTML or data inserted into the existing set of elements being displayed to the user. The initial HTML document is never reloaded or replaced, and the user can continue to interact with the existing HTML while the Ajax requests are being performed asynchronously, even if that just means seeing a "data loading" message.

4. The WebAPI controllers can send and receive data in JSON format. The JSON objects are automatically translated to C# view models. The WebAPI controllers also request domain objects to the domain services and translate it to ViewModels before sending it back to the client-side in JSON format.
5. Entity Framework allows the definition of entities for domain specific classes containing all the data related to the domain. These classes are completely independent of the view and are mapped directly to the database using EF as an object relational mapping tool.
6. GSON is a Java library used for serializing and deserializing Java objects from and into JSON. A task that is needed whenever there is communication with an API. The choice for GSON was mostly because it's lightweight and much simpler than XML.
7. Retrofit turns your REST API into a Java interface, it's an elegant solution for organizing API calls within a project. The request method and relative URL are added with an annotation, which makes code clean and simple. With annotations, you can easily add a request body, manipulate the URL or headers and add query parameters. Adding a return type to a method makes it synchronous while adding a callback will allow it to finish asynchronously with success or failure. Retrofit uses GSON by default, so there is no need for custom parsing.
8. Otto Event Bus is a library that simplifies communication between different parts of the application. For example, sending something from an activity to a running service, or easy interaction between fragments.
9. GreenDAO when developing an Android application, there will more often than not have a need to store data somewhere. In this case, the researcher chose to store the data in an embedded SQLite database. The ORM of chosen for this purpose was GreenDAO given that when it comes to performance, 'fast' and GreenDAO are synonymous.

7.4 Case Tools

Among the case tools used were:

1. Visual Studio 2013 and Android Studio were used as the Integrated Development Environments
2. Visual Studio 2013 Modelling Tools was used for drawing the analysis models
3. SQL Server Management Studio was used for managing both SQL Server and SQL Azure databases

7.5 Testing

The types of tests conducted during the implementation of the prototype as highlighted in the following sections.

7.5.1 Unit Tests

These are software tests written for programmers by programmers in a programming language and they should isolate the component under test and able to test it in a repeatable way. Junit was used in writing all the unit tests since it is the de-facto standard for writing unit tests in Android.

7.5.2 Integration Tests

These are designed to test the way individual components work jointly. Modules that have been unit tested independently are now combined together to test the integration.

7.5.2 UI Tests

These are the tests that involve the UI components, in Android only the main thread is allowed to alter the UI. This implementation used the special annotation @UIThreadTest to indicate that the particular test should run on that thread.

CHAPTER EIGHT: EVALUATION

8.1 Introduction

This chapter discusses the evaluation of the prototype. It contains what methods/techniques the researcher used in the collection of results. In the beginning, overview of usability testing is discussed. Then Pilot usability test is discussed. The test environment is discussed which explains the environment during tests. Furthermore designing of tasks and also four tasks are presented for both web and android applications. At the end questionnaires and interview are explained as to that how the researcher distributed questionnaires and carried out interviews

8.2 Pilot Usability Test

This was conducted before starting actual usability tests, the researcher selected one farmers' grower group for pilot testing. This testing was important in this study to design the actual tasks well. The results based on pilot testing are not mentioned in the actual results but this helped the researcher in refining all tasks,

8.3 Test Environment

In this study, the researcher selected the group room for testing due to the calm environment there, so the users did not feel any disturbance while performing tasks. All the users have performed tests on a laptop one by one. All the necessary equipment for testing was checked before the testing to avoid technical problems in performing tasks. The calm environment helped the users to concentrate on the tasks. Furthermore, same computer, browser, connection speed were used for testing because it gave accurate results.

8.4 Test Conduction

Before conducting the usability test, users were carefully guided through the entire test conduction procedure. The researcher gave them useful information regarding usability evaluation and tasks of web based applications. This information helped users to know in a general way what was expected of them. Think aloud technique was used for testing in this study and users have been informed to think aloud while performing the tasks. During the test, the researcher observed each user while performing the tasks. Think aloud method (Nielsen 1993) was useful in this testing, and much information was collected by the researcher regarding interactivity of users with the web based application. By using this technique, the researcher observed that the users and could share how the users perceived the web-based application. Before starting the test, the tasks list was distributed to the user for performing the tasks. Time was noted for each task and the researcher noted down all the observations and observations expressed by the user while performing the tasks.

8.5 Selection of Users

The users have the main role in performing the usability test. For this purpose, six users were selected from two different farmers' grower groups. Two users were novice who had not use smart phones and web based applications before and other the four were the kind of users who had experience of using both applications. The selection of suitable users was important which is why the researcher met with many farmers' grower groups and six users were finally selected.

1. Novice Users (NU): Users who didn't have any experience of using either of two applications.
2. Experienced Users (EU): Users who had used both applications before

Table 4: Selection of users

No	Type	Farmers' Grower Group
1	Novice Users (NU)	Romwa Ventures Karie group
2	Experienced Users (EU)	Romwa Ventures Karie group

8.6 Designing the Tasks

Before designing tasks for usability testing the researcher met with several farmer's grower groups and asked them for what information is captured during the growing cycle. It helped the researcher a lot for defining of tasks which would be helpful in evaluating usability of the applications.

8.6.1 Task 1: Register Farmer's Group

1. Go to FarmTrace site at http://farmtrace.azurewebsites.net/
2. Click on Login button
3. Enter dummy username and password
4. Click on Farmer's Menu and select Group
5. Click Add New button
6. Enter the required details
7. Click Save button

8.6.2 Task 2: Edit Farmer's Group

1. Click on Farmer's Menu and select Group
2. Select the existing group that you wish to edit from the list
3. Enter the required details
4. Click Save button

8.6.3 Task 3: Capture Growing Activity

1. Click on Home button on Android smartphone
2. Click on FarmTrace Application to open it
3. Enter dummy user name and password
4. Click on the Field whose activity you wish to capture
5. Click floating action button and choose the activity
6. Enter the required details
7. Click Save button

8.6.4 Task 4: Print Report

1. Click on Reports Menu and select report that you wish to print
2. Enter the various parameters that you wish to filter e.g. date and so on
3. Click View button
4. Click Print button

8.7 Questionnaire for Usability Evaluation

After the usability testing the designed questionnaire for evaluation of usability of both applications for different criteria were distributed to the participants. The questionnaire was designed in such a way that the researcher could get quantitative results from it. The questions in the questionnaire are related to the criteria that were selected by the researchers such as effectiveness, usefulness, user reaction, consistency, architectural and visual clarity, and functionality. Three of these criteria are presented by Koua et al. (2006), which suffice for assessing user performance and satisfaction with the applications while the remaining three criteria are adopted from IS&T guidelines, which covers its web-based nature. All six users gave feedback via the questionnaire.

8.8 Interview

After each participant had completed the usability test and filled in the questionnaire, a formal interview was conducted. The questions in the interview were open ended which encouraged the users in explaining their view in depth after testing of web-based GIS applications (Nielsen 1993). The researcher posed questions to the participants in a friendly environment and other author noted down their answers and responses regarding the interfaces of both applications in a note book. Those interviews with participants helped the researcher a lot in understanding more about the user's likes and dislikes, benefits and drawbacks of each application, their opinions and the purposes for which they are using the application.

CHAPTER NINE: RESULTS AND ANALYSIS

9.1 Introduction

All the results from the usability tests, questionnaires and interviews are presented in this chapter. First the usability test results are presented then an analysis is presented for both web-based and android applications regarding time spent on each task. Task observations for both applications are presented and questionnaire results are presented. Finally the interview results and analysis is presented.

9.2 Usability Test Results

The results have been collected through usability tests and questionnaires feedback. Six users were involved in the usability test in which two were novice users and four were intermediate users. For this purpose researcher met several farmers in Kirinyaga district to find out about their knowledge and experience of web-based applications. During tests on users, researcher noted down the time spent on each task and also observed the users while performing the tasks. The observations were noted in notebook. The timing results of tasks for two applications are shown in table 5 below.

Table 5: FarmTrace usability test results

User ID and Type	Task 1	Task 2	Task 3	Task 4
1 (NU)	02:45	01:04	02:30	01:47
2 (NU)	02:40	02:00	02:08	01:37
3 (EU)	02:28	01:40	01:47	01:07
4 (EU)	02:39	01:21	01:34	01:05
5 (EU)	00:55	00:40	01:45	00:47
6 (EU)	02:32	00:44	01:30	00:45

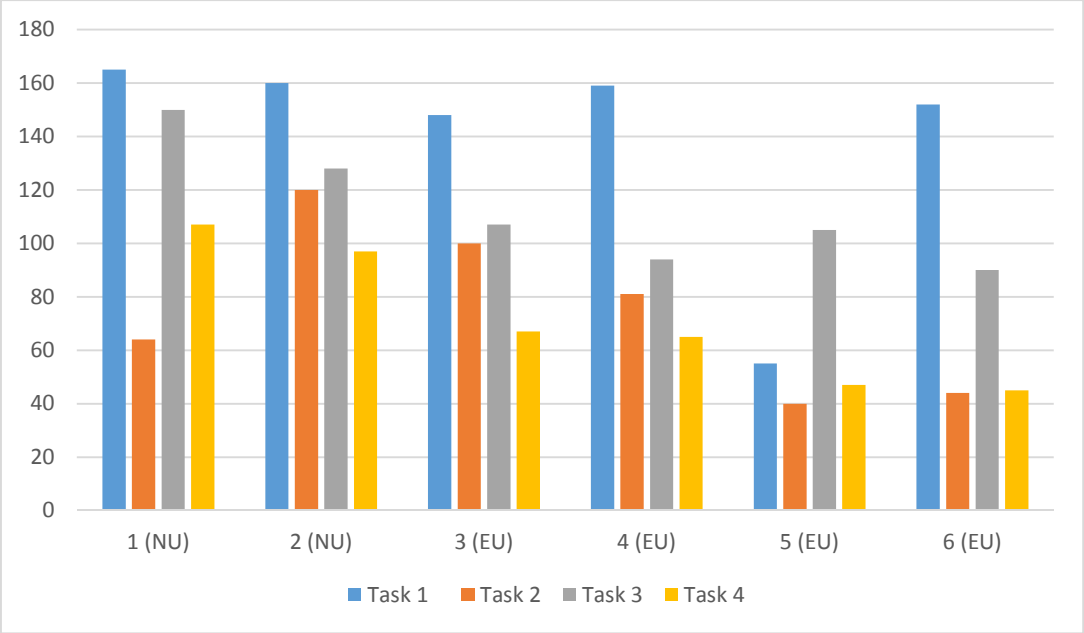


Figure 22: FarmTrace test results

9.3 Task Timing Analysis

The researcher calculated the average time of tasks of all users for both applications, figure 23 below shows a graphical representation of average time (in seconds) taken by both applications.

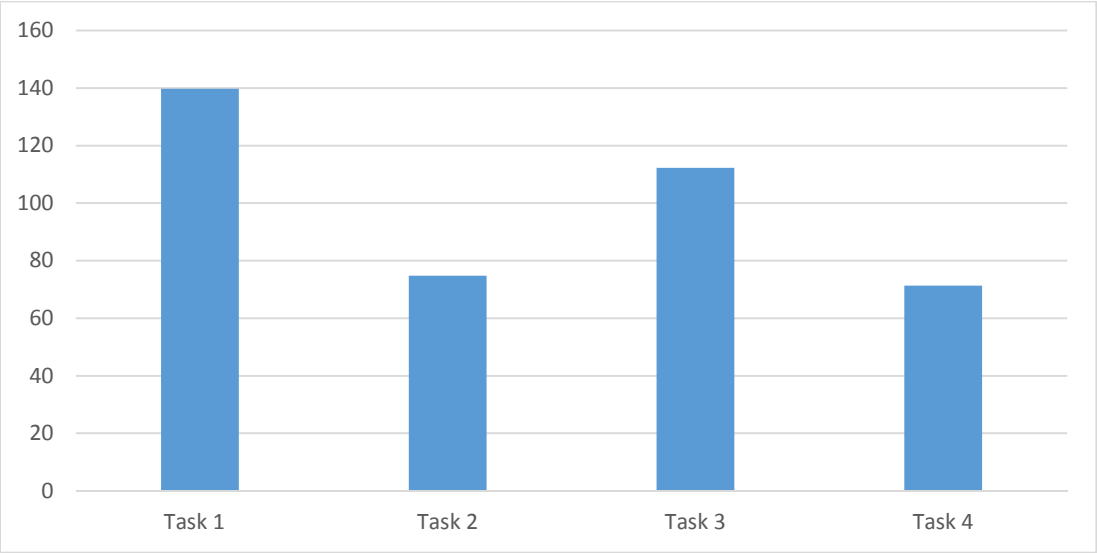


Figure 23: Average task timing

9.4 Test Observations

In this section the researcher presents the observed users performance while performing different tasks on both applications. These observations are discussed below task wise.

9.4.1 Task 1

In this task the user was required to log into the web application and register a farmers' growers group. While opening the application, it looks very simple and everything is organized. But novice users had some difficulty in finding the "Farmer > Group" link because it took some time to familiarize with the layout of the navigation menu.

9.4.2 Task 2

In this task the user was required to edit an existing farmers' growers group. The task was performed very smoothly by most users, since they could easily identify the group that they had created in task 1 and thus editing the details of the same proved easy.

9.4.3 Task 3

In this task the user was required to open the Android App and capture a growing activity. Novice users found the interface a bit non-intuitive given that most of them had not been exposed to the platform. Most didn't know where to find the floating button, overall users liked the button once they knew how to use it.

9.4.4 Task 4

Users easily located the reporting option on the menu, however average time taken was high due to the fact that most users didn't already have a filter in mind for the reports but were well satisfied that they could see a report of the growing activity that they had just captured in task 3 displayed with on a map with location information.

9.5 Questionnaire Results

The questionnaires were distributed to collect quantitative and qualitative data from the users in addition to the observations and think aloud method used during the usability test. The questionnaires were designed according to the adopted criteria for the evaluation of web based GIS applications. The adopted criteria were based on the criteria proposed by Koua et al. (2006) and the guidelines of IS&T Department, MIT (Usability Guidelines 2009) for usability evaluation of websites. As common users don't understand the criteria of evaluations, for this purpose the authors designed questionnaire according to Likert scale (5- point scale) and designed easy and understandable questions for all six criteria so that common users can answer it without difficulty. The questionnaire contains 24 questions all of which were close-ended, and the respondents have to check only one option for each question.

9.6 Distribution of Questionnaire

The questionnaires were distributed among the users in the form of hard copies. The questionnaire was handed out to all six participants after completing the usability test. Questionnaire was used to capture their sense of satisfaction concerning both applications. The designed questionnaire can be found in Appendix A.

Table 6: Relation of question to adopted criteria

Usability evaluation criteria	Question Numbers
Effectiveness	1. It looks to be more effective. 2. Every time I can use it successfully. 3. It saves my time when I use it. 4. Overall the performance of application is satisfactory. 5. It's just do what I want to do. 6. While working on it I can meet my requirements. 7. While using it, it helps me to recover from mistakes quickly and easily
Usefulness	8. It is simple to use. 9. Only fewer steps are needed to accomplish a task. 10. It is effortless to use. 11. Occasional and regular users would like it. 12. I easily remember how to use it. 13. It gives me more control for searching different locations
User Reaction	14. New users can easily learn it. 15. I quickly became skillful with it. 16. It does everything what I expect from it. 17. I would like recommend it to a friend. 18. I think I should have it
Consistency	19. Does the system remain consistent while navigating to different pages?

Usability evaluation criteria	Question Numbers
Architectural and visual clarity	20. Every page has same organized information. 21. Symbols on the screen are very effective. 22. Designed for all level of users
Functionality	23. New users can easily use it. 24. All functions are so simple

After getting response from users through the questionnaire, the researcher calculated each scale of questionnaire. The scale of these questionnaires was based on Strongly Agree, Agree, Less Agree, Disagree and Strongly Disagree. Results of both applications are shown in Table 7 and 8 below.

Table 7: Analysis of Usability Criteria Web application

Answers	Web Application				
	SA	A	LA	D	SD
Effectiveness	33	52	15	0	0
Usefulness	36	44	14	6	0
User Reaction	43	40	11	6	0
Consistency	16	67	17	0	0
Architectural and Visual Clarity	28	33	28	11	0
Functionality	42	33	25	0	0

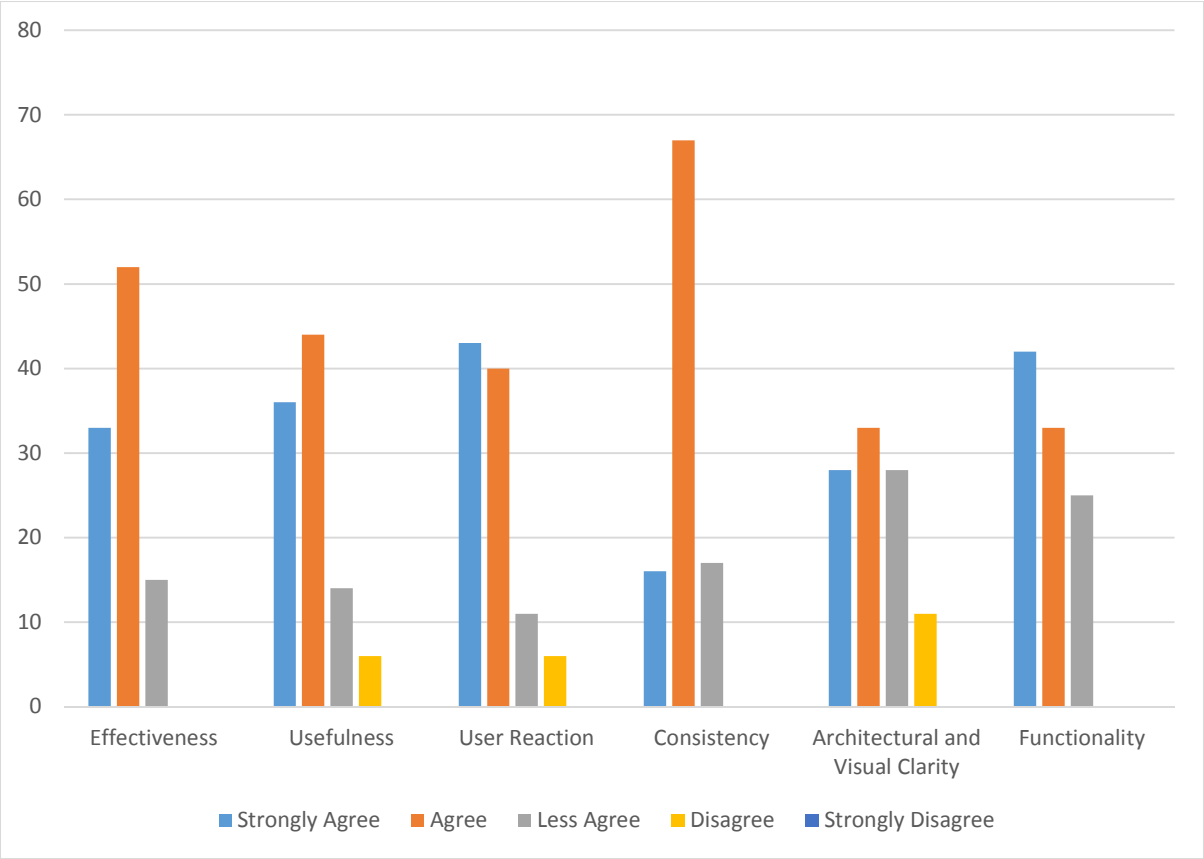


Figure 24: Analysis of Usability Criteria Web application

Table 8: Analysis of Usability Criteria Android application

Answers	Android Application				
	SA	A	LA	D	SD
Effectiveness	29	23	27	17	4
Usefulness	19	26	38	8	9
User Reaction	23	30	32	15	0
Consistency	16	16	32	18	18
Architectural and Visual Clarity	16	33	17	17	17
Functionality	33	8	33	26	0

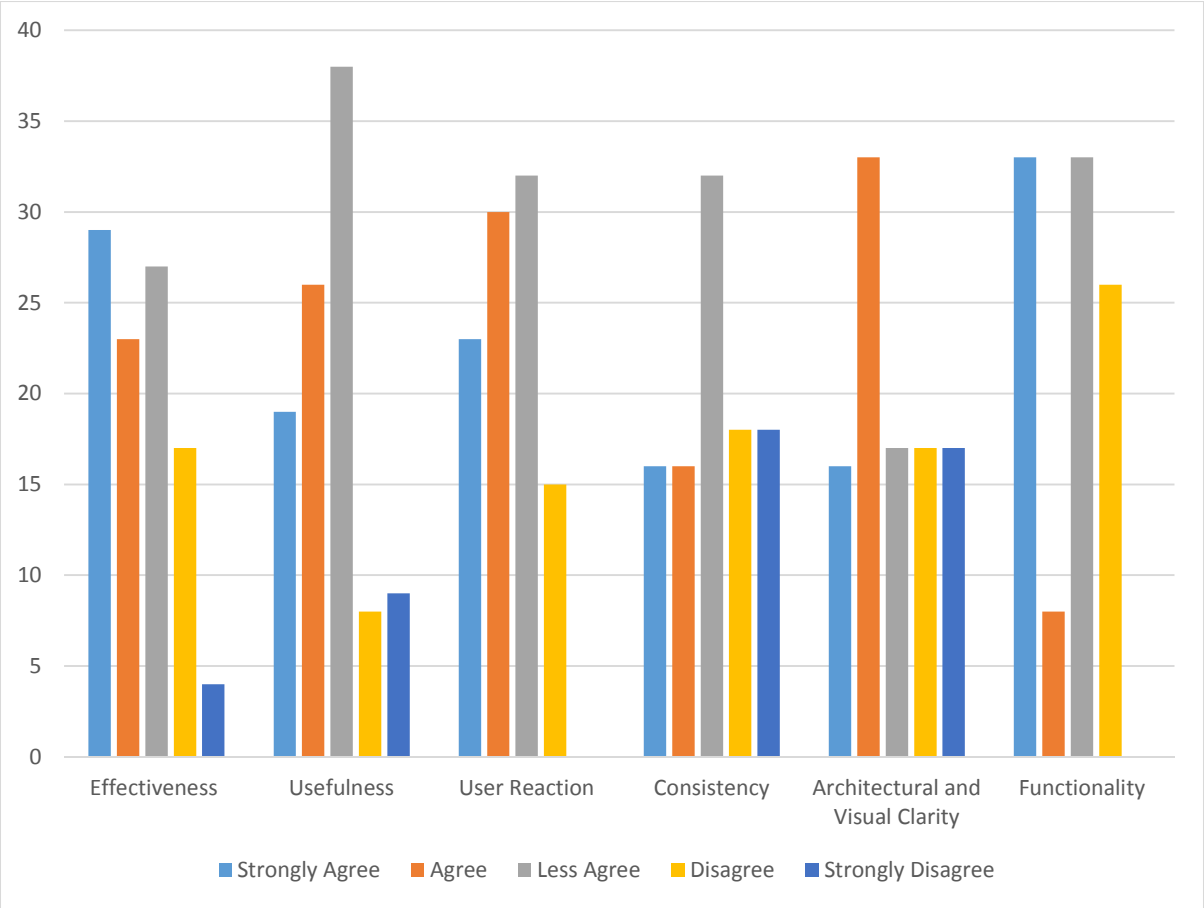


Figure 25: Analysis of Usability Criteria Android application

9.7 Comparison of Web and Android Application

According to table 7 and figure 24 above, testing results show that the percentage of Strongly Agree and Agree was high for Web Application while percentage of Less Agree, Disagree and Strongly Disagree was high for Android Application. It is worth mentioning here that “Strongly Agree” always positive and “Strongly Disagree” always negative concerning usability.

CHAPTER TEN: DISCUSSION

10.1 Introduction

This chapter contains a discussion about both the Web and the Android Application regarding the criteria adopted for usability evaluation.

10.2 Effectiveness

According to Koua et al. (2006) effectiveness deals with application functionality and observations of user performances and experiences of the tasks. It also deals with the gathering of data and any parameters available to complete a task. In the questionnaire effectiveness was measured by time taken by each task, errors rate, whether performance of the application was satisfactory or not, the correctness of outcome of the tasks, whether the application fulfils user requirements and application response against mistakes.

In the case of the Web Application users liked it and felt it was effective because requirements can be fulfilled successfully by using it. It can also save time during searching a specific record because of the simple search boxes but it requires the user to know what exactly they are looking for which makes it problematic for common users to select the right option. It helps in giving error messages clearly but it is not always in informative form. Although it is difficult for users to find help easily in Web Application, overall the performance of the Web Application was appreciated by the users.

While in case of Android Application the users considered it to be effective but not totally so, because it does not save their time when capturing growing activities. This was due to the fact that the application was designed using Material Design that a lot of users were not familiar with. Overall performance of MapQuest is good and requirements can be fulfilled by using this application.

10.3 Usefulness

According to Koua et al. (2006) usefulness deals with the user's expectations and demands while carrying out different tasks. It looks as though either application is supportive for users' goals and tasks, users can easily understand and interpret the application results, is it flexible according to user expectations, is it simple to use and how many steps it requires while carrying out a task.

Most users found that Web Application is very useful when performing the various tasks that were assigned to them. According to users the links are very much visible however most users forgot to select date range for reports which lead to frustration. But new users who don't have any idea about searching find it useful because it provide an interface in which they can easily navigate.

Users found the Android Application very useful whenever they were in a region that didn't have network coverage. The application allowed the users to work both online and offline. Users were able to capture data even in areas without mobile network coverage and when one gets in a network enabled area, they were able to synchronize the captured information

10.4 User Reaction

According to Koua et al. (2006) user reaction deals with user's opinions, views, attitude and user preferences towards an application. In the questionnaire it was measured by how this application is for new users, easy to learn or not, should I use it permanently or not and should I recommend it to a friend or not.

For Web Application the users' reaction was positive. The researcher observed that new users feel familiar with it and can learn it quickly. Most users recommend to use Web Application. The Users reaction towards Android Application was not as good. In the researcher's opinion, new users find it difficult to carry out a task the first time.

10.5 User Reaction

According to Koua et al. (2006) user reaction deals with user's opinions, views, attitude and user preferences towards an application. In the questionnaire it was measured by how this application is for new users, easy to learn or not, should I use it permanently or not and should I recommend it to a friend or not.

For Web Application the users' reaction was positive. The researcher observed that new users feel familiar with it and can learn it quickly. Most users recommend to use Web Application. The Users reaction towards Android Application was not as good. In the researcher's opinion, new users find it difficult to carry out a task the first time.

10.6 Consistency

According to Usability Guidelines (2009), consistency means navigation through different pages of the website should reflect the home page. Icons, words and phrases should be consistently described for the same item.

Consistency of any application makes it easy to learn because a consistent system uses the same basic steps for different tasks. In the researcher's opinion Web and Android Application are equally consistent and both applications need to improve their consistency. For example in the Android application while navigating different activities, the usage of card view make its interface inconsistent because on different activities these appear to be selectable.

10.7 Architectural and Visual Clarity

According to Usability Guidelines (2009) architectural and visual clarity means that the site is organized well from a user perspective, for instance the usage of colours, enough white space on the page, and unnecessary animations are avoided.

In the researcher's opinion, the main page is the first interaction point of any application with users, so it should be good looking. Both applications uses nice colours, buttons and icons which attract the users but all the links make its interface

confusing for novice users. In contrast most users like Android Application for its simple and clear interface, but most users pointed out that its buttons and links are not very visible especially on small screen interfaces.

10.8 Functionality

According to Usability Guidelines (2009), functionality of any website means that necessary functions are available, it accommodates both new and expert users and all functions are simple enough.

The users found both applications good in terms of functionality because all the functions were simple enough to carry out most tasks while they felt difficulty in some tasks, for instance printing a map of the fields in the current crop season was confusing. On the other hand, Android Application had problems regarding its functionality as the user had to do many things while searching for farm inputs, like filling many text boxes and then selecting options from dropdown menus.

CHAPTER ELEVEN: CONCLUSION

11.1 Introduction

This research project achieved its objective, which was to develop a traceability system for tracing all activities involved in the growing cycle of horticultural crops and GlobalGAP related information for use by contracted outgrower schemes in Kirinyaga County. The study achieved its stated objectives as highlighted below.

Objective One: To analyse and establish gaps in the current traceability systems among smallholder farmers in outgrower schemes within Kirinyaga.

This was achieved by using a pre-study which was carried out with the intention of doing an exploratory study. The pre-study gathered first insights into the field and identified problems and peculiarities around traceability. Using a stratified purposive approach the researcher identified the key informants. From these findings, early requirements were derived and an initial functional prototype developed.

Objective Two: To develop a prototype system for collecting information to enhance traceability along the value chain.

This was achieved by using Object Oriented Design (OOD) methodology. This involved identification of functional requirements from which use case artefacts is developed. Thereafter the dynamic and static behaviour of the system is analysed and modelled. The modelling of static behaviours was done through identification of objects and classes which are represented using Unified Modelling Language (UML) diagrams in Visual Studio 2013. The dynamic aspects of the system were modelled using sequence, interactive, state diagrams and collaboration diagrams. As regards to implementation prototyping technique was followed. The prototype development followed the four steps model proposed by Floyd, C. et al. (1984).

Objective Three: To develop a mobile app that will allow for offline capture in areas without mobile network coverage and allow for synchronization of the same when a field staff gets to a network enabled area.

All data is stored locally on the mobile devices and only synchronised when required. This has an enormous advantage over an on-line based systems as it does not need to be connected to the mobile network to continue to operate. Designed from the ground up to work with SQLite as local storage, all information is optimised to make the synchronisation time with the cloud as short and as low cost as possible.

This was implemented in Android using a sync adapter which does the work of syncing the data between the server and the local database and the sync service which is the service that ties the sync adapter into the Android sync framework.

When a sync happens the sync adapter's onPerformSync method is called by the framework and within the scope of that method anything that is permitted by the framework can be done to sync the data. In the case of the FarmTrace App the researcher built a simple REST Web API and standard calls were made to retrieve and parse JSON.

Objective Four: To incorporate GPS coordinates capture in the field to allow for accurate data capture in the respective farm blocks.

This was achieved using the Google Location Services API, part of Google Play Services, which provides a more powerful, high-level framework that automatically handles location providers, user movement, and location accuracy. It also handles location update scheduling based on power consumption parameters you provide. It also provided better battery performance, as well as more appropriate accuracy, by using the Location Services API.

Objective Five: To simplify the audit process by allowing for digital capture of all the GLOBALG.A.P required production information with real-time alerts of non-compliant activities thereby saving time that would have been spent collating information from farmers' paper based records.

This was achieved by using push notifications for Android which allows the app to send notifications about content and other updates to users when they are offline.

Objective Six: To evaluate the system in terms of speed, efficiency, usability, accuracy, and operator satisfaction.

The main purpose of usability evaluation is to find out various problems regarding user requirements. This objective was achieved by using usability evaluation of Web and Android applications. The important contributions in usability evaluation were the usability test (Think aloud technique) on users, Questionnaires and interviews. Think aloud method helped the authors to observe the users while performing their tasks and understand their reactions from a user ś perspective. The Questionnaires feedback concerned getting access to the opinions of the users about these applications.

11.2 LIMITATIONS OF THE STUDY

The prototype developed was only evaluated by two farmers' groups under one crop which was French beans. When the system is fully developed it will be expected to cover all the possible crops and different types of contracted farmers' groups.

In addition the prototype used only the free tier of the Microsoft Azure cloud hosting but when the system is fully implemented it will be required to take advantage of auto scaling options available on the platform. This will be the case whenever there is a burst of concurrent usage since a new instance would be added to handle the extra load.

The current system is implemented using an old authentication method that is cookie-based where the cookie is sent with each request from the client to the server, and on the server it is used to identify the authenticated user. With the evolution of front-end frameworks and the huge change on how we build web applications, the preferred

approach to authenticate users is to use signed token as this token sent to server with each request, this will be very advantageous especially when authenticating the users on native Android App.

11.3 CONCLUSION

For some 3 years European Union countries have been closely monitoring the incidence of pesticide residues in peas and French beans imported from Kenya. EU regulations specify the levels of pesticide residues that are permitted in different foodstuffs, and where these levels are exceeded, they take action. From 2011 onwards, residues at higher levels have been detected in a number of consignments. As a result, from January 2013, the European Commission increased the intensity of border controls on Kenyan peas and beans and now 10% of all imports are sampled for pesticide residues.

Based on the results above, smallholder farmers can now keep track of high levels of pesticide residues in their horticultural produce. Using the proposed system in this research, the farmers can manage production of their crop and at the same time monitor compliance with food safety standards such as Global Gap, a body that regulates standards for horticultural exports. This system will be particularly useful where quality standards and traceability requirements for formal markets are an issue.

11.4 RECOMMENDATIONS

Current developments in Kenya's horticultural exports highlight the need for a range of improvements that need to be brought about in close consultation with all stakeholders. These include the industry body (FPEAK), exporters, government bodies, and smallholder producers through their own organisations.

The improvements required include a review of current legislation on plant protection products in order to establish a more rigorous legal framework that fully integrates food safety concerns and export requirements. They should include mechanisms for ensuring farmers that can secure compensation from distributors of plant protection products that do not meet legal requirements.

In order to prevent the use of banned chemicals in the first place, there would also appear to be a need to:

1. Strengthen extension services, with a focus on a stricter code of practice for use of agrochemicals;
2. Improve training of farmers in good agricultural practices;
3. Increase field monitoring and inspection services;
4. Strengthen the staffing and laboratory capacity of the Kenya Plant Health Inspection Service (KEPHIS) in order to increase the frequency of testing.

It should also establish sound traceability systems that are affordable and can easily be used by smallholder farmers involved in export products, so that any products in violation of food safety requirements can be traced back to the individual producers concerned.

The implementation of such measures would go a long way to ensuring that Kenyan smallholder farmers produce safe horticultural products in line with export market requirements. In the absence of such corrective measures, Kenya risks losing its traditionally strong position in the established and lucrative EU market.

REFERENCES

1. Alfaro, J. A., Rábade, L. A. (2009) Traceability as a strategic tool to improve inventory management: A case study in the food industry. *Int. J. Production Economics*, 118, 104–110.
2. Banati H, Bedi P, Grover PS (2006) Evaluating Web usability from the user's perspective. Journal of Computer
3. Beaudouin-Lafon , M. ; Mackay, W. (2003). Prototyping Tools And Techniques. In: J. A. Jacko and A. Sears (Eds) The Human-Computer Interaction Handbook. Lawrence Erlbaum Associates.
4. Carl C, Warwick I, Neville C (2005) A User Evaluation of Synchronous Collaborative Software Engineering Tools, Proceedings of the 12th Asia-Pacific
5. Chemnitz, C. (2007). The Compliance Decision with Food Quality Standards on Primary Producer Level. A Case Study of the EUREPGAP Standard in the Moroccan Tomato Sector. Paper prepared for presentation at the I Mediterranean Conference of Agro-Food Social Scientists. 103rd EAAE Seminar 'Adding Value to the Agro-Food Supply Chain in the Future Euro Mediterranean Space'. Barcelona, Spain, April 23rd- 25th, 2007.
6. D. Van Setten, R. Oger and M. Debord (2006). —GeoTraceAgri and GTIS-CAP projects: Definition of the geotraceability concept. Peter Project, York wokshop 2006.
7. Derrick, S., & Dillon, M. (2004). A guide to traceability within the fish industry. Copenhagen, Denmark: SIPPO, Eurofish, Humber Institute of Food and Fisheries.
8. Dolan, C. and Humphrey, J. (2004). Changing governance patterns in the trade in fresh vegetables between Africa and the United Kingdom. Environment and Planning 2004, volume 36, PP 491 – 509.
9. Dupuy et al. (2005). —Batch dispersion model to optimize traceability in food industry Journal of Food Engineering, Special Issue: Operational Research and Food Logistics. v70 i3. 333-339.
10. Floyd, C., F.-M. Reisin, G. Schmidt 1989. STEPS to Software Development with Users, pp. 48-64, LNCS 387, Springer, Berlin-Heidelberg.
11. Floyd, C., "A Systematic Look at Prototyping", in: R. Budde, et al. (eds), (1984). Approaches to Prototyping, Springer, Berlin, pp. 1-18.

12. Frohberg, K., Grote, U.and Winter, E.(2006). EU Food Safety Standards, Traceability and Other Regulations: A Growing Trade Barrier to Developing Countries' Exports? International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006.
13. Gasparin, C. P. (2009) An exploratory study into the acceptance of on farm automated traceability systems. PhD thesis. Cranfield University.
14. Gasparin, C. P., Peets, S., Blackburn, D. W. K., Godwin, R. J. (2007) Stakeholder Requirements for Traceability Systems. In: Proceedings of the 6th European Conference on Precision Agriculture, edited by J. V. Stafford. Netherlands: Wageningen Academic Publishers, p. 793–799.
15. GeoTraceAgri Final Report (2005). —Geotraceabiity: an innovative concept for the qualification of crop production‖. Information Society Technologies, http://www.cordis.lu/ist/, IST- 2001 – 34281, March 2005.
16. Government of Kenya(GoK). Economic survey (2009).Kenya national bureau of statistics. Government printer.
17. Hevner, A. R., Ram, S., & March, S. T. (2004). Design Science in Information Systems Research. *Management Information Systems Quarterly, 28*(1), 75-105.
18. Ignacio, L. (2007). Implications of Standards and Technical Regulations on Export Competitiveness. African Economic Research Consortium Paper No. ESWP 03.
19. Jaffee, S., Van der Meer, K., Henson, S., De Haan, C., Sewadeh, M., Ignacio, L., Lamb, J., and Lisazo, M.B. (2005). Food-safety and agricultural health standards: challenges and opportunities for developing countries export. Washington, DC: The World Bank.
20. Jarke, M., Loucopoulos, P., Lyytinen, K., Mylopoulos, J., & Robinson, W. (2011). The brave new world of design requirements. Information Systems 36, 992–1008.
21. Jill E. Hobbs, (2003). —TRACEABILITY AND COUNTRY OF ORIGIN LABELLING". Presented at the Policy Dispute Information Consortium 9th Agricultural and Food Policy Information Workshop, Montreal, April 25 2003.
22. Josphat Njenga Gichure, Raphael Wahome, Edward Karuri, Kostas Karantininis (2014) Traceability among Smallholders in the Organic Fresh Produce Value Chain: Case of Nairobi. pp. 779 – 781

23. Karippacheril, T. G., Rios, L. D., & Srivastava, L. (2011). Module 12: Global Markets, Global Challenges: Improving Food Safety and Traceability While Empowering Smallholders Through ICT *ICT in Agriculture Sourcebook* (pp. 288 - 310): World bank.
24. K. Seine, S. Kuwabara, S. Mikami, Y. Takahashi, M. Yoshikawa, H. Narumi, K. Koganezaki, T. Wakabayashi, and A. Nagano (2004), "Development of the traceability system which secures the safety of fishery products using the QR code and a digital signature," Proc IEEE TECHNO-OCEAN '04, 2004, Nov. 9-12, Kobe, Japan.
25. Kledal, P., Oyiera, H., Njoroge, J. and Kiarii, E. (2008). Organic food and farming in Kenya. Archived at http://orgprints.org/14758
26. L. U. Opara (2003), "Traceability in agriculture and food supply chain: a review of basic concepts, technological implications, and future prospects ," J. of Food Agric. Environ. 1, 1, 101-106.
27. Mbithi, l. (2008).African experience with strategic export development: The success story of Kenya's horticultural industry. World Bank workshop. University of Pretoria. October 2008.
28. Minot, N and Ngigi, M. (2004). Are Horticultural Exports a Replicable Success Story? Evidence from Kenya and Côte d.Ivoire. International Food Policy Research Institute. EPTD Discussion Paper No. 120
29. Muriithi, B.W (2008). Compliance with EurepGap standards: determinants, costs and implications on profitability among smallholder French beans exporters in Kirinyaga District, Kenya.Unpublished Msc thesis, Egerton University, Kenya.
30. Okello, J.J. (2006). Compliance with international food safety standards: the case of green bean production in Kenyan family farms. Unpublished PhD thesis Michigan state university.
31. Okello,J.J., Narrod, C. and Roy, D.(2007). Food Safety Requirements in African Green Bean Exports and their Impact on Small Farmers. IFPRI Discussion Paper 00737 December 2007
32. Okello, J., Narrod C., and Roy, D. (2008).Smallholder Compliance with International Food Safety Standards is not a Fantasy: Evidence from African Green Bean Producers. Accessed online 26- 10-2008.http/:www.agrifoodstandards.net/en/global/fresh_perspectives.html
33. Opara, L. U. & Mazaud, F. (2001) Food traceability from field to plate. Outlook on Agriculture, 30 (4), 239–247.
34. Patton, M. (1990). Qualitative evaluation and research methods pp. 169-186). Beverly Hills, CA: Sage.

35. Roy, D., and Thorat, A. (2008). Success in High Value Horticultural Export Markets for the Small Farmers: The Case of Mahagrapes in India. World Development Vol. 36,No. 10, pp. 1874–1890.
36. S. Pouliot and D. A. Sumner (2008), "Traceability, Liability, and Incentives for Food Safety and Quality," Am. J. Agr. Econ. 90, 1, 15-27.
37. Ruiz-Garcia, L, Steinberger, G. And Rothmund, M. (2010). A model and prototype implementation for tracking and tracing agricultural batch products along the food chain. Food Control 21: 112–121.
38. Wang, X., & Li, D., (2006). Value added on food traceability: a supply chain management approach service. In *IEEE International conference on operations and logistics, and informatics,* 2006. SOLI '06. June 2006, pp. 493-498.
39. Zhao J, Coleman DJ (2006) GeoDF: Towards a SDI based PPGIS application for e-governance. Proceedings of the GSDI 9 Conference, Santiago, Chile.

APPENDIX A: QUESTIONNAIRE FOR USABILITY TEST

No.	Questionnaire for usability evaluation	Strongly agree	Agree	Less agree	Disagree	Strongly disagree
1	It looks to be more effective.					
2	Every time I can use it successfully					
3	It saves my time when I use it					
4	Overall the performance of application is satisfactory					
5	It's just do what I want to do.					
6	While working on it I can meet my requirements.					
7	While using it, it helps me to recover from mistakes					
8	It is simple to use.					
9	Only fewer steps are needed to accomplish a task.					
10	It is effortless to use.					
11	Occasional and regular users would like it.					
12	I easily remember how to use it.					
13	It gives me more control for searching different locations.					
14	New users can easily learn it.					
15	I quickly became skillful with it.					
16	It does everything what I expect from it.					
17	I would like recommend it to a friend.					

No.	Questionnaire for usability evaluation	Strongly agree	Agree	Less agree	Disagree	Strongly disagree
18	I think, I should have it.					
19	Does the system remain consistent while navigating to different pages?					
20	Every page has same organized information.					
21	Symbols on the screen are very effective.					
22	Designed for all level of users.					
23	New users can easily use it.					
24	All functions are so simple					

APPENDIX B: SAMPLING OF STAKEHOLDERS

Stratum	Stakeholder Type	Members
1	Exporters	1. Frigoken Limited 2. Meru Green Horticulture 3. Indu-Farm Limited 4. Homegrown Kenya Ltd 5. Kenya Agricultural Exporters 6. Highland Canners Ltd 7. Greenlands Agroproducers Ltd 8. Indu Farm EPZ Ltd 9. Kandia Fresh Produce Suppliers Ltd 10. Kenya horticultural exporters (KHE) 11. Makindu Growers & Packers ltd 12. Mboga Tuu Ltd 13. SACCO Fresh Ltd 14. Sian Exports Ltd 15. VEGPRO (K) Ltd 16. Wamu Investments Ltd 17. Interveg Exports Ltd 18. Fresh Approach Ltd 19. Agventure Ltd 20. Keitt Exporters Ltd 21. Emke Commodities (K) Ltd 22. Kakuzi Ltd 23. AAA Growers Ltd 24. Value Pak Foods Ltd 25. Afya Fresh Produce Ltd 26. Freshpak Horticultures Ltd 27. Reap Horticultural Exporters 28. Evergreen Crops Ltd 29. Benvar Estates Ltd

Stratum	Stakeholder Type	Members
		30. Wilham (K) Ltd
2	Auditors	1. GlobalGAP 2. AfriCert 3. FairTrade
3	Smallholder farmer groups	1. Baricho Farmers Self Help Group 2. Karie group 3. Kimuri Farmers Self-help 4. Kathiriti-Kanjau Horticulture Growers 5. Romwa Ventures
4	Industry Regulatory Agencies	1. Kenya Flower Council 2. Fresh Produce Exporters Association of Kenya (FPEAK) 3. Agro-Chemicals Association of Kenya 4. Export Promotion Council 5. Kenya National Federation Of Agricultural Producers
5	Government Regulatory Agencies	1. Pest Control Products Board (PCPB) 2. Horticulture Crops Development Authority (HCDA) 3. Kenya Plant Health Inspectorate Service (KEPHIS) 4. National Environmental Management Authority (NEMA)
6	Government bodies	1. Ministry of Agriculture (MoA) 2. Agricultural Society of Kenya (ASK) 3. Kenya Agricultural and Livestock Research Organization (KALRO) 4. Pest Control Product Board (PCPB)
7	Researchers	1. Minot, N and Ngigi, M.

Stratum	Stakeholder Type	Members
		2. Muriithi, B.W 3. Okello,J.J. 4. Josphat Njenga Gichure 5. Raphael Wahome 6. Edward Karuri, 7. Lydia Neema 8. Mwaura Florence
8	Traceability System Vendors	1. FarmForce 2. Virtual City 3. Trace Soft