

**AUTOMATION OF THE GRAIN PURCHASING
PROCESS FOR ZAMBIA'S FOOD RESERVE
AGENCY**

by

Alinani Simukanga

A thesis submitted to the University of Zambia in fulfilment of the requirements
for the degree of Master of Science in Computer Science.

The University of Zambia

Lusaka

2019

DECLARATION

I, Alinani Simukanga, declare that the work in this dissertation is original except where indicated by special reference in the text and no part of the research has been submitted for any other degree, diploma or academic qualification.

Name: _____

Signature: _____ Date: _____

Supervisor's Name: _____

Signature: _____ Date: _____

Supervisor's Name: _____

Signature: _____ Date: _____

©2019 - Alinani Simukanga

All Rights Reserved.

CERTIFICATE OF APPROVAL

This thesis of Alinani Simukanga has been approved as fulfilling the requirements of the requirements for the award of Master of Science in Computer Science by the University of Zambia

Examiner	Signature	Date
1. _____	_____	_____
2. _____	_____	_____
3. _____	_____	_____

ABSTRACT

Issues of food security, post-harvest losses, lack of a national farmer database and proper grain inventory system have plagued the Ministry of Agriculture for years. The lack of requisite tools has made the management of the sector a difficult task. This has seen an increase in the number of ghost farmers benefiting from the Farmer Input Support Programme (FISP). The aim of this work is to automate the processes of FRA, FISP and the Cooperatives Society operate, with a specific focus on the farmer registry and the grain marketing process. The objectives are as follows: Map the current business processes of FISP and FRA; Develop a model of objective 1 using cloud and mobile computing technologies; Develop a system prototype that integrates farmers spatial data and mobile computing based on the model in objective 2; and integrate multi-factor authentication into the prototype in objective 3. To meet objective 1, a baseline study was conducted at the FRA depots in Chongwe and Mumbwa. The information gathered from this and from various documents provided informed the development of the model specified in objective 2. Various web technologies such as PHP, Java and PostgreSQL were employed to achieve objective 3. Multi-factor authentication was implemented as an added security feature when interfacing with the mobile application for the final objective.

ACKNOWLEDGEMENTS

I would like to thank my parents Prof. Stephen Simukanga and Mrs. Agnes Simukanga for their financial and emotional support. I would also like to acknowledge my siblings Suwilanji, Chindikanji and Nachizya for their support and understanding. I would also like to recognise the encouragement provided by my friends Luanaledi and Ngambo. I am thankful for the guidance provided by my supervisors Dr. Jackson Phiri and Dr. Mayumbo Nyirenda which was instrumental in the completion of this work. I would also like to thank the National Science and Technological Council for funding the project. Lastly, I would like to thank the staff and fellow post-graduate students in the Computer Science for their useful input during the early stages of the project.

CONTENTS

Chapter 1: Introduction	1
1.1 Research Background	1
1.2 Motivation	2
1.3 Scope	2
1.4 Problem Statement	3
1.5 Aim	3
1.6 Objectives	3
1.7 Research Questions	4
1.8 Significance of the Research	4
1.9 Research Contributions	4
1.10 Organization of Thesis	5
1.11 Summary	5
Chapter 2: Literature Review	6
2.1 Background	6
2.1.1 Food Security	6
2.1.2 Farmer Input Support Programme (FISP)	7
FISP Electronic Voucher	8
Ghost Farmers	8
2.1.3 Food Reserve Agency (FRA)	9
2.1.4 Geography Information Systems - GIS	9
2.1.5 Multi-Factor Authentication	11
2.2 Related Work	11

2.2.1	Food Security Case Studies	11
	Public Distribution System in Karnataka, India	11
	Farm Input Subsidy Programme, Malawi	16
2.2.2	Web Technologies in Agriculture	17
	Eastern Africa Grain Council (EAGC)	18
	Better Crop Estimates in South Africa - Integrating GIS with other Business Systems	20
	Mobile Application to Secure Tenure (MAST)	22
	Design, implementation and Evaluation of a Mobile GIS so- lution for a Land Registration Project in Lesotho	23
	Planimeter-GPS area measure	24
2.3	Summary	24
Chapter 3: Methodology		25
3.1	Baseline Study	25
3.1.1	Study Setting	26
3.1.2	Sampling	26
3.1.3	Inclusion Criteria	26
3.1.4	Data Collection	26
3.1.5	Data Processing and Analysis	27
3.1.6	Ethical Consideration	27
3.1.7	Limitations of the Baseline Study	27
3.2	System Automation	27
3.2.1	Current Business Processes	28
	Current FISP Business Process	28
	Current FRA Satellite Depot Stock Purchase Business Process	29
3.2.2	Proposed Business Processes	30
	Proposed FISP Business Process	30

	Proposed FRA Satellite Depot Stock Purchase Business Process	30
3.3	System Architecture	31
3.4	System Requirements	32
3.4.1	User Requirements	32
	Functional Requirements	32
	Non-Functional Requirements	35
3.5	System Modelling and Design	36
3.5.1	Data Model	37
3.5.2	Interaction Models - Use Cases	40
3.5.3	Interaction Models - Use Case Specification	44
3.5.4	Interaction Models - Communication and sequence diagrams	53
	Approve Farmer	54
	Search for Farmer	55
	Login	55
	Add Farmer	56
	Edit Farmer	57
	Delete Farmer	57
	Add Grain	58
	Create User	59
	Edit User	60
	Remove User	60
3.5.5	Structural Models - Class Diagram	61
3.6	System Implementation - Web Application	62
3.6.1	REST API	62
3.7	System Implementation - Mobile Application	63
3.8	Limitations of the Prototype Development	63
3.9	Summary	63

Chapter 4: Results	65
4.1 Baseline Study	65
4.1.1 Demographic Data	65
4.1.2 Information Technology	66
4.2 System Implementation	66
4.2.1 Small-scale Farmer Database	67
Registration Process	68
Approval Process	69
4.2.2 Mobile Grain Bag Tagging	72
4.3 Summary	73
Chapter 5: Discussion and Conclusion	74
5.1 Discussion	74
5.1.1 Business Process Mapping and Modelling	74
5.1.2 System Implementation	74
5.2 Conclusion	75
5.3 Recommendations	75
5.4 Future Works	76
Appendix A - Data collection authorisation	76
Appendix B - Questionnaire	79
Appendix C - FISP Forms	87
Appendix D - Miscellaneous Images	89

LIST OF TABLES

2.1	Entitlement to Foodgrains under the Karnataka PDS [28]	12
2.2	Summary of E-PDS Modules [25]	16
3.1	Functional requirements - application processes	32
3.2	Functional requirements - system information and data flows	34
3.3	Non-functional requirements - software requirements	35
3.4	Non-functional requirements - reliability, safety and confidentiality	36
3.5	Entities and attributes	38
3.7	Actors and Actor Descriptions	40
3.8	Use Case Descriptions	43

LIST OF FIGURES

2.1	Maize Surplus/deficit data between 2012 and 2016 [6]	7
2.2	PDS supply chain [25]	14
2.3	Biometric Weighing-Point of sale machine [25]	15
2.4	View of EAGC module	18
2.5	View of location details	19
3.1	Current FISP business process	29
3.2	System Architecture	31
3.3	Use Case diagram	42
3.4	Boundary Class Stereotype symbol	54
3.5	Control Class Stereotype symbol	54
3.6	Entity Class Stereotype symbol	54
3.7	Approve farmer communication diagram	54
3.8	Approve farmer sequence diagram	55
3.9	Search for farmer communication diagram	55
3.10	Search for farmer sequence diagram	56
3.11	Login communication diagram	56
3.12	Login sequence diagram	56
3.13	Add Farmer communication diagram	57
3.14	Add Farmer sequence diagram	57
3.15	Edit Farmer communication diagram	57
3.16	Edit Farmer sequence diagram	58

3.17	Delete Farmer communication diagram	58
3.18	Delete Farmer sequence diagram	58
3.19	Add Grain communication diagram	59
3.20	Add Grain sequence diagram	59
3.21	Create User communication diagram	59
3.22	Create User sequence diagram	59
3.23	Edit User communication diagram	60
3.24	Edit User sequence diagram	60
3.25	Remove User communication diagram	60
3.26	Remove User sequence diagram	61
3.27	Class Diagram	61
4.1	Demographic data pie chart	65
4.2	Number of computers in offices at depot locations - summarized . .	66
4.3	System login interface	67
4.4	Camp Extension Officer dashboard	68
4.5	Farmer land parcels	68
4.6	Farmer land parcels - detailed	69
4.7	Storage locations	69
4.8	Storage locations - detailed	70
4.9	Farmer registration form	70
4.10	Farmer record	71
4.11	Farmer register	71
4.12	Camp Approver dashboard	72
4.13	Pending approvals	72
4.14	Approval view	73
1	FRA data collection authorisation letter	78
2	FISP Form 1	87

3	FISP Form 2	88
4	Entity-Relation Diagram	89
5	Satellite Depot Supervisor dashboard	90
6	Mobile application login page	90
7	Barcode scanning	90
8	Farmer record	90
9	Grain addition success message	91

Publications

1. Simukanga Alinani, Phiri Jackson, Nyirenda Mayumbo, and Kalumbilo-Kabemba Monica. “E-Governance Systems: A Case Study of the Development of a Small-Scale Farmer Database”, *Zambia ICT Journal*, Vol. 2, no. 1, pp. 7-15, June 2018. ISSN 2616-2156. doi: <https://doi.org/10.33260/zictjournal.v2i1.41>.
2. Simukanga Alinani, Phiri Jackson, Nyirenda Mayumbo, and Kalumbilo-Kabemba Monica. “ICT in Governance Systems: A Case Study of the FISP Farmer Registration System”. In *Proceedings Zambia Association of Public Universities and Colleges (ZAPUC) International Conference 2018*.
3. Chihana Sipiwe, Phiri Jackson, Kunda Douglas, and Simukanga Alinani. “Securing Grain in Transit for the Food Reserve Agency Based On the Cloud Model”. In *Proceedings Zambia Association of Public Universities and Colleges (ZAPUC) International Conference 2018*.
4. Simukanga Alinani, Muhone Patrick Madaliso, Mulenga Joseph, Phiri Jackson, and Nyirenda Mayumbo. “Creation of an Agricultural Geographical Information System”, *Zambia ICT Journal*, Vol. 2, no. 2, pp. 8-15, November 2018. ISSN 2616-2156. doi: <https://doi.org/10.33260/zictjournal.v2i2.57>.

CHAPTER 1: INTRODUCTION

This chapter gives a background to the study. It begins by laying out the background against which the work is being done. This is followed by the motivation, scope and the statement of the problem. The aim, objectives and research questions come after these. The significance of the research as well as the research contributions are then presented to highlight the implications of this work. Lastly, the organisation of the thesis as well as the summary of the chapter are presented.

1.1 Research Background

The Government, through the Ministry of Agriculture has been implementing the Farmer Input Support Programme (FISP) in order to improve access to inputs by small-scale farmers and to stimulate the participation of the private sector in the supply and timely distribution of agricultural inputs [1]. Alongside FISP, the Food Reserve Agency (FRA) is mandated to manage the country's strategic reserve. A third body exists, and this is the Cooperatives Society. It has the duty of meeting the common interests of the various small-scale farmers in the country. It is also the body through which farmers have access to various support programmes such as FISP. All three bodies face challenges in their operations due to relying on mainly paper records for record keeping.

In 2013, the Department of Computer Science at the University of Zambia began a collaboration with FRA to find solutions to the problems they were facing. This led to research project jointly funded by the National Science and Technological

Council (NSTC)[2] of Zambia and the National Research Foundation (NRF)[3] of South Africa. The study is being jointly carried out by researchers from Tshwane University of Technology and the University of Zambia. The Zambian group is working towards the automation of the processes in the various agricultural bodies (FRA, FISP and Cooperatives Society). The South African group is working on providing farmers in marginalized areas with access to market information.

1.2 Motivation

Ensuring food security is a major challenge faced by developing countries. Ensuring efficiency in farmer support programmes as well as the grain purchasing process assists in producing high grain output while minimizing post-harvest losses.

1.3 Scope

This research included a baseline study which was conducted at three depots, with the permission of the Ministry of Agriculture. These depots were located in Lusaka, Chongwe and Mumbwa districts. This was to gain an insight into the operations at both the rural and urban depots. The internal business processes of FRA and FISP was where this work was focused.

Business processes of FRA and FISP were mapped. A model based on cloud and mobile technologies was developed. A web application prototype was created based on the model. A mobile application prototype was also developed. Multi-factor authentication was implemented in the mobile application prototype.

1.4 Problem Statement

The Farmer Input Support Programme struggles with ensuring the authenticity of the programme's beneficiaries. This is the result of a manual paper-based registration system with minimal oversight. Certain individuals are profiting off the current system by adding *ghost* farmers onto the farmer register and selling the inputs provided. This is at the disadvantage of genuine small-scale farmers in need of input support. The Food Reserve Agency also lacks a streamlined way of managing its stock purchase process. If left unsolved, the efficiency of both initiatives is compromised.

1.5 Aim

To automate the processes of FRA, FISP and the Cooperatives Society with a specific focus on the farmer registry and the grain marketing process with security in mind.

1.6 Objectives

1. Map the current business processes of FISP and FRA.
2. Develop a model of (1) using cloud and mobile computing technologies.
3. Develop a system prototype that integrates farmers spatial data and mobile computing based on the model in (2).
4. Integrate multi-factor authentication into the prototype in (3).

1.7 Research Questions

1. What are the current business processes of the Cooperatives Society, FRA and FISP?
2. How can the business processes in (1) be automated using cloud, sensor networks and mobile computing technologies?
3. How can extra factors of authentication be added to improve security?

1.8 Significance of the Research

Consolidating the majority of the agriculture related processes will assist in providing information to support decision-making. The relevant stakeholders will have access to the real-time state of the national food basket. This information would also be critical in monitoring the farmer's progress upon receiving support. Accurate data as it relates to how long a farmer has been receiving support, the area on which they have been cultivating and their outputs will help ensure that only those who are making progress remain on the scheme.

1.9 Research Contributions

This study has resulted in the following research outputs:

1. A journal paper "E-Governance Systems: A Case Study of the Development of a Small-Scale Farmer Database" published in the Zambia ICT Journal.
2. A conference paper "ICT in Governance Systems: A Case Study of the FISP Farmer Registration System" presented at the Zambia Association of Public Universities and Colleges (ZAPUC) International Conference 2018.

3. A conference paper “Securing Grain in Transit for the Food Reserve Agency Based On the Cloud Model” presented at the Zambia Association of Public Universities and Colleges (ZAPUC) International Conference 2018.
4. A journal paper “Creation of an Agricultural Geographical Information System” published in the Zambia ICT journal.

1.10 Organization of Thesis

This thesis includes the following chapters: Chapter 1 brings forth the background of the study as well as the problem it intends to solve. Chapter 2 is the literature review as well as a review of related systems. Chapter 3 describes the research methodology used to meet the research objectives. Chapter 4 presents the findings of the baseline study as well as those of the system testing. Lastly, Chapter 5 draws conclusions and makes recommendations based on the findings.

1.11 Summary

This chapter covered the introduction to the research, motivation, scope, problem statement and aim. This was followed by the objectives, research questions, significance of the research and research contributions. Lastly, the organization of the thesis was provided.

CHAPTER 2: LITERATURE REVIEW

In this chapter, a thorough review of the related literature is carried out. It begins with an investigation into food security and the impact of post harvest losses on the state of the national strategic reserve. This is followed by a look into the farmer input support programme and the problems experienced in its roll-out. Thirdly, the state of e-governance in Zambia is reviewed. A review of applications of ICT in agriculture then follows. The chapter is then closed with an in-depth review of related works.

2.1 Background

2.1.1 Food Security

The Food and Agriculture Organization (FAO) is a United Nations agency specialized in ending hunger worldwide [4]. This organization defines food security as all people having “physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life” [5].

The Zambia Food Security Issues Paper created by the Forum for Food Security in Southern Africa [7] investigated the state of food security in Zambia. An interesting finding was that “Zambia’s food security situation is serious despite the occasional surpluses the country produces during good crop years” [7] - as shown in Figure 2.1 (Data retrieved from [6]). This can be attributed to “inadequate market

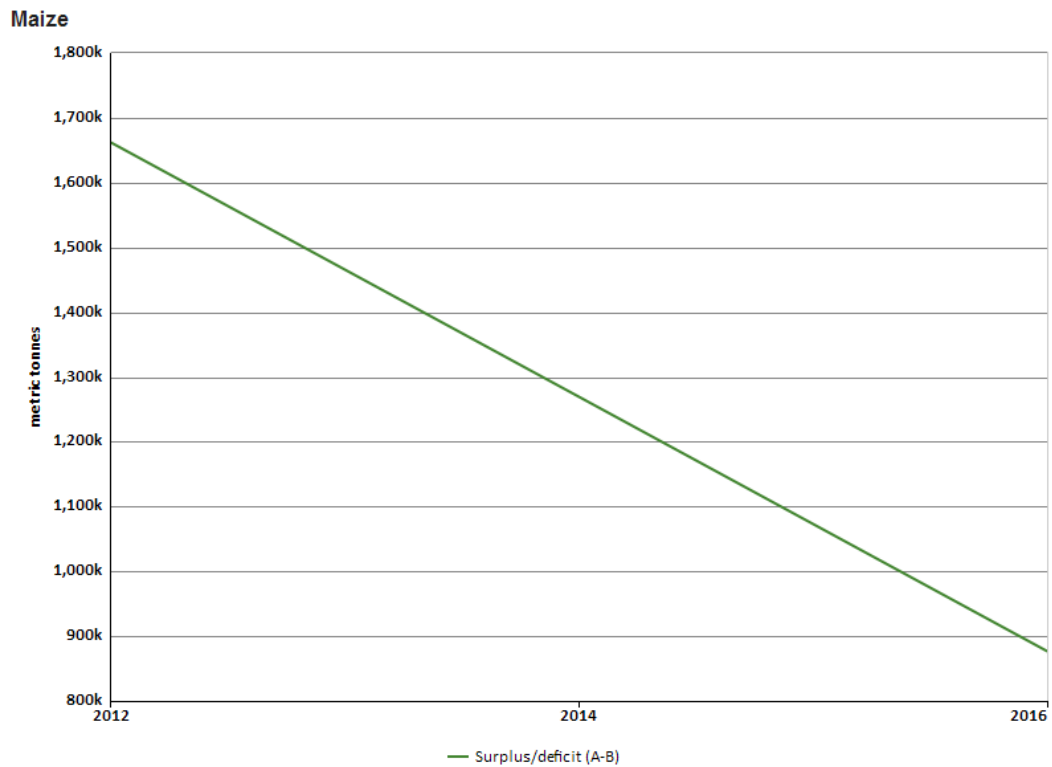


Figure 2.1: Maize Surplus/deficit data between 2012 and 2016 [6]

and transport systems to take food from surplus to deficit areas within the country” [7].

2.1.2 Farmer Input Support Programme (FISP)

The Government of the Republic of Zambia developed the Fertilizer Support Programme (FSP) in 2001 [8] with the view of providing inputs to small-scale farmers and in the process prop up the private sector. It was a three-year programme that involved progressive disengagement. This means that subsidy level would begin at 50% in the first year, before dropping to 25% in the second year. It would then fall to 0% in the third year [9]. In 2009, FSP was reworked and renamed to FISP. Part of the reworking involved reducing the quantities of inputs provided from eight 50kg bags of fertilizer to four 50kg bags and from two 10kg bags of seed to one 10kg bag [8]. This was done to increase the reach of the programme.

FISP Electronic Voucher

The electronic voucher (e-voucher) system was initially piloted in 2015 [10], targeting 13 districts in Central, Copperbelt, Lusaka and Southern provinces. It was created to augment FISP by providing recipients of the programme a wide number of options of agro dealers they could buy inputs from. In collaboration with the Zambia National Farmers Union (ZNFU) [10] and a number of banks [11] the E-Voucher programme used the existing VISA card system that was used by ZNFU in the LIMA Credit Scheme. Upon completion of the registration and approval process in each farming season, a VISA debit card would be provided to each beneficiary of the input programme. The card would only be activated upon payment of a fee. And as a security mechanism, these cards could only be used at the various registered agro dealers.

Ghost Farmers

‘Ghost farmers’ [12][13][14] have proven to be a recurring problem since the introduction of the e-voucher system. The term refers to individuals registered in the system who are not peasant farmers. It also covers cases where deceased individuals appear [15] in the system. According to a news article by Muwanei [12], some of the ghost farmers are officers from the Ministry of Agriculture. According to Mulenga [15] the ghost farmers use FISP as a social cash transfer benefit. The individuals receive the inputs and immediately sell them [15][16]. Attempts have been made to to purge the programme of ghost farmers. The most recent purge [17][18] resulted in the removal of about 600,000 ghost farmers. The taxpayer saved approximately K1 billion as a result of this exercise.

2.1.3 Food Reserve Agency (FRA)

The Food Reserve Agency was created through the Food Reserve Act of No. 12 of 1995 [19]. The agency was created to carry out the following functions:

1. administer the food reserve;
2. establish and operate a market information system for agricultural food commodities and agricultural inputs;
3. promote the use of the weighing and grading standards approved under the Weights and Measures Act and the Standards Act for designated commodities;
4. establish and conduct a programme under which storage facilities owned by the Government may be leased or sold;
5. establish a programme under which traders and processors shall register and report, for statistical purposes, information on the stocks of agricultural commodities handled or held by them; and
6. assess storage requirements for marketing a designated commodity and plan for their establishment as needed;

2.1.4 Geography Information Systems - GIS

GIS is a technological tool for comprehending geography and making intelligent decisions. GIS technology is a combination of statistical analysis with visualization and geographic analysis, making it a useful tool to a wide range of public and private sector entities. Uses can range from data visualization to predicting outcomes [20].

GIS systems can provide up-to-date and reliable information needed in order for efficient planning. Researchers and policy makers may integrate spatial, temporal, and socio economic data in order to get better manageability, higher and quality

productivity [21]. Understanding geography and people's relationship to location allows for informed decisions to be made about the way we live on our planet. Providing the current population and future generations with an indefinite food supply is an economic, environmental, and social concern. GIS technology enables community planners, economists, agronomists, and farmers to research and devise practices that will enable the sustainability of food production to ensure the survival of the human race. Whether implementing organic farming methods, finding the most profitable and healthy places to plant new crops, or allocating farmland for preservation to secure future food production; GIS has the capabilities to collect, manage, analyse report, and share vast amounts of agricultural data to aid in discovering and establishing sustainable agriculture practices [22]. GIS has massive potential in agriculture as it can help provide agricultural planning, attractive implications for future of managing our crop production and increasing yields in line with other technologies. Agricultural scientists are always looking at ways to best produce our crops, manage soils while respecting the environment and protect them from disease and pests. There is an ongoing challenge to cope with the changing climate and needs of today. GIS can play a vital part in tackling these challenges.

GIS take the guesswork out of the crop planning management with effective collection of soil data and seasonality of topography in line with changing conditions. It allows for precision farming. GIS is essential in mapping areas, especially food sources that are vulnerable to natural disasters such as drought and flood. The world Food Program, the division of the United Nations concerned with food security, is one of the biggest users of GIS data for this purpose. They are involved in protecting food supplies by effectively building simple civil engineering projects such as dams, levies and irrigation to protect food supplies [20].

2.1.5 Multi-Factor Authentication

According to Jacomme [23], authentication requires an authenticator which he defines as “something the claimant possesses and controls that is used to authenticate the claimant’s identity”. Authenticators can be classified according to the following authentication factors:

- Something you know, e.g. a password or pin code
- Something you have, e.g. a hardware token or access card
- Something you are, e.g. a biometric measurement like a fingerprint

Passwords are the most widely used authentication mechanism. But if a secure system is sought, this presents a problem. Having a single authentication factor makes it easy for intruders to gain access to a system especially if a common password is used or if the user tends to use the same password for multiple systems. A report by the National Institute of Standards and Technology (NIST) discourages the requirement of special characters in passwords [24].

Improving the security of a system involves stacking authentication factors. A combination of factors can be used such as a password and a hardware token or a password and a one-time code sent over SMS or email. The two (or more) factors used do not necessarily have to be of different classification.

2.2 Related Work

2.2.1 Food Security Case Studies

Public Distribution System in Karnataka, India

The Public Distribution System (PDS) is a mechanism of the Food Corporation of India (FCI) focused towards the procuring and distribution of grains [25]. The programme was designed in 1965 with an initial focus on being a universal scheme [25]

but due to fiscal crisis experienced in the early 1990s the PDS was converted into a targeted scheme[25]. The targeted version of the PDS was restricted to the poorest households (BPL - Below Poverty Line) which were provided increased quantities of subsidized products. Even though the PDS is controlled by government directives, the implementation is at state level and this has seen a sizeable difference on the programme's impact on poverty reduction among the states [26][27].

The state of Karnataka is known for a well functioning PDS programme involving high levels of involvement of BPL households [28].

Table 2.1: Entitlement to Foodgrains under the Karnataka PDS [28]

Status	Entitlement - quotas (per size of household)	Entitlement - price
Above Poverty Line (APL)	None	None
Below Poverty Line (BPL)	1 member: 8 kg 2 members: 16 kg 3 or more members: 24 kg	Rice: Rs. 1/- per kg Wheat: Rs. 1/- per kg

Table 2.1 (Table sourced from [28]) depicts the entitlements provided to APL and BPL households. The system faces challenges, one of which is the diversion of goods. The low price of the PDS goods leads to an estimated total of about 57% [25] [29] of commodities which do not reach the intended households. Leakage of goods hampers the effectiveness of the programme, limiting the quantity of goods available to eligible citizens.

Steps were taken to begin the process of computerising the Karnataka PDS system in 2005 [25]. The initial plan was to create a database of users entitled to the PDS. This would facilitate the issuance of ration cards based on a list of genuine beneficiaries. And to ensure that people had access to the goods, the PDS supply chain would also be computerized including transactions taking place in ration shops [25].

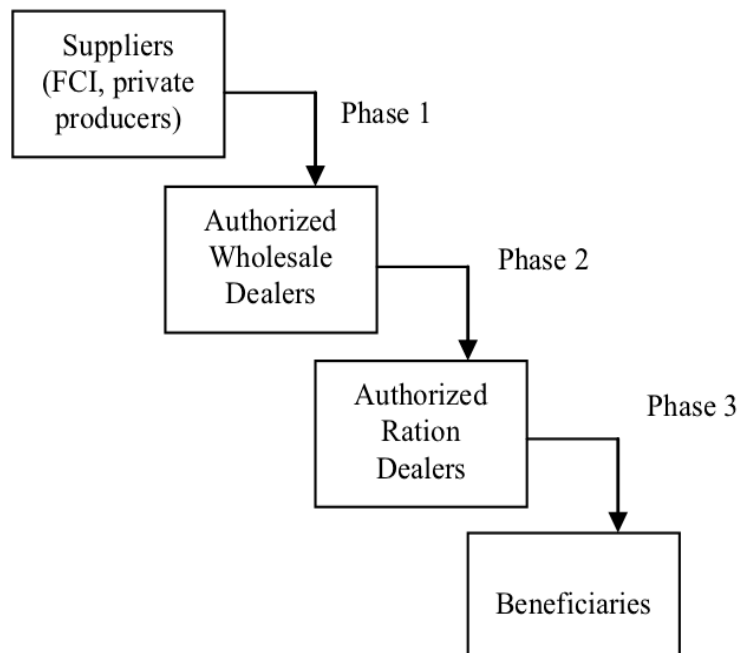


Figure 2.2: PDS supply chain [25]

The current version of the PDS system developed by the National Informatics Centre (NIC) Karnataka is divided into three distinct modules, each guaranteeing the good functioning of the programme:

- **Module 1** known as Ahara (a local word that translates to “food”) is a ration card database that holds details of all the cardholders in the state [25]. Ration cards serve as proof of entitlement as citizens attempt to buy PDS commodities [28].

According to Masiero [25], a few difficulties were experienced during the development of the database. Initial attempts at outsourcing the project to a private vendor ended unsuccessfully. The lack of database saw a large number of citizens taking advantage of the “temporary ration cards” issued in 2009.

To remedy this situation, a system was developed internally to guarantee the authenticity of the ration cards.

- **Module 2** is the Financial and Stock Accounting System (FIST) which is a software system used for supply chain management. This primarily involved



Figure 2.3: Biometric Weighing-Point of sale machine [25]

verifying PDS transactions prior to the goods arriving at the ration shops [25].

The PDS supply chain as depicted in Figure 2.2 contains three phases: goods procured are distributed to authorized wholesale dealers (1), who then distribute the goods to the various authorized ration dealers (2) who in turn provide the goods to beneficiaries (3) [25].

The function of the FIST software is to impede the diversion of commodities at the back-end by tracking all transactions in phases 1 and 2.

- **Module 3** is a system to manage transactions taking place at each ration shop [25]. While FIST handles phases 1 and 2, the transaction tracking system handles phase 3. This involved the use of biometric weighing-point of sales (as shown in Figure 2.3).

The machines work as follows. Beneficiaries, as they buy their rations are identified using their ration card number (which is entered) as well as their thumb impression. As these details are provided, the machine recognizes the beneficiary, displaying their card number and entitlement on the screen if successful. As the goods are being weighed, the machine announces the weights in the local language. Upon completion of the transaction, the machine prints a bill.

Use of the biometric weighing-point of sale machines is meant to prevent ration dealers selling less (or more) than one's entitlement at each transaction. The information of transactions completed is sent back to FIST which is useful in determining the allotment that a particular ration shop is due for the subsequent month [25].

Table 2.2: Summary of E-PDS Modules [25]

E-PDS Modules			
No.	Name	Core Function	Nature
1	Ahara - Ration Card Database	Guarantees authenticity of users' entitlements	Back-end
2	Financial and Stock Accounting System (FIST)	Registers the amount of goods received by wholesale points and of those lifted by ration dealers every month	Back-end
3	Biometric Control on Transactions	Guarantees authenticity of users' entitlements and regularity of PDS purchases	Front-end

Table 2.2 is a summary of the three modules of the system. Together they form the anti-poverty component at the core of PDS.

Farm Input Subsidy Programme, Malawi

The Farm Input Subsidy Programme was introduced in the year 2005 (initially known as the Agriculture Input Subsidy Programme) with an initial target of about 50 percent of the farmers in the country. The programme would distribute fertilizers as well as maize seeds. The programme is run by the Government through the Ministry of Agriculture, Irrigation and Water Development. The main aim of the programme is to achieve national food sufficiency as well as increase the income of poor smallholder farmers by improving maize and legume production through the provision of improved inputs [30].

At present, the programme targets smallholder farmers who are resource poor but own a piece of land [30]. The programme also caters for other vulnerable groups such as child-headed, female-headed and orphan-headed households as well as households with members affected by HIV/AIDS. A study conducted by Kilic, Whitney and Winters [31] revealed that the programme does not reach its intended group and instead the majority of the beneficiaries are in the middle of the income distribution. The authors noted that this is caused by community-based targeting where village residents collectively identify beneficiaries. These open fora are often co-opted by the more influential community members.

In 2013, a new tonnage allocation formula was introduced in order to reduce fertilizer costs. Further reforms were introduced in 2015 to facilitate private sector retailing as well as to reduce the subsidy level from 95 percent to 80 percent [30]. A large change was made to the beneficiary selection method. This involved the random selection of 1.5 million beneficiaries each year. The idea behind this move was to alternate beneficiaries while ensuring all farmers have the opportunity of accessing the programme at least once in every three year window.

2.2.2 Web Technologies in Agriculture

With the unlimited growth of the Internet and ever expansion of information on the web, this has brought the world and agriculture to a new information era. The Web offers a new medium for storage, presenting, assembling, allocation, processing and consuming information. Web technologies [32] are frequently used to give access to knowledge and information, for example, to offer immediate solutions to practical problems. Though, digital technologies may provide the chance for new relations within the farming community and along the value chains. When used on a shared basis, farm machinery can become a negotiation tool that benefits collective skill development.

Data collection and sharing provide farmers with the chance to develop their networking, sharing data is easy and cheap and it leads to better management on the farm (for example, by sharing information on diseases and weather) and within a community (sharing information on practices). Sharing data makes it possible to further develop good practices as collective knowledge increases. Creative applications to increase knowledge and information sharing have yet to be developed. The benefits of the web technology have been over the years.

The web offers disseminated substructure for information processing. It is used as a network to debate on one of the most popular support systems. The web [33] can provide appropriate, secure information and tools with user friendly interfaces. The web has no time limitations and also no geographic constraints. Farmers can access the system at any time, any place. Users (farmers) can control and retrieve results remotely and instantly. With the rapid development of web technology, computerized support systems are evolving more diverse groups, such as learning support system, education support system and also research support system.

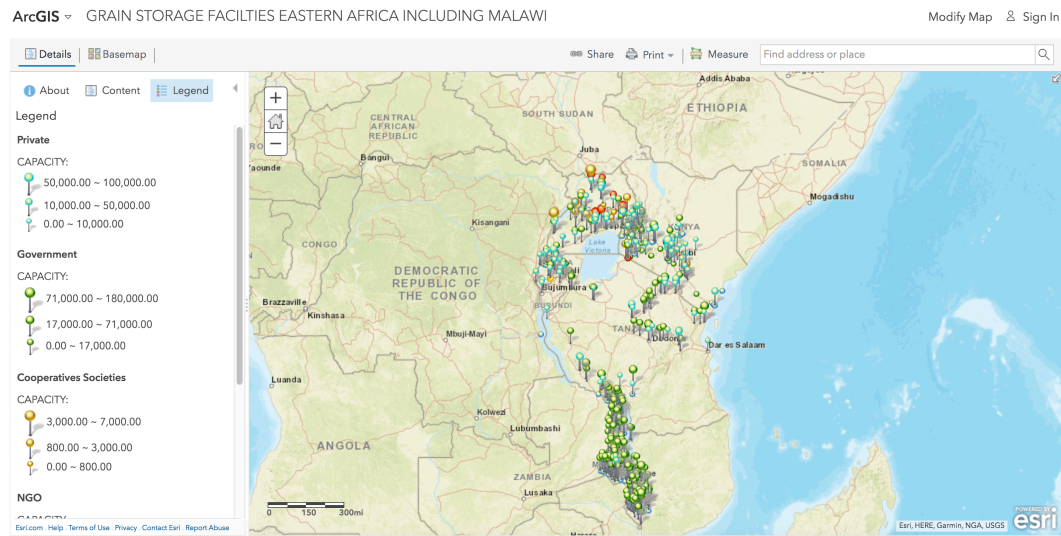


Figure 2.4: View of EAGC module

Eastern Africa Grain Council (EAGC)

In East Africa, a membership organisation of the grain stakeholders called Eastern Africa Grain Council (EAGC). EAGC has developed a number of grain commodities and promotes the exchange of information on matters affecting the regional grain industry. The stakeholders represent the three main council has used ArcGIS online publisher to display GIS of grain storage facilities in Eastern Africa and Malawi.

The EAGC module displays spatial data of 710 storage facilities across the following countries: Kenya (185), Uganda (73), Tanzania (81), Malawi (310), Rwanda (51), Burundi (7) and Democratic Republic of Congo-DRC (1) [34]. The storage facilities are organised into five groups based on their ownership and storage capacity. Each group of these facilities are placed on a separate layer. The first four groups are made up of facilities in which the storage capacities have been provided. These are private, Government, Cooperatives and NGO (Non-Governmental Organisations) storage facilities. The final group named 'other' is made of facilities whose storage capabilities could not be determined.

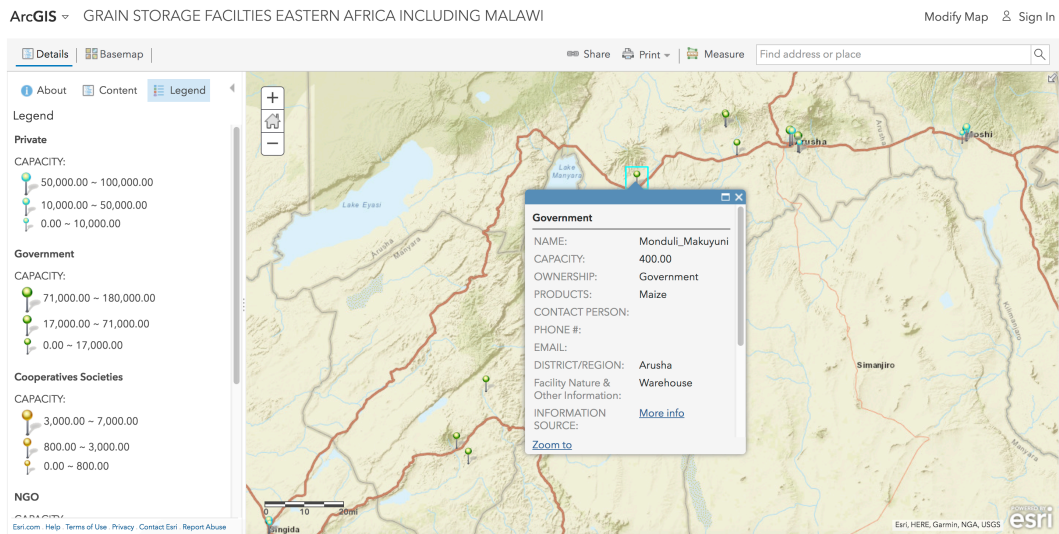


Figure 2.5: View of location details

Better Crop Estimates in South Africa - Integrating GIS with other Business Systems

Reliable crop information is vital to the functioning of grain markets. It is used to inform decision on planting, marketing and policy. Applying GIS to the process of preparing crop estimates has improved accuracy while lowering costs. The South African Department of Agriculture Crop Estimated Committee was tasked with producing crop estimated for South Africa on a monthly basis. To perform this task, the committee received data from various input suppliers. SiQ, a member of the National Crop Statistical Consortium (NCSC), uses statistical methods to provide inputs to the committee. Since 2002, crop information provided by producers has been used for statistical analysis. However, problems caused by producers who do not provide complete information, combined with a great emphasis on improving statistical accuracy and efficiency, led to the development on an alternative system. The Producer Independent Crop Estimate System (PICES) was developed in 2005, implemented after a successful pilot study conducted in the Gauteng province, PICES uses crop field boundaries digitized from satellite imagery with a point frame sampling system to objectively estimate the area planted with grain crops. The PICES

process consists of the following steps:

- Obtain satellite imagery.
- Digitize crop field boundaries from satellite imagery.
- Design the point frame and select random sample point.
- Use aerial survey sample points to capture crop data.
- Perform statistical analysis

Satellite imagery for the project is made available by the South African government through the Department of Agriculture. Spot Image Spot 5 satellite imagery with a 2.5 meter resolution is obtained from the department and is used as the base layer for digitizing. This is done in ArcMap at a scale of 1:10,000. Comprehensive quality control measures are part of the digitizing process to ensure clean, accurate data of high quality. Detailed metadata is captured in ArcCatalog as soon as the dataset for a province has been finalized. This metadata is updated whenever changes are made to the dataset. All nine provinces of South Africa have been digitized - a lot of approximately 12,965,000 hectares. The updating schedule and procedures ensure that the dataset remains current. In the next steps, sample points are randomly selected to represent cropped fields.

These points will be surveyed in the field. A point grid of 45 meters by 45 meters is set up for the total provincial area. Grid points located outside field boundaries are removed from the sample population because these points are unlikely to locate crops. Digitized fields are stratified based on the probability of finding a crop. The crop strata used are high, medium, and low cultivation. High, medium, and low refer to the densities of fields within any given area as well as the presence of pivot irrigation and small scale farming. Stratification is done to increase sampling efficiency. More sample points are used in strata where there is a higher likelihood of finding crops of interest. This will obtain the most useful data within budget.

The grid points are selected per stratum and exported to a Microsoft SQL Server database.

These points are sorted systematically from west to east and north to south. This is done to ensure an optimal geographic distribution of sample points. A random starting point is chosen and points selected at regular intervals according to the number of points needed in the specific stratum. The selected points are inserted into a new table in the database, and the process is repeated for each stratum. Finally, the SQL Server tables are added in ArcMap and converted to shapefiles containing the sample points for each stratum. An aerial survey of the sample points is conducted.

This aerial survey determines which crop is planted in the field represented by each sample point. These survey are conducted by a field observation team that consists of a pilot and an observer in a very light aircraft. The observer is from the agricultural community and is very experienced at distinguishing between different crops and differentiating between dry land and irrigated cultivation. Typically, the number of sample points verified for each survey requires the use of more than one field observation team. This system of capturing field information for crop estimated purposes is believed to be unique in the world [35].

Mobile Application to Secure Tenure (MAST)

United States Agency for International Development - USAID is using technology to strengthen Land Rights, is addressing land rights problems through an innovative pilot called the Mobile Application to Secure Tenure (MAST) project. The project team has developed an easy to use, open source smartphone application that can capture the information needed to issue formal documentation of land rights. Couple with a cloud based data management system to store geospatial and demographic information, the project is designed to lower costs and time involved in registering land rights and importantly, to the more process more transparent and accessible to local people.

The project is being implemented in rural Tanzania, where USAID is working directly with villagers to map and record individual land rights, strengthen local governance institutions, and build government capacity. The MAST application suite consist of two components: a smartphone application that is specifically developed for the capture of land rights information and a cloud based data management infrastructure. It captures land rights information (spatial, alphanumeric, and multimedia) and captures data in offline mode and transfer data to cloud based data management sever when a connection is available.

The land rights infrastructure component is an open source data management and storage facility that is designed to receive, manage and store land rights information collected on mobile devices. It has functionalities which include providing administration tools to allow for customizable set-up and security of data. Furthermore, it configures the database, including the addition of customized fields and porting of attributes to data collection forms on mobile applications, visualizes and edits spatial data collected in the field, via a web based GIS and configures and integrates template reports and land rights documentation [36].

Design, implementation and Evaluation of a Mobile GIS solution for a Land Registration Project in Lesotho

The GIS solution was developed as an application for the Android platform, primarily with the tablet computer format in mind, to be used for land registration field work. The application was developed and tested on site in Lesotho on two tablet computers. In the land registration project, all the data is collected by hand by a Claimant Support Officer (CSO) from every potential claimant in Maseru in the field. The CSOs visit every concerned claimant and collect data on a printed form, the parcel plan. This form involves some general data regarding the claimant's name and telephone number, as well as some general data concerning the parcel. These are GPS coordinated and demarcations, in this embodiment, the CSOs are

required to bring a binder of printed Parcel Plan forms, an A3 overview map, and a hand held GPS device to every parcel that they visit in order to carry out their task. The GIS application was developed in the java programming language. The Software Development Kits from Android: Google Android SDK (API 11) and ESRI: ESRI Android SDK v10.1.1 were used. In addition to the SDKs, the standard database system for Android: SQLite was also used and the open source spatial SQL-extension SpatialLite (v3.0.1). Except for some SQL development in a simple Graphical User Interface (GUI) for spatialite, all of the development took place in the widespread Eclipse Software Development Environment [37].

Planimeter-GPS area measure

Planimeter [38] is a maps ruler tool to calculate area, distance, perimeter, bearing, angle and GPS coordinates on map. You can set notes for each point and use this app for mapping or store favourite locations or landmarks and create GPS tracks. The app provides unique real-time GPS tracking feature that allows measuring a field, property or region simply by walking or driving around. This feature is useful for people working in such areas as farming, landscaping, architecture and construction, real estate business and fencing, sport, golf (distance between points) and hiking, tour and trail planning. With this feature, Planimeter operates as GPS tracker/logger or pedometer to record walking path or track.

2.3 Summary

In this chapter a comprehensive overview of the background theory as well as some related works were provided. Case studies related to the management of input support systems around the world were described. Projects that involved the application of Geographical Information Systems were listed. While similar works were identified, none of them fit the exact requirements of the Zambian setup. Finally, secure

authentication schemes in the shape of multi-factor authentication were discussed.

CHAPTER 3: METHODOLOGY

In this chapter, a thorough review of the methodologies used in achieving the objectives of this study are given. It begins with a description of the methodology used in carrying out the baseline study. This is followed by system automation, which focuses on the current and proposed business processes. The various system design models are then presented. The chapter is then closed with a look at the limitations of the prototype.

3.1 Baseline Study

The purpose of the study was to find out what challenges the FRA faced in regard to grain inventory management. A Mixed Methods Research Methodology was used to carry out this study. This involves “combining quantitative and qualitative data within an investigation” [39]. It proves useful when using either a quantitative or qualitative study alone would be inadequate.

Unstructured interviews with staff were held to gain an insight into the staff workflows. These were conducted through pre-arranged meetings and during visits to depots. Document sampling is another techniques that was used. The researcher was provided with the FISP implementation manual[1] that lays out in detail the FISP business processes as well as the forms involved. Questionnaire output would give the researcher an idea of of the infrastructure available at depot locations as well as what ICT tools are currently used if any.

3.1.1 Study Setting

The study focused on 3 warehouse depots in Lusaka and Central provinces. The two provinces were selected due to their high maize output as well as proximity. In Central province, the depot selected is located in Mumbwa district. In Lusaka province, the Chongwe district warehouse depot was selected as well as the Mwem-beshi and Mungwi warehouse depots located in Lusaka.

3.1.2 Sampling

The homogeneous purposive sampling technique was used on the study population. This is a technique that aims to achieve a homogeneous sample. That is a sample whose units share certain traits. The sample size selected was 42 for all the warehouse depots selected. This sample size was informed by the number of employees working at under grain inventory management. This sample was used for the questionnaires.

3.1.3 Inclusion Criteria

The study population focused on members of staff that work in the grain inventory management department at the FRA warehouse depots in the selected depots.

3.1.4 Data Collection

Data collection was done over a five week period, starting on the third week of November 2016 to the last week of December 2016. During data collection, questionnaires (See Appendix B) were administered to the respondents at all the target locations in Lusaka and Central provinces in the first two weeks. The respondents were given ample time to answer the questionnaires; which amounted to a few days or even a week depending on when the respondent received the questionnaire. The questionnaires were collected in the third and fourth weeks of the data collection

period. Unstructured interviews were then conducted during the fifth week. Qualitative data was collected in these interviews as well as from forms that are used during the day-to-day operations.

3.1.5 Data Processing and Analysis

Data was analysed using the IBM Statistical Package for Social Sciences (SPSS).

3.1.6 Ethical Consideration

All respondents were not required to reveal their identities or any other personal information (See Appendix B) that would give away their identities on the questionnaires. The FRA Systems Administrator provided authorization (See Figure 1 in Appendix A) for the collection of data at various FRA offices.

3.1.7 Limitations of the Baseline Study

Collection of data from all the FRA warehouse depot locations in all provinces and districts would have been ideal. This was hindered by time and financial limitations. Widening the study to also include the FISP satellite depots would have added useful information to this study.

3.2 System Automation

The system automation phase of the study was mainly informed by the qualitative data supplied through the unstructured interviews with warehouse and Ministry of Agriculture staff as well as forms used in day-to-day operations. The interviews with the staff provided the researcher with a perspective into the current business processes used in the daily operations.

3.2.1 Current Business Processes

Interviews with the staff led to the identification of two business processes.

Current FISP Business Process

The FISP process is largely a paper based process. The application process begins at the farmer group level. Here, the Camp Agriculture Committee (CAC) sets the date and venue where details pertaining to the programme are to be explained to prospective beneficiaries. The Village Farmers' Committee (VFC), Village Headmen and other local leadership are usually in attendance. At this meeting:

- Rules and modalities of the programmes are explained by the CAC.
- Each farm organization receives applications from intending beneficiary farmers using FISP FORM 1 (See figure 2 in Appendix C), and will ensure that each applicant meets the laid down selection criteria.

The CAC is responsible for all agricultural activities at camp level. The Block Extension Officer (BEO) will supervise the creation of CACs and endorse CAC members. The CAC plays a further role in the process by:

- Appraising applicants from farmer organizations.
- Ensure that applicants follow the process.
- Ensure that inputs are rationally allocated to farmer organizations within the camp.
- Ensure that the total sum of approved inputs does not exceed the specific camp's allocation.
- Ensure that farmer organizations are informed of the approval list (See figure 3 in Appendix C).

The BEOs have the duty of verifying that the beneficiary farmers (selected by the CACs they oversee) are bona-fide farmers in their respective camps. The beneficiary lists are then submitted to the District Agriculture Committees (DACs) and back to the CACs following ratification by DACs. The entire FISP business process is summarised in figure 3.1.

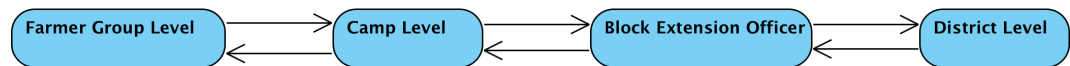


Figure 3.1: Current FISP business process

Current FRA Satellite Depot Stock Purchase Business Process

This process takes place at the various satellite depots set up by FRA. These are locations set up in camps for the purpose of purchasing grain from individual farmers. The depots are staffed by a supervisor as well as guards to secure the grain. The stock purchase process begins with the farmer presenting their National Registration Card (NRC). This is the basic form of identification used. The next step involved the inspection of the grain. This involves removing the grain from the bags supplied by the farmer and sieving it to remove the spoiled grain. The clean grain is then placed into UV treated bags provided by FRA. Each bag is then weighed and a Product Receipt and Certification Note (PRCN) is then issued for all the bags. Each bag is then sewn shut with twine and labelled with the issued PRCN number. Tagging the bags allows FRA to trace back each bag to the supplier and depot. The bags are then stacked onto a slab or placed in a shed if available. At close of business, the depot supervisor sends the day's figures to a data entry clerk by short message service (SMS). The means of data handling differs from depot to depot. Some rely on paper files while others use excel spreadsheets. Some rely on a hybrid solution due to frequent power outages.

3.2.2 Proposed Business Processes

Proposed FISP Business Process

The proposed FISP process also begins at the farmer group level. The Camp Extension Officer registers prospective beneficiaries through the web application. Upon completion of this stage, the Camp Approver verifies the details entered. This approval process is key in ensuring valid data has been entered and is also a safe-guard against attempts to defraud the programme. The Camp Approver views the entered details for each farmer and decides whether to approve the registration at that level. The approved list is then sent to the Block Extension Officer. He/she then approves the farmer list at block level. That means the farmer lists of all the camps within his/her block. The approved farmer list then moves to the District Agricultural Coordinator. The farmer list received contains the approved farmers from all the blocks with his/her district.

Proposed FRA Satellite Depot Stock Purchase Business Process

The proposed process is an alteration of the current process. The process begins again at a satellite depot. The farmer presents their farmer registration card to the satellite depot supervisor. The satellite depot supervisor scans the barcode on the card using his/her mobile device. The mobile application on the device retrieves the farmer's profile from the backend system. As in the current process, inspection and sieving of the grain takes place. Once the grain is placed in the FRA bags, a unique barcode is sewn onto each bag. Upon weighing of a bag, the satellite depot supervisor scans the barcode attached to said bag. The mobile application links the bag to the farmer. This information is pushed to the remote server in real-time.

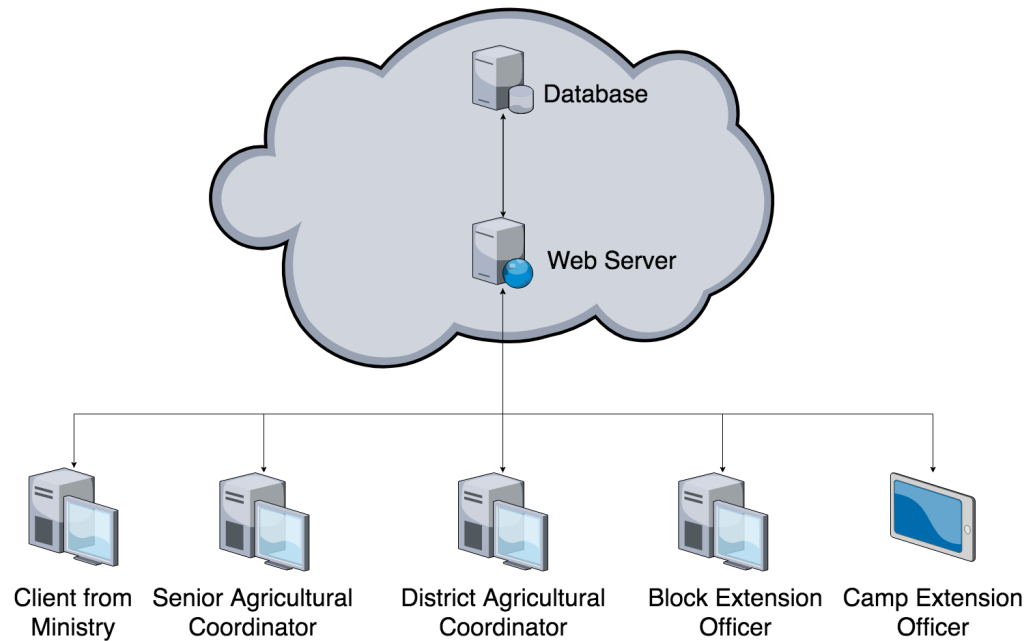


Figure 3.2: System Architecture

3.3 System Architecture

A diagrammatic representation of the system architecture is shown in figure 3.2.

The architecture has two main components:

- **Cloud component** - which consists of the application and database storage. While this may not be ideal for rural depots due to problems with connectivity, it is necessary because real-time data pertaining to agricultural activities.
- **Client component** - which consists of the various system clients.

All client interaction is handled by the same application on server-side. From delivering web pages for the web application to handling the authentication and data handling processes for the mobile application.

3.4 System Requirements

3.4.1 User Requirements

Sommerville [40] defines a user requirement as “statements in a natural language of what services the system is expected to provide to system users and the constraints under which it must operate”. User requirements can be classified as functional requirements or non-functional requirements. Functional requirements are statements that describe services a system should provide and how the system should behave. In some cases, functional requirements may explicitly state what a system should not do. Non-functional requirements are constraints on the services offered by the system. These may include timing constraints, constraints on the development process or constraints imposed by standards.

The User Requirement section provides a complete description of all the functionality and specifications for the proposed system.

Functional Requirements

Table 3.1: Functional requirements - application processes

Requirement ID	Detailed Requirement
FR1	Users with the System Administrator access rights shall have the ability to create accounts for staff at all the laid out levels.
FR2	Users with the Camp Extension Officer access rights shall have the ability to create farmer records of farmers registered to their assigned camp.
FR3	Users with the Camp Extension Officer access rights shall have the ability to edit farmer records of farmers registered to their assigned camp.
FR4	Users with the Camp Approver access rights shall have the ability to approve farmer records of farmers registered to their assigned camp.
FR5	Users with the Block Extension Officer access rights shall have the ability to approve farmer records of farmers registered to their assigned block.
FR6	Users with the District Agricultural Coordinator access rights shall have the ability to approve farmer records of farmers registered to their assigned district.
FR7	Users with the System Administrator access rights shall have the ability to remove a user from the system.
FR8	Users with the System Administrator access rights shall have the ability to edit a user's account details.
FR9	Users with the Satellite Depot Supervisor access rights shall have the ability to log into the mobile application.
FR10	Users with the relevant access rights shall have the ability to perform inventory transactions.

Table 3.2: Functional requirements - system information and data flows

Requirement ID	Detailed Requirement
FR11	The system shall retrieve data from mobile applications performing grain tagging operations.
FR12	The system shall implement a multi-factor authentication scheme for the mobile application.

Non-Functional Requirements

Table 3.3: Non-functional requirements - software requirements

Requirement ID	Detailed Requirement
NFR1	The system shall be user-friendly and intuitive to use.
NRF2	All input and output operations will make efficient use of system resources making sure to reduce latency.
NRF3	All software modules must be easy to debug.
NRF4	All software processes shall be killable, restartable and testable without affecting normal operations.
NRF5	Modular design shall be employed to their maximum extent.

Table 3.4: Non-functional requirements - reliability, safety and confidentiality

Requirement ID	Detailed Requirement
NRF6	The system shall continue operations, not necessarily at full capacity, during partial shut-downs for maintenance, repair and/or upgrade.
NFR7	The system shall be able to sit at idle and resume operations with minimal delay.
NRF8	System failure shall not compromise data integrity.
NRF9	The system shall keep a log of specific system functions. Linking the action to the user and the time said action occurred.
NRF10	Users will be limited to viewing farmer data linked to their assigned area.
NRF11	All users shall login using a unique form of identification.
NRF12	All login attempts shall be done in a secure manner. This involves encrypting user credentials being sent to the web application.
NRF13	Each user shall have a set of system access properties that defines the user's privileges within the system.
NFR14	Encryption shall be used at all interfaces where data could be intercepted.

3.5 System Modelling and Design

To create the various models Object Oriented Analysis (OOA) was used [41].

3.5.1 Data Model

Data modeling refers to the process of designing a database as an abstraction of a determined problem domain [42]. A data model is therefore a representation - usually graphical - of real-world data structures [42]. When done properly, the resulting data model will act as a blueprint for the building of the system's database.

A data model is made of the following basic building blocks:

- **Entities** - An entity is an abstraction of a person, place, thing or event being modelled [42]. An entity is distinguishable - each occurrence is unique and distinct.
- **Attributes** - An attribute is a property of an entity [42]. Attributes define characteristics of an entity e.g. a Human entity would have attributes such as first name, last name, date of birth and height.
- **Relationships** - A relationship defines associations amongst entities. Three basic types of relationships occur among entities: *one-to-many (1..*)*, *many-to-many (*..*)* and *one-to-one (1..1)*.

An entity-relation diagram is a representation of the entities, the attributes within those entities, and the relationships between those entities [42]. The entity model created for this system is shown in Figure 4 (See Appendix E).

Table 3.5: Entities and attributes

Entity	Attribute
Agents	id, email, name, password
Animal	id, name
Animals_kept	id, animal_id, quantity, farm_area_id
Approval	id, farmer_id, camp, block, district, date_camp, date_block, date_district
Bag	id, stock_id, weight, farmer_id, barcode, added_by, dateAdded
Bag_location	id, bag_id, date, depot_id
Block	id, name, district_id, lat, long, polygon
Camp	id, name, block_id, lat, long, polygon
Crop	id, name
Crops_grown	id, crop_id, farm_area_id, season_id
Daily_reconciliation	id, date, stack_code, season, opening_stock, transfers_in, total_receipts, sales, transfers_out, deficit, surplus, closing_stock, entered_by, approved_by
Daily_stack_ledger	id, stack_code, season, transaction_date, opening_balance, goods_receipt_note_no, goods_issue_note_no, closing_balance, prepared_by
Depot	id, depot_name, district_code, lat, long, capacity, contact_person, phone_number, current_temperature, product
District	id, name, province_code, polygon
Driver	id, first_name, last_name, other_name, identity_no, transporter_no

Farm	id, farm_name, farmer_id, geom, crop, m_lat, m_lng, imagePhoto
Farm_area	id, farm_id, area
Farmer	id, firstName, lastName, otherName, dob, gender, idNumber, camp_id, mobile_number, email, photo, physical_address, date_registered, created_by, nrc1, nrc2, lat, long
Goods_issue_note	id, depot_code, date, buyer_name, description, bags, metric_tonnes, issued_by
Goods_receipt_note_crop	id, depot_no, date, ipt_idt_ref, supplier_code, description_of_goods, bags, metric_tonnes, remarks, received_by, bags_sample_weighed, average_weight, driver_no, vehicle_no
Inter_depot_transfer	id, depot_code, date, load_order_no, destination, description_of_goods, bags, bags_sample_weighed, average_weight, metric_tonnes, issued_by, vehicle_no, driver_no
Notification	id, target, message, datetime, seen
Proivince	id, name, polygon
Season	id, name, year
Shed	id, shed_no, manager, depot_code
Stack	id, stack_no, shed_code, commodity, year_purchased, date_last_fumigation, crop_condition
Stack_card	id, stack_code, date, opening_stock, receipts, dispatches, closing_balance, remarks, user_id
Stock_type	id, name
Supplier	id, name, address

Tally_sheet	id, date, shed_code, carrier, package_type, waybill_manifest_lo_do_no, grn_ipt_idt_gin_no, start_time, end_time, source_destination, commodity, packaging_unit_weight, truck_wagon_no, manifested_units, manifested_weight, received_sent_units, received_sent_weight, variance_weight, condition, checker, supervisor, carrier_inspector_name
Transporter	id, name
User	id, first_name, last_name, other_name, position, username, password, usertype_id, auth_key, created, updated, lat, long, device_serial, camp, block, district
User_type	id, type
Vehicle	id, transporter_no
Zone	id, name, district_id, lat, long, polygon

3.5.2 Interaction Models - Use Cases

Use cases are a useful requirements discovery tool [40]. A use case defines the actors involved in an interaction as well as the types of interaction. Actors may be human or other systems. Table 3.7 shows the actors in this system as well as their description.

Table 3.7: Actors and Actor Descriptions

Actor	Description
Camp Extension Officer	The Camp Extension Officer has the responsibility of managing a camp's farmer register in this system. That involves the creation, editing and deletion of farmer records registered to their assigned camp.
Camp Approver	The Camp Approver verifies and approves farmer details on behalf of a camp's CAC.
Block Extension Officer	The Block Extension Officer verifies and approves farmer details of farmers registered to camps within his/her block.
District Agricultural Coordinator	The District Agricultural Coordinator verifies and approves the beneficiary lists from blocks within his/her district.
Satellite Depot Supervisor	The Satellite Depot Supervisor uses the mobile application for the purpose of linking the supplier to their grain.
System Administrator	The System Administrator is responsible for the administration of the entire system.

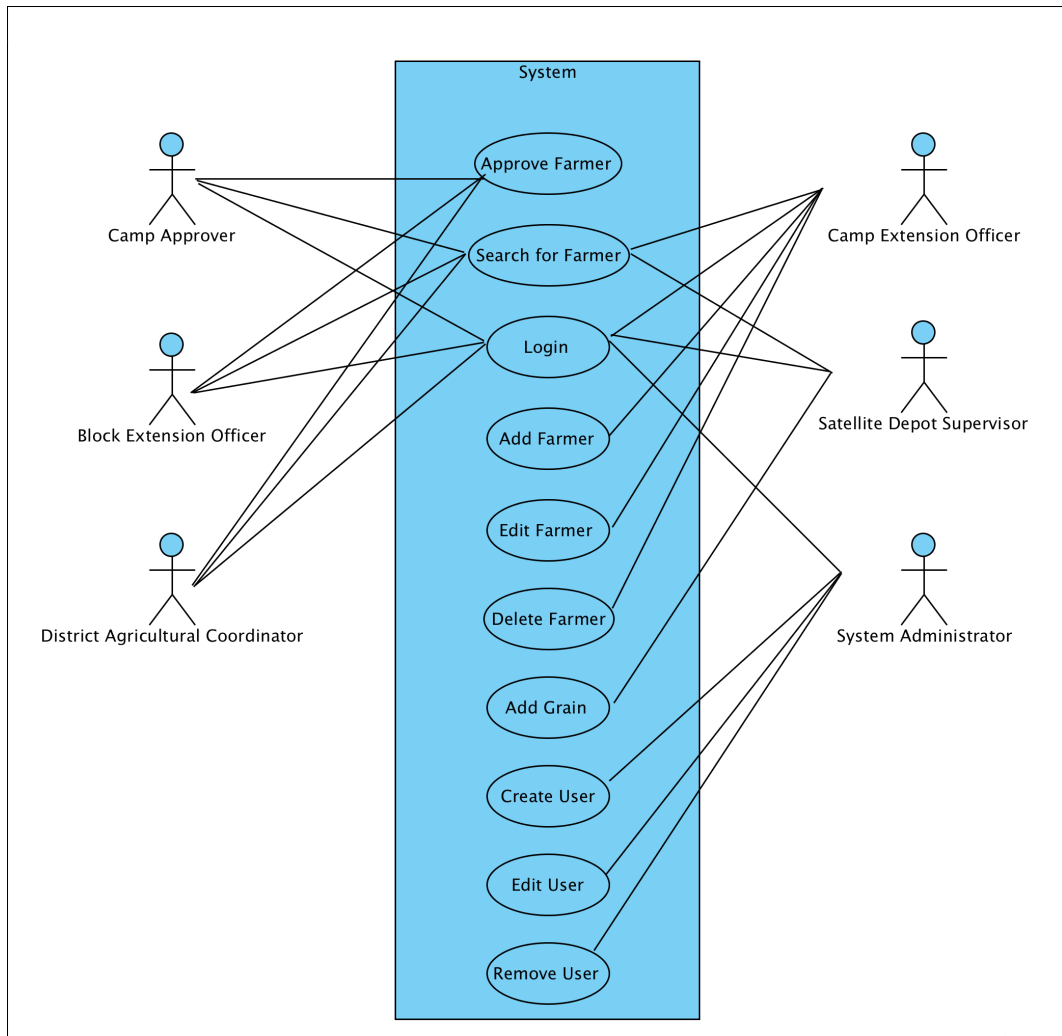


Figure 3.3: Use Case diagram

Table 3.8 describes each Use Case identified in the Use Case diagram in Figure 3.3.

Table 3.8: Use Case Descriptions

Use Case	Description
Approve Farmer	Users with the appropriate access rights can approve farmer details linked to their role (i.e. Camp, Block or District) and assigned location.
Search for Farmer	Users can search for farmers within their assigned locations.
Login	A registered user is able to login to access system functionality according to his/her access rights using his/her authentication details.
Add Farmer	A Camp Extension Officer is able to create a farmer record. By default, this farmer is registered to the user's assigned camp.
Edit Farmer	A Camp Extension Officer is able to edit the farmer details of farmers registered to his/her camp.
Delete Farmer	A Camp Extension Officer is able to delete a farmer record of a farmer registered to his/her camp.
Add Grain	A Satellite Depot Supervisor is able to add a grain receipt entry upon the purchase of grain.
Create User	The System Administrator is able to create a user account.
Edit User	The System Administrator is able to edit the user account details of any system user.
Remove User	The System Administrator is able to delete the user record of any user.

3.5.3 Interaction Models - Use Case Specification

Use Case 1	Approve Farmer
<i>Scope:</i>	System-wide
<i>Level:</i>	User-goal
<i>Primary Actor:</i>	Camp Approver, Block Extension Officer, District Agricultural Officer
<i>Preconditions:</i>	<ul style="list-style-type: none">• User is logged in• Farmers have been registered
<i>Postconditions:</i>	Farmer details have been approved at a certain level (e.g. Camp, Block or District).
<i>Main Success Scenario:</i>	<ol style="list-style-type: none">1. User navigates to /texts/Farmer Approvals page2. User views the profile of a specific farmer3. User clicks the <i>Approve Farmer</i> button4. User is redirected to list of pending approvals
<i>Frequency of Occurrence:</i>	Once a year
Use Case 2	Login
<i>Scope:</i>	System-wide
<i>Level:</i>	User-goal
<i>Primary Actor:</i>	Camp Approver, Block Extension Officer, District Agricultural Officer, Camp Extension Officer, Satellite Depot Supervisor, System Administrator
<i>Preconditions:</i>	None

Postconditions: User is logged in to the system.

Main Success Scenario:

1. User enters their username and password into the login form
2. User clicks the *Login* button
3. User is redirected to dashboard

Alternative Scenarios:

2.a Invalid login data:

1. System shows failure message
2. User returns to step 1

2.b User is Satellite Depot Supervisor:

1. System authenticates device IMEI (International Mobile Equipment Identity)
2. System checks device location
3. User is redirected to dashboard

2.b.i Device IMEI is incorrect

1. System shows failure message
2. User returns to step 1

2.b.ii Device location is incorrect

1. System shows failure message
2. User returns to step 1

Frequency of Occurrence: Regular

Use Case 3**Add Farmer**

Scope:

System-wide

Level:

User-goal

Primary Actor:

Camp Extension Officer

Preconditions:

User is logged in

Postconditions:

A Farmer record is created

Main Success Scenario:

1. User clicks the *Farmer Registration* link
2. User populates the form with the farmer's details
3. User takes a photo of the farmer and both sides of his/her National Registration Card (NRC)
4. User attaches the documents to the form
5. User submits the form
6. User is redirected to the created record

Alternative Scenarios:

5.a Required form elements not entered:

1. System shows failure message on specific fields
2. User is allowed to fill form and resubmit
3. User is returned to step 6

5.b Existing NRC number has been entered:

1. User is notified that the provided NRC number is linked to an existing farmer record
2. User is allowed to correct the NRC number and resubmit
3. User is returned to step 6

Frequency of Occurrence: Regular

Use Case 4

Edit Farmer

Scope:

System-wide

Level:

User-goal

Primary Actor:

Camp Extension Officer

Preconditions:

- User is logged in
- The particular Farmer record has been created

Postconditions:

The Farmer record is edited.

Main Success Scenario:

1. User clicks the *Farmer Register* link
2. User clicks the *Update* button on a particular record
3. User alters information on the provided form
4. User clicks the *Save* button
5. User is redirected to the farmer record

Alternative Scenarios:

4.a Required form elements left empty:

1. System shows failure message on specific fields
2. User is allowed to fill form and resubmit
3. User is returned to step 6

4.b Existing NRC number has been entered:

1. User is notified that the provided NRC number is linked to an existing farmer record
2. User is allowed to correct the NRC number and resubmit
3. User is returned to step 6

Frequency of Occurrence: Regular

Use Case 5	Delete Farmer
<i>Scope:</i>	System-wide
<i>Level:</i>	User-goal
<i>Primary Actor:</i>	Camp Extension Officer

Preconditions:

- User is logged in
- The particular Farmer record has been created

Postconditions: The Farmer record is deleted.

Main Success Scenario:

1. User clicks the *Farmer Register* link
2. User clicks the *Delete* button on a particular record
3. User is prompted to confirm the action
4. User clicks the *Confirm* button
5. User is redirected to the farmer register

Frequency of Occurrence: Regular

Use Case 6 Search for Farmer

Scope: System-wide

Level: User-goal

Primary Actor: Camp Approver, Block Extension Officer, District Agricultural Coordinator, Camp Extension Officer, Satellite Depot Supervisor, System Administrator

Preconditions:

- User is logged in
- The particular Farmer record has been created
- The Farmer lies with the user's assigned jurisdiction

Postconditions: The Farmer record is retrieved.

Main Success Scenario:

1. User clicks the *Farmer Register* link
2. User enters the farmer's identifier into a search field
3. User is presented with records that match given identifier

Alternative Scenarios:

5.a Farmer is outside of the user's jurisdiction:

1. User is returned an empty result

Frequency of Occurrence: Regular

Use Case 7

Add Grain

Scope:

System-wide

Level:

User-goal

Primary Actor:

Satellite Depot Supervisor

Preconditions:

User is logged in

Postconditions:

A grain bag is recorded.

Main Success Scenario:

1. User clicks the *Scan Farmer* button
2. User scans the barcode on the Farmer's registration card
3. User is presented with the Farmer's profile
4. User clicks the *Scan Grain* button
5. User scans the barcode attached to the bag of grain
6. User is informed that the bag has been added

Alternative Scenarios:

5.a Barcode is linked to existing bag:

1. User is informed that the scanned code is linked to an existing bag

Frequency of Occurrence: Regular

Use Case 8

Create User

Scope: System-wide

Level: User-goal

Primary Actor: System Administrator

Preconditions:

- User is logged in

Postconditions: A user account is created.

Main Success Scenario:

1. User clicks the *Add User* button
2. User populates the form with the user details
3. User clicks the *Save* button
4. User is redirected to the user's profile

Alternative Scenarios:

3.a Required form elements left empty:

1. System shows failure message on specific fields
2. User is allowed to fill form and resubmit
3. User is returned to step 4

Frequency of Occurrence: Regular

Use Case 9**Edit User**

Scope:

System-wide

Level:

User-goal

Primary Actor:

System Administrator

Preconditions:

- User is logged in
- The particular User record has been created

Postconditions:

The User record is edited.

Main Success Scenario:

1. User clicks the *Users* link
2. User clicks the *Update* button on a particular record
3. User alters information on the provided form
4. User clicks the *Save* button
5. User is redirected to the user profile

Alternative Scenarios:

4.a Required form elements left empty:

1. System shows failure message on specific fields
2. User is allowed to fill form and resubmit
3. User is returned to step 5

Frequency of Occurrence: Regular

Use Case 10**Delete User**

Scope:

System-wide

Level:

User-goal

Primary Actor: System Administrator

Preconditions:

- User is logged in
- The particular User record has been created

Postconditions: The User record is deleted.

Main Success Scenario:

1. User clicks the *Users* link
2. User clicks the *Delete* button on a particular record
3. User is prompted to confirm the action
4. User clicks the *Confirm* button
5. User is redirected to the users page

Frequency of Occurrence: Regular

3.5.4 Interaction Models - Communication and sequence diagrams

Communication diagrams provide a view of the interaction between objects using sequenced messages[40]. Sequence diagrams are used to model the interaction between the actors and the various system objects as well as the interactions between the objects themselves [40]. This section details the communication and sequence diagrams for each Use Case depicted in Figure 3.3.

In communication diagrams, three types of classes are encountered. The first one is the Boundary Class Stereotype. This models the interaction between a system and it's actors. The symbol used to represent this type of class is depicted in Figure 3.4. Control Class Stereotype is used to represent the coordination, sequencing, transactions and control of other objects. The symbol used to represent this type of

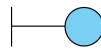


Figure 3.4: Boundary Class Stereotype symbol

class is depicted in Figure 3.5. Entity Class Stereotype models information as well



Figure 3.5: Control Class Stereotype symbol

as behaviour of phenomena or concepts. The symbol used to represent this type of class is depicted in Figure 3.6.

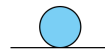


Figure 3.6: Entity Class Stereotype symbol

Approve Farmer

In Figure 3.7, the approve farmer user interface (UI) is started. The corresponding control object is then instantiated. The user prompts to view a farmer record. The control object fetches the requested farmer record and displays the information on the user interface. The user then sends an approve message. The sequence dia-

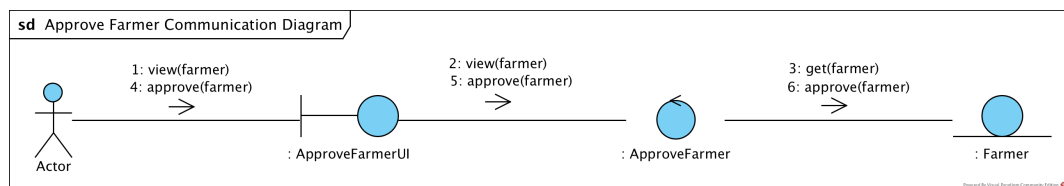


Figure 3.7: Approve farmer communication diagram

gram in Figure 3.8 is based off of the communication diagram in Figure 3.7. The sequence of events for the Approve Farmer Use Case are shown.

Search for Farmer

In Figure 3.9, the view farmer user interface (UI) is started. The corresponding control object is then instantiated. The user prompts to search for a farmer record.

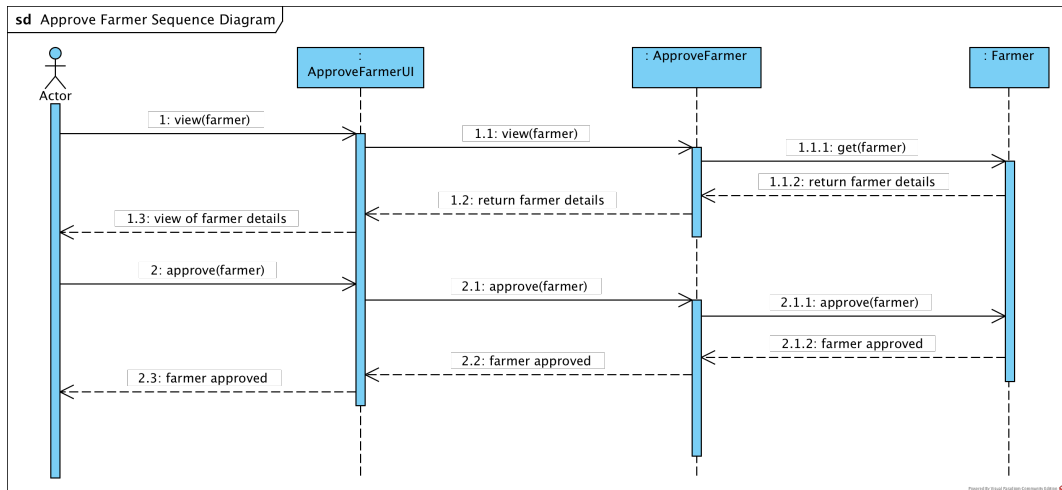


Figure 3.8: Approve farmer sequence diagram

The control object searches for the requested farmer record and displays the results on the user interface. The sequence diagram in Figure 3.10 is based off of the

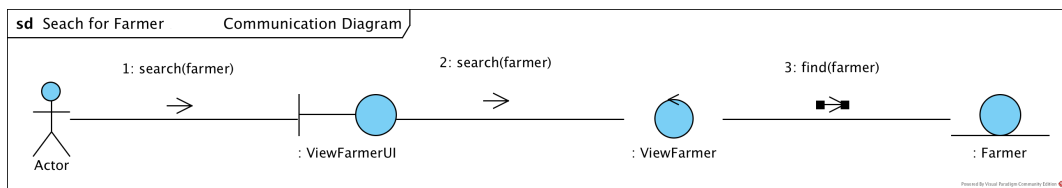


Figure 3.9: Search for farmer communication diagram

communication diagram in Figure 3.9. The sequence of events for the Search for Farmer Use Case are shown.

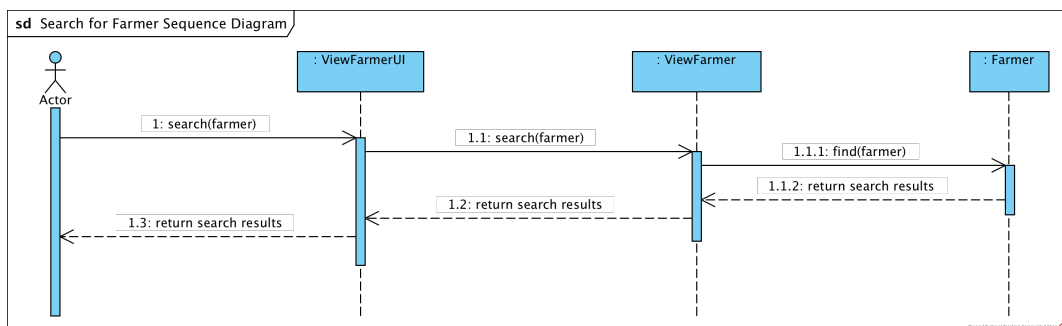


Figure 3.10: Search for farmer sequence diagram

Login

In Figure 3.11, the login user interface (UI) is started. The corresponding control object is then instantiated. The user sends their login credentials. The control object authenticates the user. The sequence diagram in Figure 3.12 is based off of the

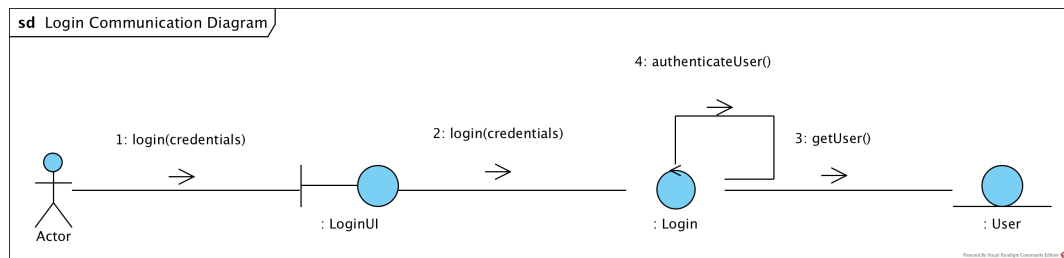


Figure 3.11: Login communication diagram

communication diagram in Figure 3.11. The sequence of events for the Login Use Case are shown.

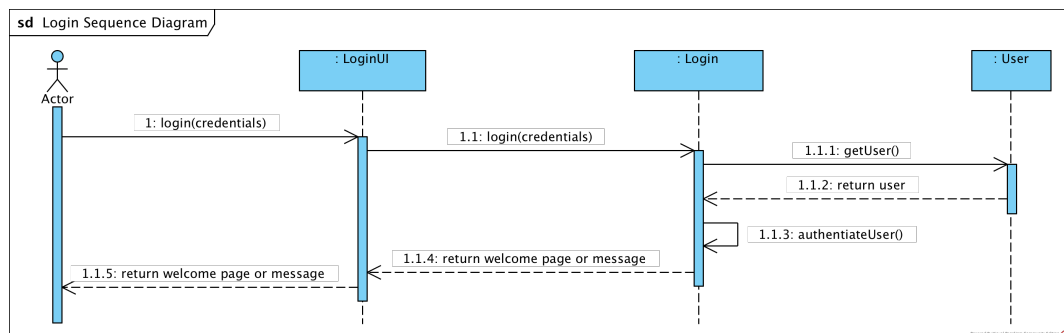


Figure 3.12: Login sequence diagram

Add Farmer

In Figure 3.13, the farmer register user interface (UI) is started. The corresponding control object is then instantiated. The user sends their details of the farmer record being created. The control object creates and stores the farmer object. The sequence diagram in Figure 3.14 is based off of the communication diagram in Figure 3.13. The sequence of events for the Add Farmer Use Case are shown.

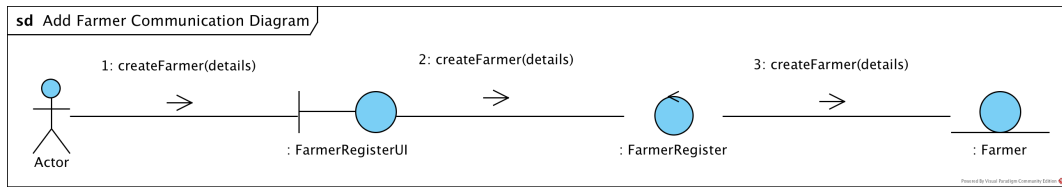


Figure 3.13: Add Farmer communication diagram

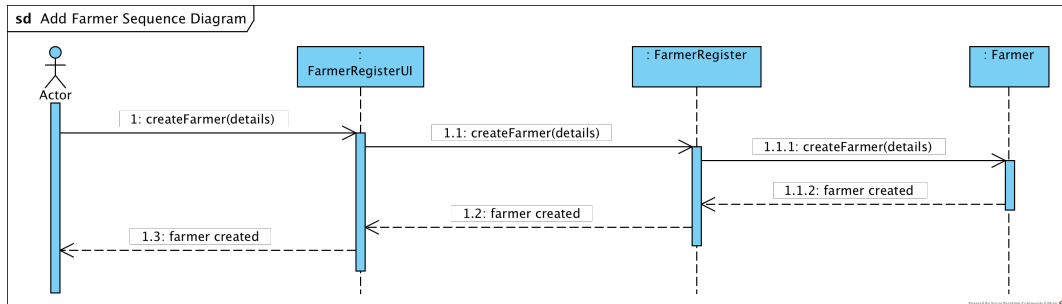


Figure 3.14: Add Farmer sequence diagram

Edit Farmer

In Figure 3.15, the farmer register user interface (UI) is started. The corresponding control object is then instantiated. The user sends their details of the farmer record being edited. The control object updates the farmer object. The sequence diagram

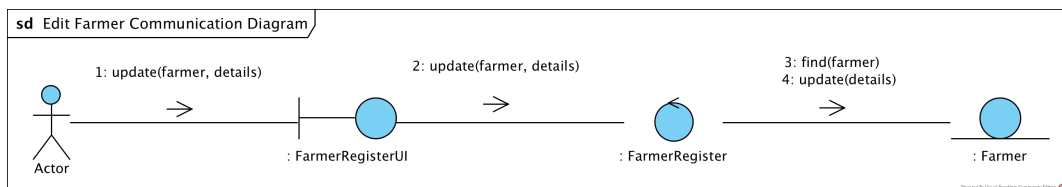


Figure 3.15: Edit Farmer communication diagram

in Figure 3.16 is based off of the communication diagram in Figure 3.15. The sequence of events for the Edit Farmer Use Case are shown.

Delete Farmer

In Figure 3.17, the farmer register user interface (UI) is started. The corresponding control object is then instantiated. The user sends their details of the farmer record being deleted. The control object deletes the farmer object. The sequence diagram

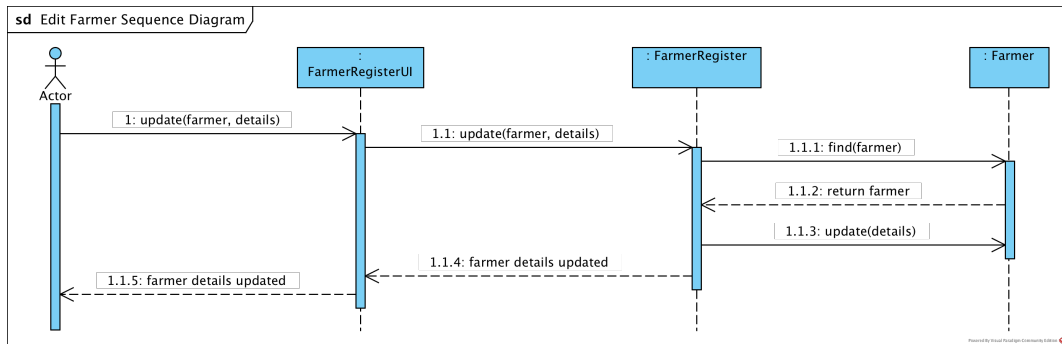


Figure 3.16: Edit Farmer sequence diagram

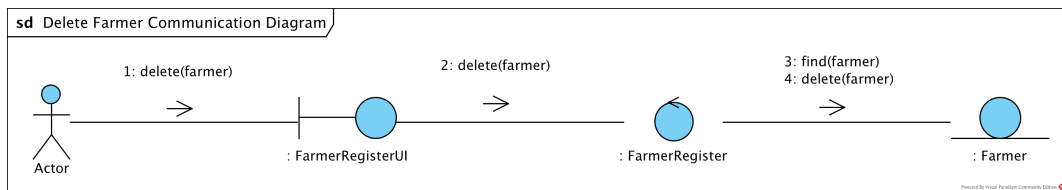


Figure 3.17: Delete Farmer communication diagram

in Figure 3.18 is based off of the communication diagram in Figure 3.17. The sequence of events for the Delete Farmer Use Case are shown.

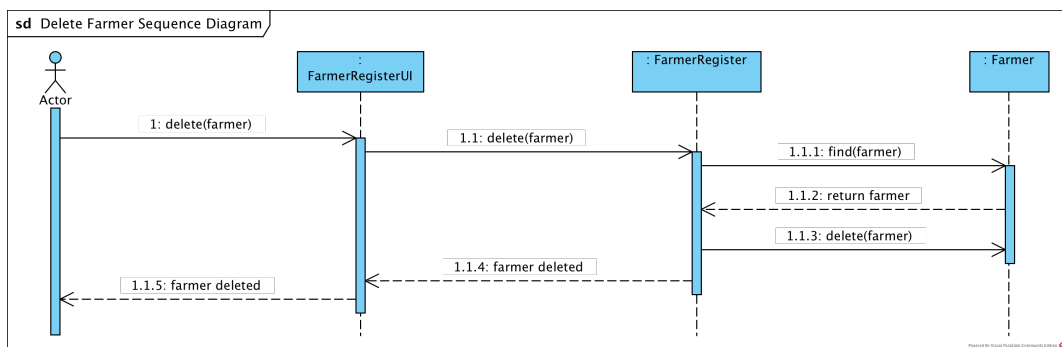


Figure 3.18: Delete Farmer sequence diagram

Add Grain

In Figure 3.19, the grain ledger user interface (UI) is started. The corresponding control object is then instantiated. The user sends their details of the grain being added. The control object stores the information in the bags object. The sequence diagram in Figure 3.20 is based off of the communication diagram in Figure 3.19. The sequence of events for the Add Grain Use Case are shown.

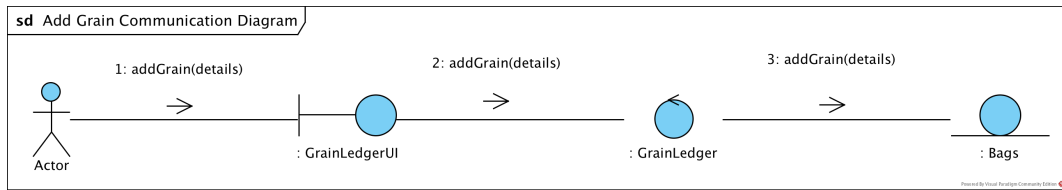


Figure 3.19: Add Grain communication diagram

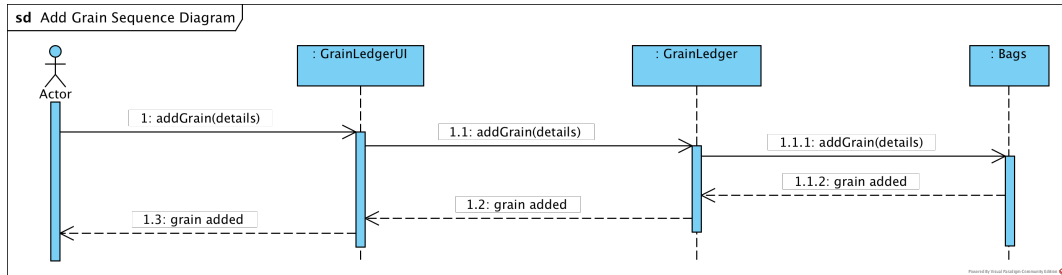


Figure 3.20: Add Grain sequence diagram

Create User

In Figure 3.21, the user list user interface (UI) is started. The corresponding control object is then instantiated. The user sends their details of the user being created. The control object creates and stores the user object. The sequence diagram in Figure

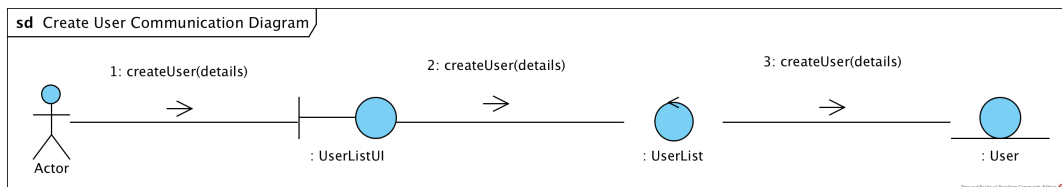


Figure 3.21: Create User communication diagram

3.22 is based off of the communication diagram in Figure 3.21. The sequence of events for the Create User Use Case are shown.

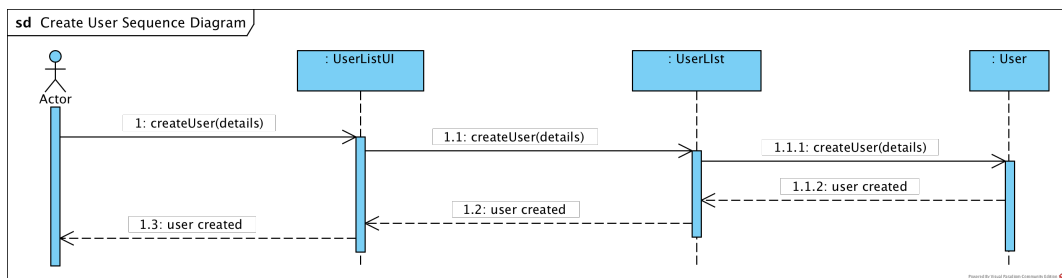


Figure 3.22: Create User sequence diagram

Edit User

In Figure 3.23, the user list user interface (UI) is started. The corresponding control object is then instantiated. The user sends their details of the user being edited. The control object updates and stores the user object. The sequence diagram in Figure

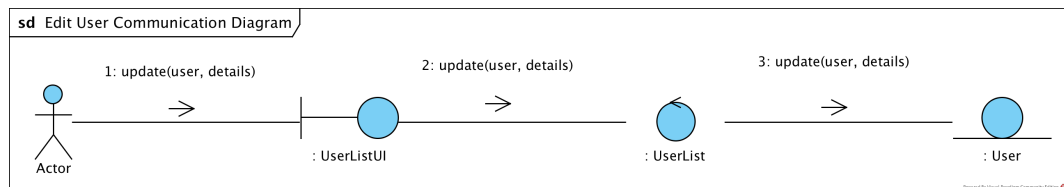


Figure 3.23: Edit User communication diagram

3.24 is based off of the communication diagram in Figure 3.23. The sequence of events for the Edit User Use Case are shown.

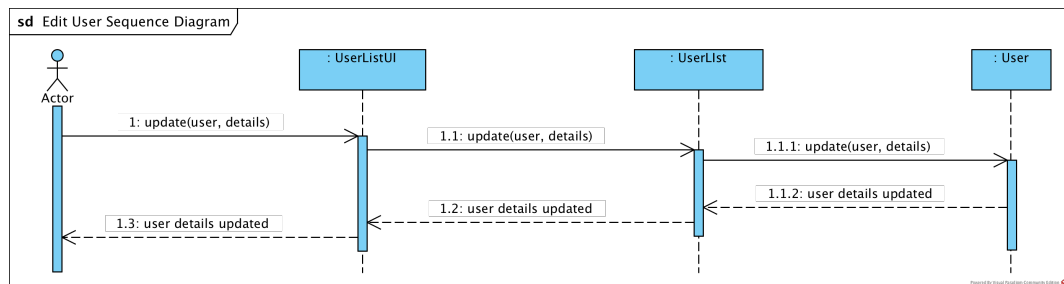


Figure 3.24: Edit User sequence diagram

Remove User

In Figure 3.25, the user list user interface (UI) is started. The corresponding control object is then instantiated. The user sends their details of the user being deleted. The control object deletes the user object. The sequence diagram in Figure 3.26 is

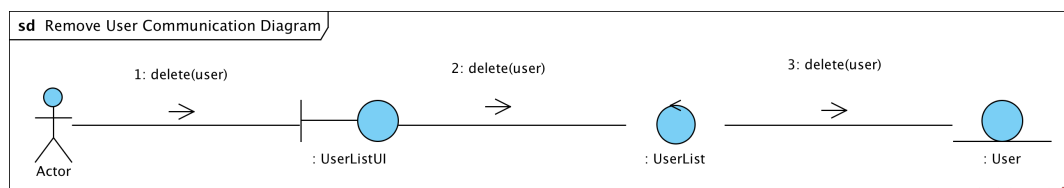


Figure 3.25: Remove User communication diagram

based off of the communication diagram in Figure 3.25. The sequence of events for the Remove User Use Case are shown.

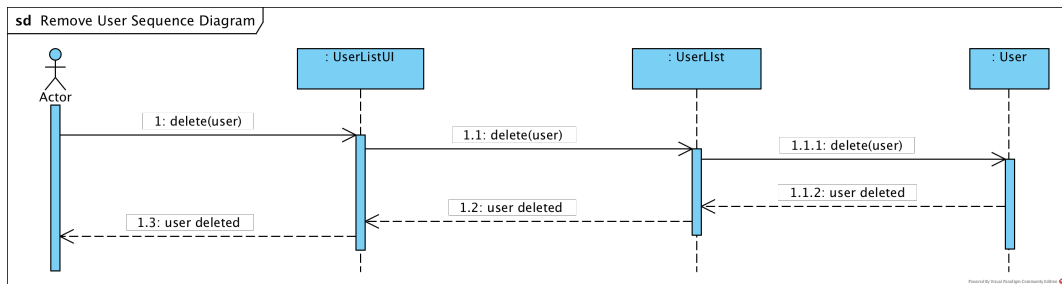


Figure 3.26: Remove User sequence diagram

3.5.5 Structural Models - Class Diagram

Figure 3.27 is a class diagram depicting the various system entites and their relationships.

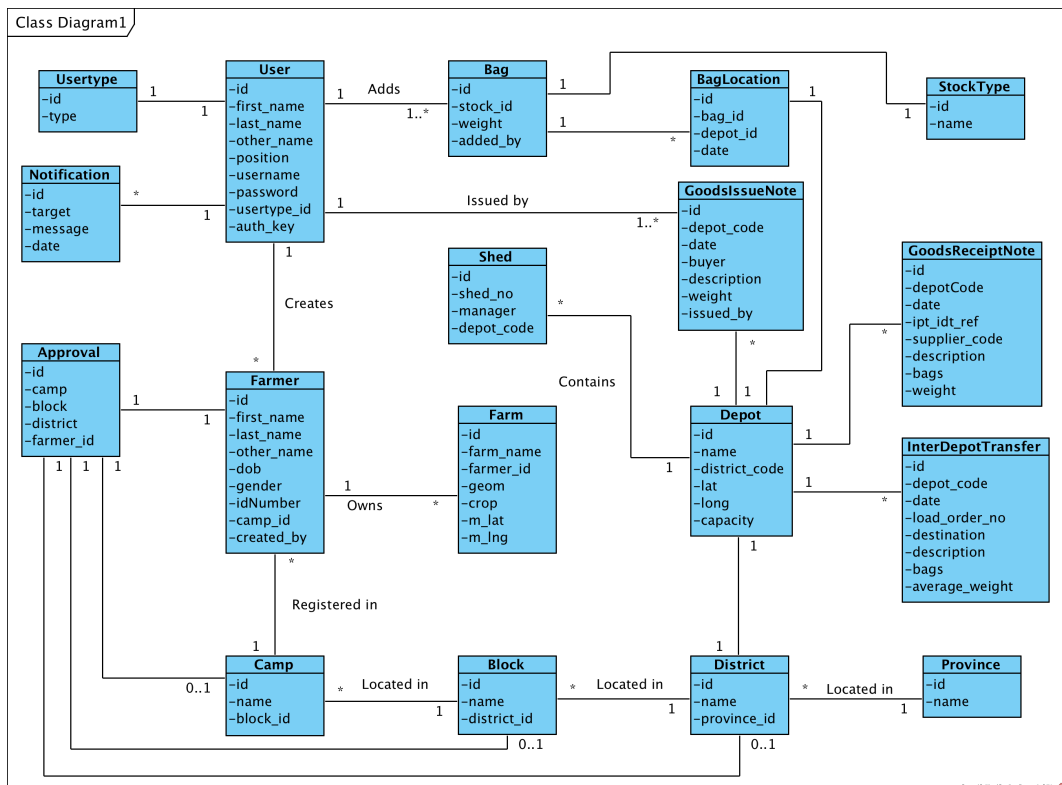


Figure 3.27: Class Diagram

3.6 System Implementation - Web Application

The system prototype backend was developed on the Yii framework [43]. Yii is a component-based Hypertext Processor (PHP) [44] framework well suited to the development of high performance web applications.

3.6.1 REST API

REpresentational State Transfer (REST) Application Programming Interface (API) is a design pattern that allows for parts of a program to be exposed using an existing protocol like HTTP [45].

A REST API implementation needs to follow six key principles:

1. **Client-server** - separating the user interface from the backend application. This allows for flexibility and portability [45].
2. **Stateless** - The sessions must be managed by the client rather than the server. This means that every request must carry with it all the required information [45].
3. **Cacheable** - declare explicitly whether response data is cacheable or not [45].
4. **Uniform interface**
5. **Layered system** - each path in the API is independent of the others [45].
6. **Code on demand** - (optional) allowing for the download of applets to bring in additional functionality [45].

3.7 System Implementation - Mobile Application

The mobile application was developed using the Java programming language. The Android Studio platform was used to design and package the application.

3.8 Limitations of the Prototype Development

1. Being a prototype, certain assumptions were made on some parameters. For example, that every grain bag was maize and weighed 50 kg.
2. The mobile application requires that the device has a stable internet connection. The prototype was developed with the idea of providing real-time information, so allowing users to sync with the server at their leisure goes against that idea.
3. Due to variance in the accuracy of mobile device GPS readings, a wide window of a few hundred metres is set as the error margin for position authentication.
4. Barcoding is the identification scheme chosen for this system. This was due to cost considerations.
5. Handling of input requests was not handled in this prototype.

3.9 Summary

In this chapter, the methods and materials used while carrying out the baseline study and development of the system prototype were outlined. Mixed-Methods approach was employed while carrying out the baseline study. The Object Oriented Development Methodology was used during requirement elicitation. The proposed business process models for both the FISP and FRA processes were presented after a description of the current processes. System models, including interaction and structural models, were presented to provide the means in which this system was developed

CHAPTER 4: RESULTS

In this chapter, the results derived from the baseline study are presented. The results of the implementation of the system prototype are also presented.

4.1 Baseline Study

4.1.1 Demographic Data

FRA depots in Lusaka, Chongwe and Mumbwa were targeted for the collection of quantitative data. The pie chart in Figure 4.1 shows the demographic study results.

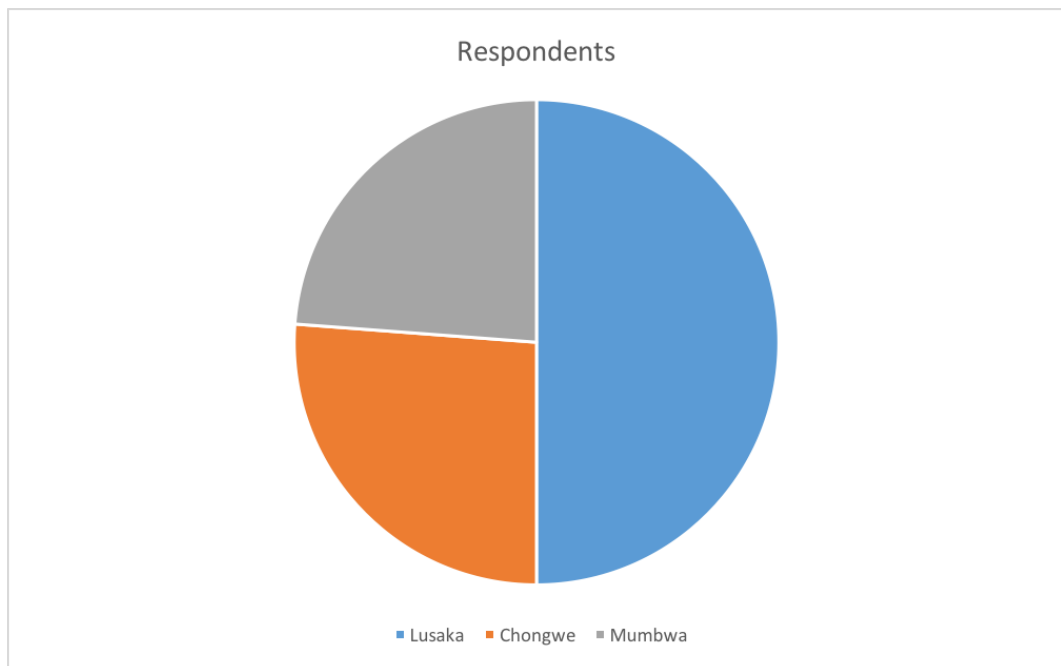


Figure 4.1: Demographic data pie chart

The questionnaire respondents broke down as follows: 11 (26.2%) from Chongwe Main depot, 10 (23.8%) from Mumbwa depot and 21 (50%) from the Lusaka depots (Mungwi and Mwembeshi depots).

4.1.2 Information Technology

Regarding the computer infrastructure available at depot locations, Figure 4.2 shows that 45.2% of the respondents say that their depot only has one computer.

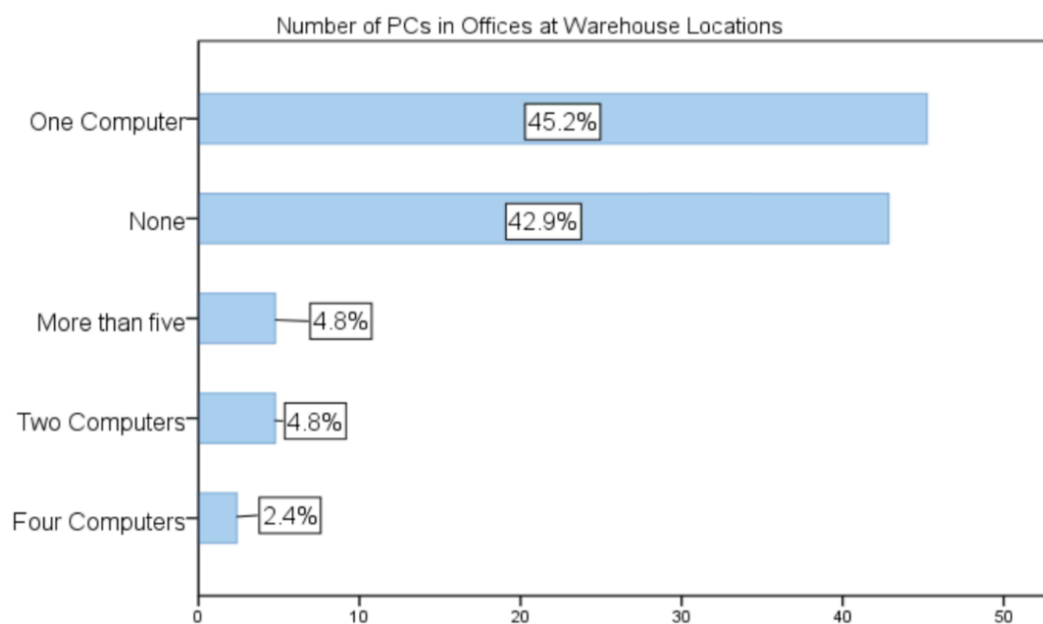


Figure 4.2: Number of computers in offices at depot locations - summarized

Given that the three depots were in what would be considered more urbanized locations compared to the rest of the country, it is no surprise that the majority of respondents had access to a computer at their locations. It is expected that the result would be vastly different if more rural locations were sampled.

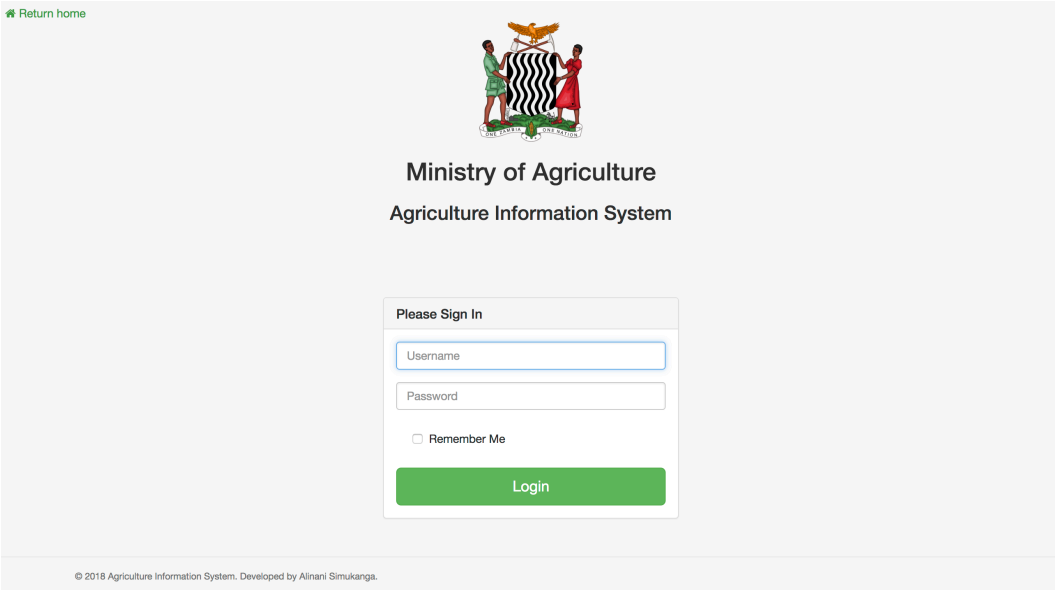
4.2 System Implementation

One of the things the baseline study shows is the reliance on manual methods. In order to show how an automated system would help manage the challenges faced

with the manual system, a prototype was developed as a proof of concept. The prototype had two main parts to it: the small-scale farmer database and the mobile grain bag tagging system.

4.2.1 Small-scale Farmer Database

Figure 4.3 depicts the system login page. For this prototype, the password was the only factor used to authenticate the user in the web application.



The screenshot shows the login page for the Ministry of Agriculture Agriculture Information System. At the top left, there is a "Return home" link. In the center, there is the national emblem of Nigeria, followed by the text "Ministry of Agriculture" and "Agriculture Information System". Below this, there is a "Please Sign In" form with fields for "Username" and "Password", a "Remember Me" checkbox, and a green "Login" button. At the bottom, there is a copyright notice: "© 2018 Agriculture Information System. Developed by Alinani Simukanga."

Figure 4.3: System login interface

Figure 4.4 shows the Camp Extension Officer's dashboard. Basic statistics relating to how many farmers have been registered and approved in their assigned camp are displayed. Due to the module not being developed, only placeholder figures appear for both the input requests sent and the input requests approved.

Figures 4.5 and 4.6 show the land parcel of a farmer. The location data is collected through a separate mobile application developed by Mulenga [46]. The location data is parsed and displayed as a shape on a map provided by Google Maps.

Figures 4.7 and 4.8 show some storage locations around the country. Some basic details pertaining to each location is visible on clicking the marker icon.

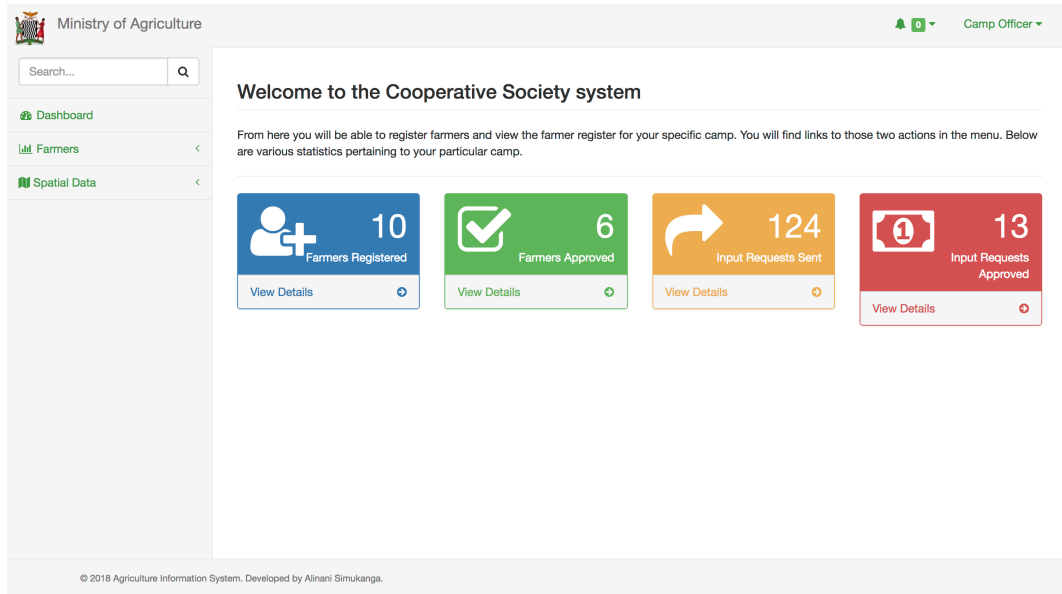


Figure 4.4: Camp Extension Officer dashboard

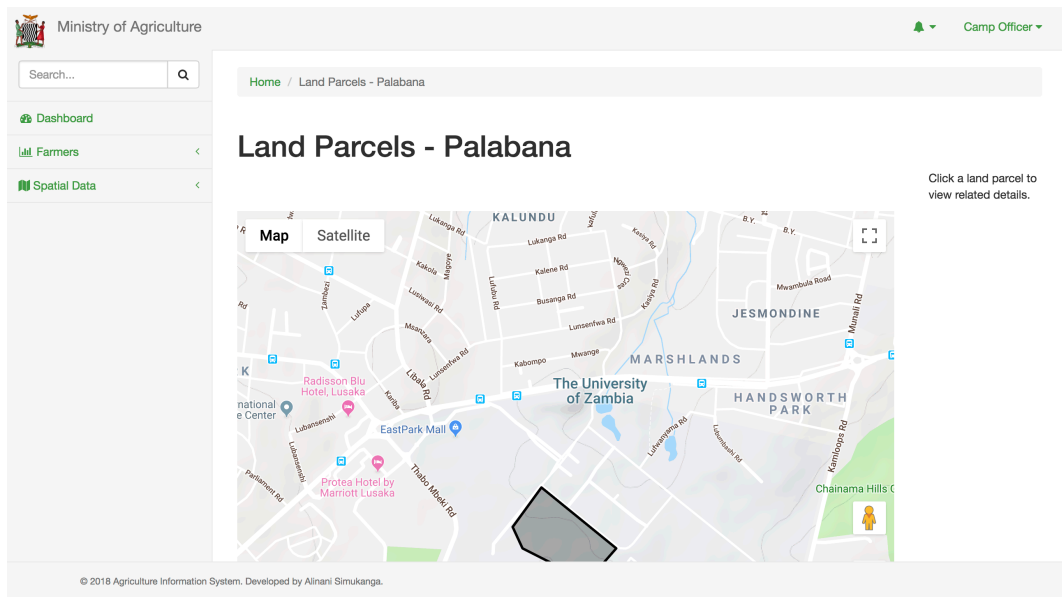


Figure 4.5: Farmer land parcels

Registration Process

The registration process begins by clicking the *Register Farmer* link under the *Farmers* menu. The farmer registration form as seen in Figure 4.9 is then displayed.

Upon filling in the form and saving the entry, the farmer record is then displayed.

An example of this can be seen in Figure 4.10.

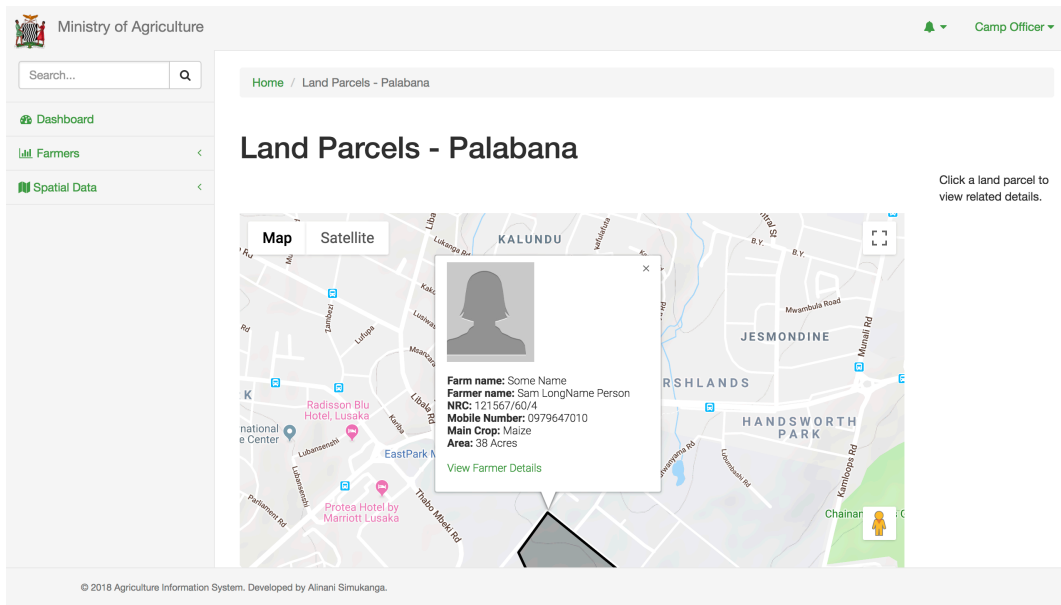


Figure 4.6: Farmer land parcels - detailed

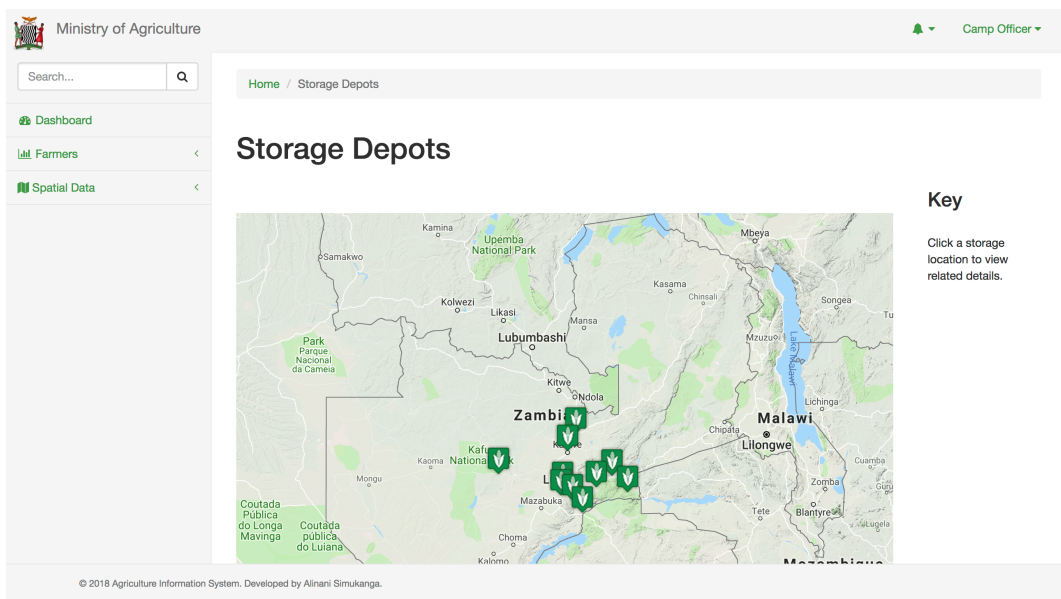


Figure 4.7: Storage locations

The entire farmer register of the particular camp can be viewed by clicking the *Farmer Register* item under the *Farmers* menu link. This is shown in Figure 4.11.

Approval Process

Approval of farmers takes place at three levels:

1. Camp level

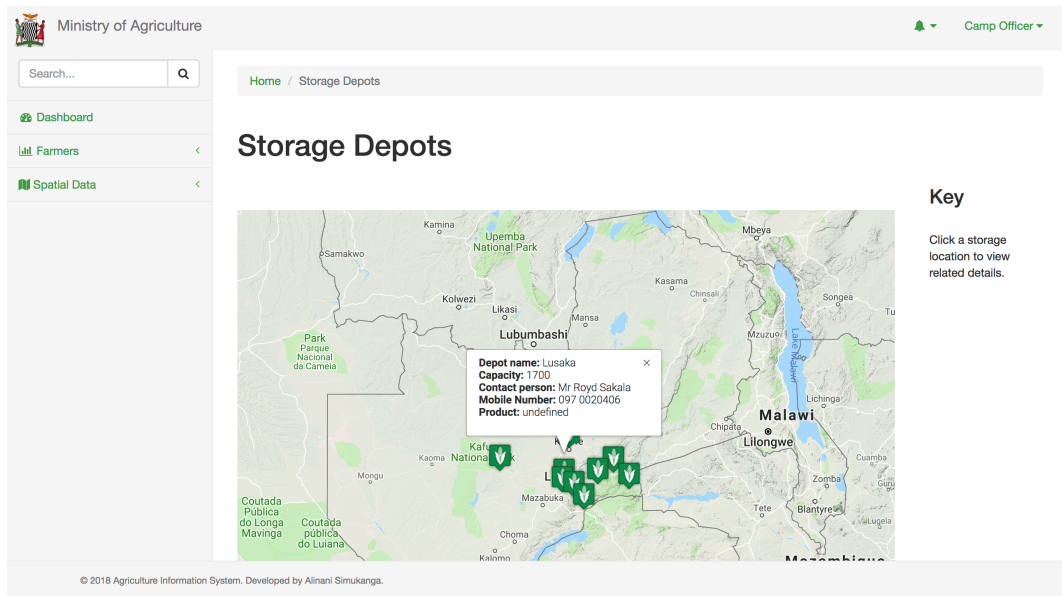


Figure 4.8: Storage locations - detailed

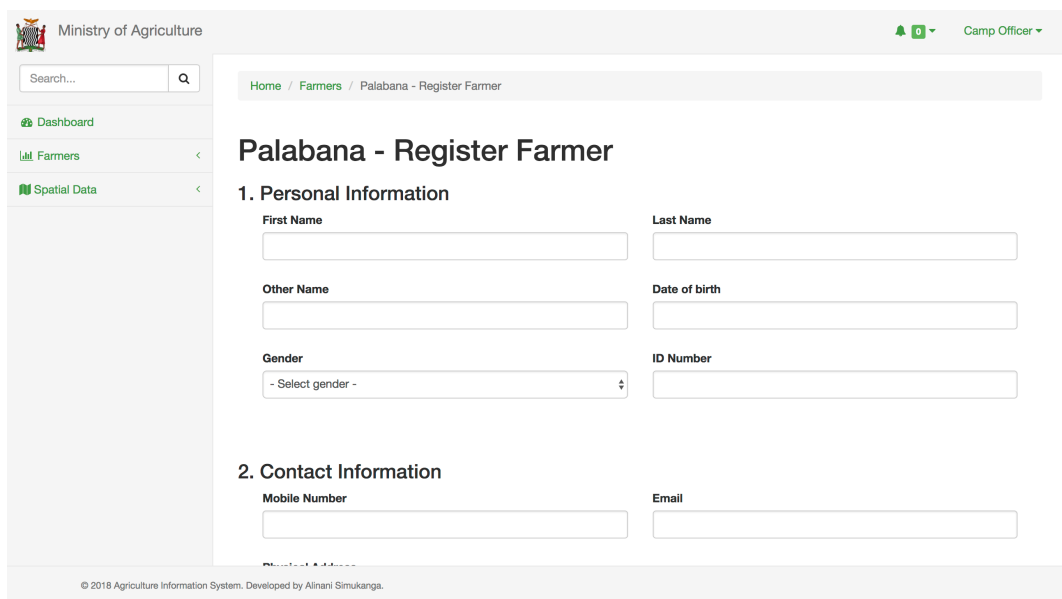


Figure 4.9: Farmer registration form

2. Block level
3. District level

The process begins from the camp level and ends at the district level. Approval at each level is handled similarly within the system. The figures that follow focus on approval at camp level.

Figure 4.12 shows the camp approver dashboard.

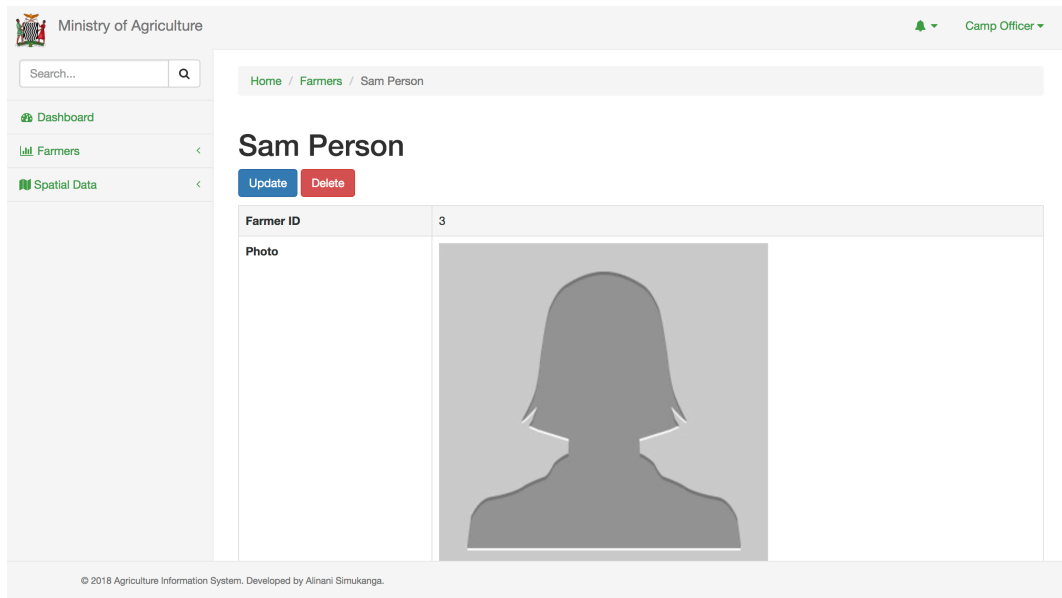


Figure 4.10: Farmer record

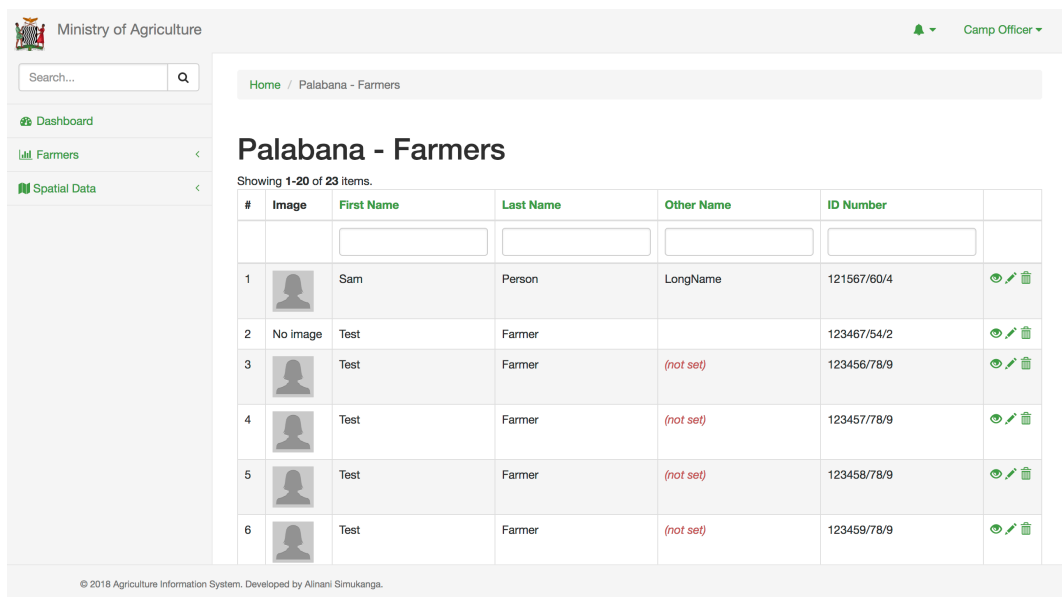


Figure 4.11: Farmer register

Figure 4.13 shows the pending farmer approvals for the Palabana camp. On clicking the eye (view) button, the user is directed to the farmer record as show in Figure 4.14.

On viewing the farmer details, if the approver feels the information entered is in order he/she can click the *Approve* button. Doing this moves the record to the next level of approval.

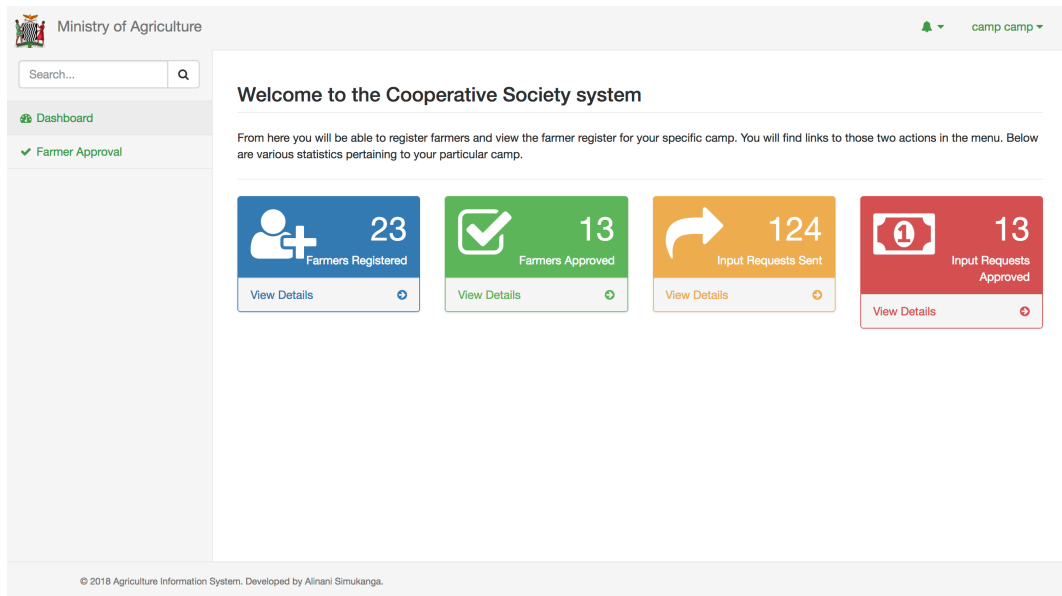


Figure 4.12: Camp Approver dashboard

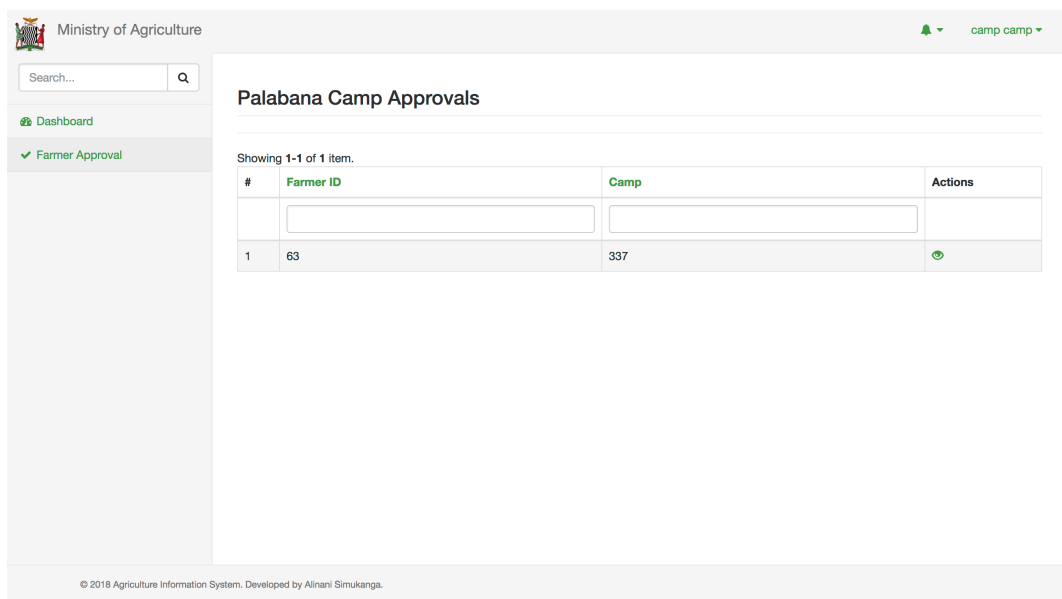


Figure 4.13: Pending approvals

4.2.2 Mobile Grain Bag Tagging

Figure 6 shows the mobile application login screen. Upon correct entry of a Satellite Depot Supervisor's details and if the other factors of authentication are met, the user is then redirected to the Satellite Depot Supervisor dashboard as seen in Figure 5. Clicking the yellow capture button brings up the barcode scanning activity shown

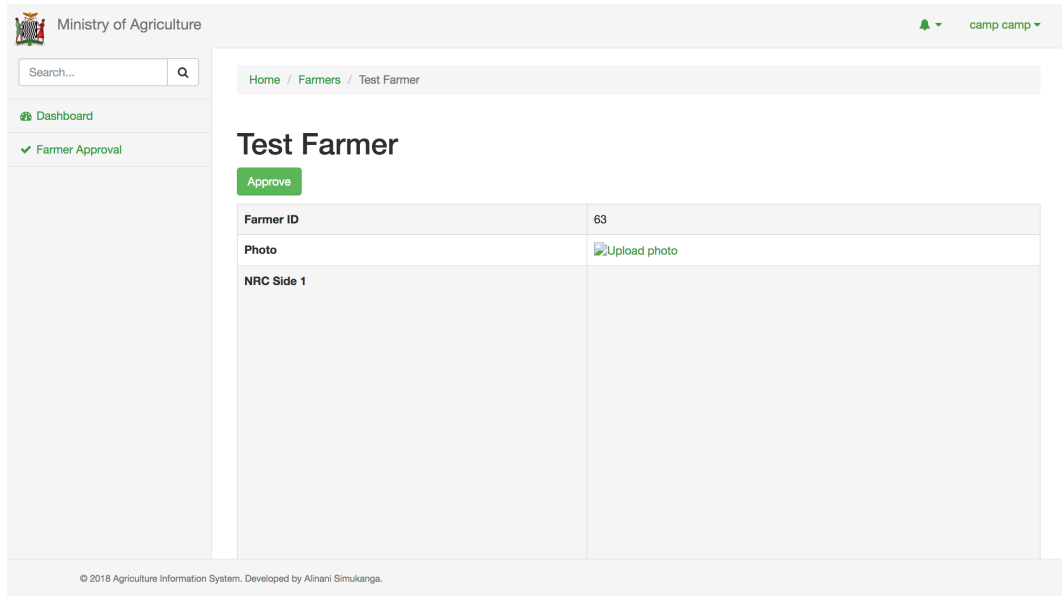


Figure 4.14: Approval view

in Figure 7. If the barcode corresponds to a valid and approved farmer record, the user is redirect to the particular record. This is depicted in Figure 8.

The barcode scanning activity as seen in Figure 7 is displayed upon clicking the *SCAN* button. The grain bag linked to that barcode is then linked the farmer in question. A message is then displayed as seen in Figure 9.

4.3 Summary

In this chapter, the data collected was analysed and presented in the form of figures and tables. The challenges faced by FRA with regard to stock thefts and stock management were identified. Under system implementation, a system prototype was successfully implemented.

CHAPTER 5: DISCUSSION AND CONCLUSION

In this chapter, a discussion of the results presented in the previous chapter are presented. This is followed by a discussion of the business process models. A discussion of the system implementation then follows. The conclusion is then followed by recommendations and future work.

5.1 Discussion

5.1.1 Business Process Mapping and Modelling

In Chapter 3, the business processes pertaining to the farmer registration and stock purchase processes were defined. These were modelled off of the information provided through the FISP implementation manual as well as from informal interviews with staff from FRA. From these business processes, automated business processes are then proposed. The use of computer systems in place of paper based records is introduced. For the most part, the proposed records closely match the current processes.

5.1.2 System Implementation

Based on the business processes that were proposed, use cases and system requirements were extracted. Data models were then developed from the gathered requirements. Two system prototypes were then developed based on this information: 1)

a prototype web application and; 2) a prototype mobile application. The web application was built upon a PHP and PostgreSQL backend. The mobile application was built using the Java programming language and the Android SDK. The web application was used for farmer management (both registration and approval). The mobile application was used for the grain capturing process. This begins by fetching the farmer record. This is done by scanning the barcode printed on the farmer's identification card. Doing this pulls up the farmer's record on the device. The user then has the option of scanning grain bags. Bags that have not been previously linked to other farmers can be paired to the current farmer by scanning their barcodes. While this process is taking place, the mobile application is constantly sending data to the server over the defined API.

5.2 Conclusion

Based on the objectives of the study, the following conclusions were arrived at:

- A dynamic web-based system prototype could be developed that integrates spatial data and mobile computing. This prototype could also be developed to fit the current business processes of FRA and FISP.
- A multi-factor authentication was implemented on the mobile application prototype.

5.3 Recommendations

Strides were made to get this project off the ground. There is a lot that could still be done in implementing ICTs in the agriculture sector. A few identified modules have been listed in the Future Works section that would definitely add to the usefulness of this system.

5.4 Future Works

- Implementation of an RFID system for grain bag identification.
- Implementation of an input request management system.
- Merging of barcode scanning component into main mobile application.
- Implementation of depot grain inventory management.

BIBLIOGRAPHY

- [1] MAL, *Farmer Input Support Programme (FISP) Implementation Manual 2014/2015 Agricultural Season*. Ministry of Agriculture and Livestock, 2014.
- [2] *National Science and Technological Council*. [Online]. Available: <https://www.nstc.org.zm/> (visited on Feb. 18, 2019).
- [3] *National Research Foundation*. [Online]. Available: <https://www.nrf.ac.za/> (visited on Feb. 18, 2019).
- [4] *About FAO*, 2018. [Online]. Available: <http://www.fao.org/about/en/> (visited on Apr. 22, 2019).
- [5] FAO, *Food Security*. [Online]. Available: <http://www.fao.org/docrep/006/Y5061E/y5061e08.htm> (visited on Mar. 14, 2018).
- [6] Knoema, *Maize Surplus/deficit (A-B) 2012 - 2016*, Feb. 2016. [Online]. Available: <http://zambia.opendataforafrica.org> (visited on Sep. 29, 2018).
- [7] T. Kalinda, F. Maimbo, and M. Mushimba, “Zambia Food Security Issues Paper”, Forum for Food Security in Southern Africa, Tech. Rep., Jul. 2003. (visited on Sep. 29, 2018).
- [8] PMRC, *Farmer Input Support Programme Infographic*, 2015. [Online]. Available: <http://www.pmrzambia.com/wp-content/uploads/2015/09/Farmer-Input-Support-Programme-Infographic.pdf> (visited on Mar. 1, 2018).

- [9] MAC, *Implementation Manual*. Ministry of Agriculture and Cooperatives, Zambia, 2002.
- [10] T Lungu-Jere, *FISP Electronic Voucher System Approved*, Aug. 2015. [Online]. Available: http://www.agriculture.gov.zm/index.php?option=com_content&view=article&id=301:fisp-electronic-voucher-system-approved&catid=100&Itemid=1546 (visited on Mar. 1, 2018).
- [11] Mwambazi, “Talking Notes - FISP E-VOUCHER”, *Ministry of Agriculture*, Nov. 2017. [Online]. Available: http://www.agriculture.gov.zm/index.php?option=com_content&view=article&id=369:fisp&catid=100&Itemid=1546 (visited on Mar. 1, 2018).
- [12] M Muwanei, “Get Rid of Ghost Farmers on E-Voucher, FISP”, *Times of Zambia*, Feb. 2018. [Online]. Available: <http://www.times.co.zm/?p=102908> (visited on Mar. 1, 2018).
- [13] H Siame, *3,000 Ghost FISP Farmers Exposed*, Jan. 2017. [Online]. Available: <https://www.daily-mail.co.zm/3000-ghost-fisp-farmers-exposed/> (visited on Mar. 1, 2018).
- [14] N Kachemba and A Mwansa, “Clean-up Nets 20,000 Ghosts”, *Zambia Daily Mail*, Apr. 2017. [Online]. Available: <https://www.daily-mail.co.zm/clean-up-nets-20000-ghosts/> (visited on Mar. 1, 2018).
- [15] D Mulenga, “FISP Malpractices Rife - Farmers”, *African Farming*, Dec. 2016. [Online]. Available: <https://www.africanfarming.com/fisp-malpractices-rife-farmers/> (visited on Mar. 1, 2018).
- [16] D Chanda, “Stop Those Farmers Selling Subsidised Inputs!”, *Times of Zambia*, Jan. 2018. [Online]. Available: <http://www.times.co.zm/?p=102563> (visited on Mar. 1, 2018).

- [17] *Zambia has saved up to One-billion kwacha from ghost Farmers - Mutati*, Oct. 2017. [Online]. Available: <https://www.lusakatimes.com/2017/10/01/zambia-saved-one-billion-kwacha-ghost-farmers-mutati/> (visited on May 29, 2018).
- [18] C. Sichone, *Govt Saves K1bn From 'Ghost' Farmers*, Sep. 2017. [Online]. Available: <http://www.times.co.zm/?p=98787> (visited on May 29, 2018).
- [19] *Chapter 225 The Food Reserve Act*, 1992. [Online]. Available: <http://41.77.4.165:6510/www.parliament.gov.zm/sites/default/files/documents/acts/Food%20Reserve%20Act.pdf> (visited on Oct. 6, 2018).
- [20] *Agriculture Science and GIS*, 2017. [Online]. Available: <http://www.environmentalscience.org/agriculture-science-gis> (visited on Sep. 12, 2017).
- [21] A. Ghosh and R. Amitava, "GIS anchored integrated plantation management: Tea", in *Map India 2004 Proceedings*, 2004. [Online]. Available: <https://www.geospatialworld.net/wp-content/uploads/images/pdf/mi04111.pdf> (visited on Oct. 9, 2018).
- [22] M. Braun, "GIS for Sustainable Agriculture", *GIS Best Practices*, pp. 1–3, Sep. 2008. [Online]. Available: <http://www.esri.com/library/bestpractices/sustainable-agriculture.pdf> (visited on Oct. 9, 2018).
- [23] C. Jacomme and S. Kremer, "An Extensive Formal Analysis of Multi-factor Authentication Protocols", in *2018 IEEE 31st Computer Security Foundations Symposium (CSF)*, Oxford: IEEE, Jul. 2018, pp. 1–15, isbn: 978-1-5386-6680-7. doi: [10.1109/CSF.2018.00008](https://doi.org/10.1109/CSF.2018.00008).
- [24] P. A. Grassi, J. L. Fenton, E. M. Newton, R. A. Perlner, A. R. Regenscheid, W. E. Burr, J. P. Richer, N. B. Lefkovitz, J. M. Danker, Y.-Y. Choong, K. K.

- Greene, and M. F. Theofanos, “Digital identity guidelines: Authentication and lifecycle management”, National Institute of Standards and Technology, Gaithersburg, MD, Tech. Rep. NIST SP 800-63b, Jun. 2017. doi: [10.6028/NIST.SP.800-63b](https://doi.org/10.6028/NIST.SP.800-63b).
- [25] S. Masiero and A. Prakash, “The politics of anti-poverty artefacts: Lessons from the computerization of the food security system in Karnataka”, en, in *Proceedings of the Seventh International Conference on Information and Communication Technologies and Development - ICTD '15*, Singapore, Singapore: ACM Press, 2015, pp. 1–10, isbn: 978-1-4503-3163-0. doi: [10.1145/2737856.2738011](https://doi.org/10.1145/2737856.2738011).
- [26] J. Drèze and R. Khera, “Rural Poverty and the Public Distribution System”, Centre for Development Economics, Delhi School of Economics, Working papers, 2013. [Online]. Available: <https://EconPapers.repec.org/RePEc:cde:cdewps:235> (visited on Oct. 6, 2018).
- [27] Himanshu, *PDS: A story of changing states*, Aug. 2013. [Online]. Available: <https://www.livemint.com/Opinion/TTLqUOCg2iF4hYtJSHtMRI/PDS-a-story-of-changing-states.html> (visited on Oct. 6, 2018).
- [28] R. Khera, “India’s Public Distribution System: Utilisation and Impact”, en, *Journal of Development Studies*, vol. 47, no. 7, pp. 1038–1060, Jul. 2011, issn: 0022-0388, 1743-9140. doi: [10.1080/00220388.2010.506917](https://doi.org/10.1080/00220388.2010.506917).
- [29] UIDAI, “UID and PDS System”, Unique Identification Authority of India (UIDAI) Planning Commission, Working paper, 2009. [Online]. Available: <http://www.uidai.gov.in> (visited on Oct. 6, 2018).
- [30] S. Daibone, B. Davis, R. Pickmans, N. Pace, S. Handa, and M. Knowles, “The Social Cash Transfer and the Farm Subsidy Programme in Malawi”, Food and Agriculture Organization, United Nations, Rome, Tech. Rep., 2017. [Online].

Available: <http://www.fao.org/3/a-i6810e.pdf> (visited on Oct. 8, 2018).

- [31] T. Kilic, E. Whitney, and P. Winters, “Decentralised Beneficiary Targeting in Large-Scale Development Programmes: Insights from the Malawi Farm Input Subsidy Programme”, en, *Journal of African Economies*, vol. 24, no. 1, pp. 26–56, Jan. 2015, issn: 0963-8024, 1464-3723. doi: [10.1093/jae/eju021](https://doi.org/10.1093/jae/eju021).
- [32] A. Mporokoso and J. Phiri, “Using Information Technology (ICT) Tools in Managing Customary Land, Demarcation, Conflict and Tenure Data in Developing Countries: A Case Study of Zambia”, *International Journal of Computer Science and Mobile Computing*, vol. 5, no. 3, pp. 594–603, Mar. 2016, issn: 2320–088X. [Online]. Available: <https://ijcsmc.com/docs/papers/March2016/V5I3201699a33.pdf> (visited on Oct. 26, 2018).
- [33] Y. A. Aina, “Applications of geospatial technologies for practitioners: An emerging perspective of geospatial education”, *Emerging informatics-innovative concepts and applications*, 2012.
- [34] *Grain Storage Facilities Eastern Africa Including Malawi*, 2013. [Online]. Available: <http://www.arcgis.com/home/webmap/viewer.html?webmap=c4959bfc26734c44bdc8b2a8aee4d397> (visited on Feb. 7, 2017).
- [35] *GIS for Agriculture*, Jun. 2009. [Online]. Available: <https://www.esri.com/library/bestpractices/gis-for-agriculture.pdf> (visited on Apr. 22, 2019).
- [36] *Tanzania: Mobile Application to Secure Tenure*. [Online]. Available: <https://www.land-links.org/tool-resource/mobile-applications-to-secure-tenure-mast/> (visited on Oct. 14, 2018).
- [37] A. Bronder, “Design, Implementation and Evaluation of a Mobile GIS solution for a Land Registration Project in Lesotho”, PhD thesis, Royal Institute

- of Technology, 2013. [Online]. Available: <http://kth.diva-portal.org/smash/get/diva2:634214/FULLTEXT01.pdf> (visited on Oct. 9, 2018).
- [38] *Planimeter*. [Online]. Available: <https://en.wikipedia.org/wiki/Planimeter> (visited on Feb. 16, 2017).
- [39] J. Wisdom and J. W. Creswell, *Mixed Methods: Integrating Quantitative and Qualitative Data Collection and Analysis While Studying Patient-Centered Medical Home Models*, Mar. 2013. [Online]. Available: <https://pcmh.ahrq.gov/page/mixed-methods-integrating-quantitative-and-qualitative-data-collection-and-analysis-while> (visited on Oct. 14, 2018).
- [40] I. Sommerville, *Software engineering*, 9th ed. Boston: Pearson, 2011, OCLC: ocn462909026, isbn: 978-0-13-703515-1 978-0-13-705346-9.
- [41] R. Weinberg, T. Guimaraes, and R. Heath, “Object-Oriented Systems Development”, *Journal of Information Systems Management*, vol. 7, no. 4, pp. 18–26, 2007. doi: [10.1080/07399019008968364](https://doi.org/10.1080/07399019008968364).
- [42] C. Coronel, S. Morris, and P. Rob, *Database systems: design, implementation, and management*, 10e [edition]. Boston, MA: Course Technology/Cengage Learning, 2013, OCLC: ocn780100102, isbn: 978-1-111-96960-8 978-1-133-52679-7.
- [43] *Yii Framework*. [Online]. Available: <https://www.yiiframework.com> (visited on Dec. 17, 2018).
- [44] K. Tatroe, R. Lerdorf, and P. MacIntyre, *Programming PHP*, 3rd ed. Sebastopol, CA: O’Reilly Media, 2013, OCLC: ocn812688349, isbn: 978-1-4493-9277-2.
- [45] *REST API Tutorial*. [Online]. Available: <https://www.restapitutorial.com/> (visited on Apr. 22, 2018).

- [46] J. Mulenga, “Web Portal and Geographical Information System (GIS) Mapping for the Ministry of Agriculture”, Bachelors Report, University of Zambia, Lusaka, Zambia, 2017.

APPENDICES

Appendix A - Data collection authorisation



Plot No. 7419, Manda Road, Industrial Area
 P.O. Box 34054, Lusaka, Zambia
 Tel: (260-211) 286097, 286106 & 286113
 Fax: (260-211) 286096
 E-mail: fra@fra.org.zm / www.fra.org.zm

11th November, 2015

COLLECTION OF DATA FOR THE UNZA – FRA PROJECT

Please be informed that the University of Zambia Department of Computer Science will be collecting data through questionnaires.

They will be visiting FRA Offices in various locations. You are advised to accord them any information that they will require to assist in speeding up the Project that is currently going on.

Please do not hesitate to call the undersigned for any clarifications on mobile 095 [redacted]

Kindly be advised accordingly.

Joseph A Phiri

Systems Administrator

WITH REGIONAL OFFICES IN:

CHOMA Lufuza, A77 CIDA Office Muzono, Road P.O. Box 102	CHIPATA B3961, B22/589 P.O. Box 310875 Tel: (2155) 21684	KASAMA Industrial Area Nandabwa's Moka Road P.O. Box 11011	KABWE Industrial Area P. Mutumba Road Fax: No. 6222 P.O. Box 80426	NDOLA Dheena M'chewe Woodang Road Plot No 2987 P.O. Box 11796	LUSAKA Industrial Area Mwambeshi Rd Fax: No. 7429/17487 P.O. Box 39825	SOLWEZI Industrial Area CIDA Sheda Fax: No. 7429/17487 P.O. Box 110255	MANSA Charles Mwanza Plot No 287A P.O. Box 73364 Tel: 2173 823581	ISOKA CIDA Sheda P.O. Box 441158 Tel/Fax: (21) 4550109	MONGU CIDA Sheda Lusaka/Ka 81 P.O. Box 510235 Tel: 2173 22356
--	--	---	---	--	---	---	--	--	--

Figure 1: FRA data collection authorisation letter

Appendix B - Questionnaire



THE UNIVERSITY OF ZAMBIA

DEPARTMENT OF COMPUTER SCIENCE

RESEARCH QUESTIONNAIRE

FOOD RESERVE AGENCY INVENTORY MANAGEMENT AUTOMATION RESEARCH QUESTIONNAIRE



ZAMBIA SOUTH AFRICA RESEARCH COOPERATION



National
Research
Foundation



QUESTIONNAIRE FOR FRA WAREHOUSE STAFF

Instructions

1. Answer all questions
2. Tick or circle the correct answers where they are provided
3. Write answers for the other questions in the spaces provided.

SECTION A: FACILITY

1. Name of Facility _____
2. Location _____ of _____ Facility
(Town/City/Village) _____
3. Region/Province/District _____

SECTION B: INVENTORY

FOR OFFICIAL USE

4. Does your organization have inventory? []
]
 1. Yes
 2. No
 3. Do Not Know
5. List the inventory types that are currently stored by your organization?

6. Do you have a special numbering system for the stock in the warehouse? []
]
 1. Yes
 2. No
 3. Do Not Know
7. If the answer to (6) is yes, what are the numbering requirements?

8. What type of inventory system do you maintain? []
]

1. system manually maintained with spread sheets,
2. an in-house system
3. Other, specify _____

SECTION C: STOCK COUNTS

9. What is the approximate storage capacity of each warehouse?

10. What is the approximate quantity of the stock kept at each warehouse?

11. How do you keep track of stock in the warehouse? []
]

1. Physical Counting
2. Automated Counting
3. Other, specify _____

12. How often do you count the stock in the warehouse? []
]

1. Daily
2. Weekly
3. Monthly
4. Quarterly
5. Every six months
6. Annually
7. Other, Specify _____

13. Do you use a maximum/minimum system for monitoring stock levels? []
]

1. Max/min stock levels have been set and are monitored
2. Max/min stock levels have been set but are not monitored
3. No max/min stock levels have been set

14. How long does it take for you complete counting stock in the warehouse? []
]

1. One Day

2. One Week
3. One Month
4. More than one month
5. One Year
6. Other, specify_____

15. When was the last time you did a complete physical stock count and produced an inventory report? []

1. A day ago
2. A week ago
3. A Month ago
4. 6 months ago
5. 1 year ago
6. 2 years ago
7. Other, specify_____

16. Approximately how many people do you engage to count the stock per warehouse? []

1. Two
2. Five
3. Ten
4. Fifteen
5. More than twenty
6. Other, specify_____

SECTION E: STOCK THEFT

17. Do you experience theft of stock in the warehouse? []

1. Yes
2. No
3. Do Not Know

18. How often do you experience theft at the warehouses? []

1. Daily
2. Weekly

- 3. Monthly
- 4. Quarterly
- 5. Every 6 months
- 6. Annually
- 7. Other, specify_____

19. Is security implemented to mitigate theft? []

- 1. Yes
- 2. No
- 3. Do Not Know

20. What security measures are put in place to ensure safety of stock in the warehouse?

SECTION F: STOCK RECORDS

21. Do you keep records of stock you currently have in the warehouse? []

- 1. Yes
- 2. No
- 3. Do Not Know

22. In what form do you keep records relating to inventory in the warehouse? []

- 1. Paper
- 2. Excel Spreadsheet
- 3. Database
- 4. Other, specify_____

SECTION G: INFORMATION TECHNOLOGY

23. How many computers, if any, are in the offices at the warehouse locations?

- 1. One computer

2. Two Computers
 3. Three Computers
 4. Four Computers
 5. None
 6. Other, Specify _____
24. Are computers at the warehouse and offices at the warehouse locations linked?
 []
1. Yes
 2. No
 3. Do Not Know
25. How reliable is electrical supply at the warehouse? []
1. Power outages occur daily
 2. Power outages occur weekly
 3. Power outages occur monthly
 4. Other, Specify _____
26. Is there a standby power supply such as a generator or UPS at the warehouse?
 []
1. Generator
 2. UPS
 3. No standby power supply
27. How many people would be operating the computer? (Count both warehouse staff and any other staff involved in the use of the computer for stock management)
- _____ Number of staff who would use the computer for stock management
28. How many among the staff that would operate the computer are at each of the following skill levels?
- _____ know how to program or have advanced knowledge of databases
- _____ know how to use at least one software, such as word processor or spreadsheet
- _____ have been introduced to basic computer operations, such as turning on/off, using the keyboard, DOS or Windows
- _____ have used a typewriter
- _____ have no experience with computers or typewriters

29. What type of advanced computer support is available to the warehouse? []
1. In-house computer support person
 2. Maintenance contract with external firm
 3. None

THANK YOU FOR ANSWERING

Appendix C - FISP Forms

ANNEX 1

FISP Form 1 No:



REPUBLIC OF ZAMBIA
MINISTRY OF AGRICULTURE AND LIVESTOCK

FARMER INPUT SUPPORT PROGRAMME
MATCHING GRANT SCHEME

INDIVIDUAL FARMER APPLICATION FOR INPUTS (to be submitted to the CAC)

TAILS OF APPLICANTS

Farmer Organization: Village/Farm area:
 Name: Camp:
 District:

To be completed by the Farmer

Applicant's Surname: Mr./Mrs./Ms
 Other Names: Farmer No. Gender F/M)
 NRC No.: Age:
 Marital Status (Single/Married/Widowed):
 Area of the Farm under cultivation: hectares or Limas.....
 Major Crops normally grown:
 Major Crops to be grown this year:
 Farm implements owned:

I am applying for the following packs of inputs:

Type	Number of Fertilizer Bags		Seed Variety	Farmer Contribution (K)
	Basal Dressing	Top Dressing		
so				
hum				
in				
in				

Signature of Applicant: Date:

To be completed by the Farmer organization

I, of recommend/do not recommend the above applicant and certify he/she is a/not a genuine member in our farmer organization.

Signature of Chairperson: Signature of Secretary:
 Name:
 Date:

To be completed by Camp Agricultural Committee

Application Approved / Not approved:
 Signature of Chairperson: Signature of Secretary:
 Name:
 Date:

Figure 2: FISP Form 1

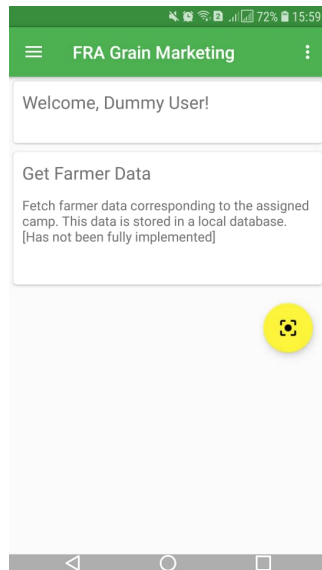


Figure 5: Satellite Depot Supervisor dashboard



Figure 6: Mobile application login page

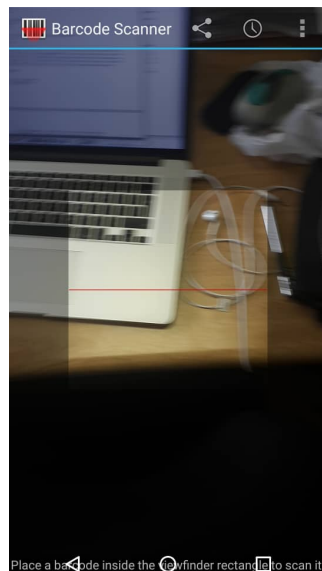


Figure 7: Barcode scanning



Figure 8: Farmer record

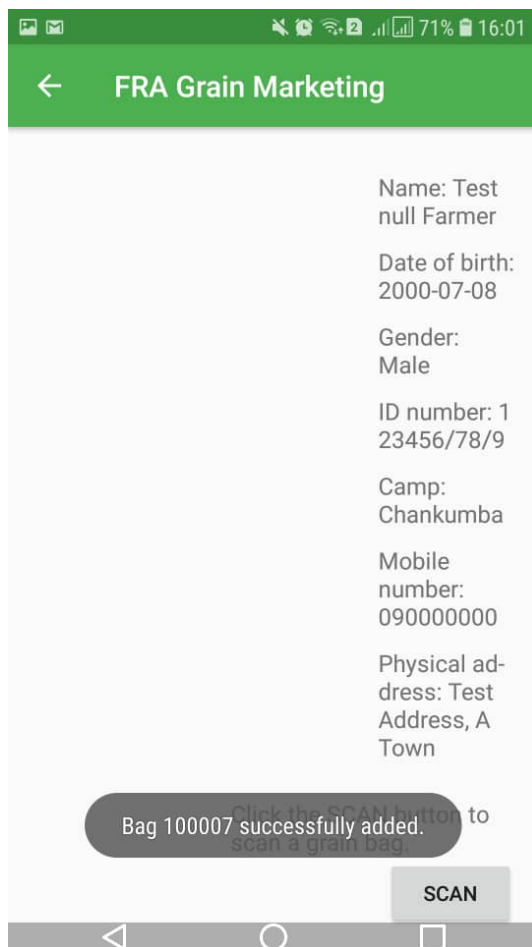


Figure 9: Grain addition success message