ARTIFICIAL INTELLIGENT SYSTEM FOR DIAGNOSIS AND MANAGEMENT OF MAIZE PEST IN UASIN GISHU COUNTY, KENYA

By

NYANG'ANGA THADIAS HILLARY

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Department of Agricultural Economics

Faculty of Agriculture

College of Agriculture and Veterinary Sciences

University of Nairobi

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DECLARATION

I, Nyang`anga Thadias Hillary hereby declare that this thesis is my original work and has not been presented for an award of a degree at any other University.

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HILLARY THADIAS NYANG`ANGA Date

This thesis has been submitted for examination with our approval as university supervisors

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PROF WILLIAM OKELLO ODONGO Date

....

DR FRED INUANI MUGIVANE Date

....

PROF JOHN DEMESI MANDE Date

DEDICATION

This work is dedicated to my dear wife Lonita Manoa Nyang`anga and my lovely daughters Hilda and Kayla for their love, constant encouragement, patience and support throughout the study period. I dedicate this work to my mother, Jane Obede for sacrificing so much to my education and well being since childhood.

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ABSTRACT

Agriculture contributes 24.5percent of the Kenyan Gross Domestic Product (GDP). This makes it one of the economic pillars of the country's Economy (Government of Kenya, Agricultural Sector & Strategy, 2010). Maize is the largest consumed staple food in Kenya. However, losses are always incurred by farmers due to diseases and pest infestation throughout the plants life cycle. It was evident that proper control and management of pest and diseases affecting crops will increase production output and hence economic growth. Pest diagnostics and management services are currently offered by the Government to farmers through the extension officers. However, delivery of these services is hindered by several factors such as understaffing, poor infrastructure and reduced budgetary allocation to agriculture by the Government of Kenya at a time when the operation costs are on the increase. Due to these challenges, extension officers are not in a position to deliver diagnostics and disease management services to the farmers efficiently, timely and effectively. On the other hand, there has been an increased investment by the Government on Information and Communication Technology (ICT) infrastructure and increase usage of mobile telephones by the Kenyan population, it was important to consider the use of information communication technologies to deliver diagnostics and management services to farmers efficiently, timely and cost effectively.

The study was carried out to investigate how artificial intelligent systems could be used for agricultural diagnostics and management of Maize diseases in Uasin Gishu County, Kenya. The research design was a case study of maize pests, extension officers and maize farmers in Uasin Gishu County. The population targets for the study were maize farmers, extension officers, and publications on maize pests. The sample size of the farmers was determined using the formula by Mugenda and Mugenda, (2003). No sampling procedure was used on extension officers and publications on Maize pest because of their low numbers hence data was collected from the whole population. Sample size of ninety farmers, eighteen extension officers and twelve publications was used. Interview guides was used to collect primary data from the farmers and extension officers while forms were used to collect secondary data from publications. The data was statistically analysed using SPSS software and results presented. In the case of developing an electronic database on existing knowledge and practices on maize disease diagnostics and management, secondary data was collected on the various maize diseases and their management from published work. An open electronic database was developed using mySQL and the resulting database schema, entity relationship diagram, relational tables and database architecture presented. The artificial intelligent system was developed and implemented using the Object oriented analysis and design methodology.

The results showed that both farmers and extension officers wanted a system which is web based and could be accessed using mobile phones and computers through the mobile interface and main site respectively. They also required the query interface to have both pictures and textual description of symptoms for ease of the selection options. Printable format and full diagnostic information content was preferred by both the farmers and extension officers. Full information on the various maize disease which include name, symptoms, picture of every symptom, available management options, chemical/drugs to administer, how to administer and where to purchase the chemicals from, were found and used in the building of the open database. The modules from MICDES of retrieve, reuse, revise and retrain and algorithms were found to be the appropriate module for the artificial intelligent system. The system was developed, tested and hosted. The system was found to provide accurate diagnostics service. It was therefore concluded that artificial intelligent system can be used to provide extension services such as diagnosis and disease management information sharing.

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List of Acronyms and Abbreviations

GDP-Gross Domestic Product

ICT-Information Communication Technology

NGO-Non-Governmental Organizations

F**AA**-Focal Area Approach

CIG-Common Interest Groups

TPS-Transaction Processing System

GSM-Global System of Mobile

OIS- Office Information System

TPS-Transaction Processing System

DSS-Decision Support System

MANAGE-National Institute of Agricultural Extension Management

CDDS-Cattle Disease Diagnostic System

WWW-World Wide Web

MICDES-Mobile Interfaced Crop Diagnosis Expert System

CAMD-Computer Assisted Medical Diagnostic systems

CAD-Computer Aided Diagnostics

PACS-Picture Archiving and Communication Systems

RAD-Rapid Application Development

ES-Expert Systems

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

1.1.1 Agriculture and economies

Agriculture is considered the source of food to the world's population. It contributes about 3percent to the worlds total Gross Domestic Product (FAO, 2011). Three quarters of the world's 1.1 billion, who are extremely poor people live in rural areas and depend on agriculture for their survival. Globally, more than 800 million people are held back by lack of access to information, knowledge, land, water, financial services and other assets essential in agriculture to overcome poverty (Lennart, 2006).

The history of the world provides overwhelming global evidence that general economic growth of any nation must be preceded, or at least accompanied by, solid agricultural growth. This process still applies today and poor countries in Africa, Asia and South America are no exception (Rukuni, 2006).

In developing countries, agriculture contributes up to 25percent of the Gross Domestic Product (FAO, 2011). In the developed world, agriculture is considered a great pillar in the primary stage of economic development, where it acts as the major contributor to GDP, employment and raw material among others. Agriculture fuels industrialization by providing raw material and food for the work force. Its contribution to the total GDP diminishes further at the tertiary stage where the developed countries concentrate more on provision of services. (Sachs, 2004)

In Kenya, 70percent of the populations depend on agriculture and 77.8percent of the population lives in the rural areas (FAO, 2011). Total land as at 2009 was 56,914,000ha, 48.1 percent was under agriculture, 1.1percent was under permanent crops, 9.5percent was arable and 37.4percent was under pastures, arable land per person was only at 0.1ha (FAO, 2011). The total labor force is estimated at 18.7 million people with agriculture contributing to 7.7million people. Agriculture therefore, contributes up to 61.1percent of the employment, leaving industry and service to contribute 32.2percent and 6.7percent respectively (FAO, 2011). Agriculture contributed up to

24.5percent of the Kenyan GDP in 2011. This is a clear indication on the stage of development where Kenya is and how important the sector is to the country. In order for country to achieve efficiency in agricultural production, there is need for optimal technical resource allocation. Agricultural disease diagnosis is one of the technical inputs required in the agricultural production value chain.

1.1.2 Agricultural diagnostics

Diagnostics is defined as serving to distinguish or identify. Diagnosis is the act or process of identifying or determining the nature and cause of a disease or injury through evaluation of patient history, examination, review of laboratory data and the opinion derived from such an evaluation. Agricultural diagnostics is therefore the art or practice of identifying crop and animal diseases.

Agricultural diagnostic services have over the years been provided by the Government of Kenya through veterinary and extension officers. Recently, non-Governmental organizations (NGOs) have supported the provision of these services. However, this is only done in small pockets of the country where the NGOs undertake their activities. Private sector actors have also been providing these services, but only to specific large scale farmers who employ their own extension and veterinary officers to work on their farms (Food and Agricultural Organization (FAO, 2005).

Costs associated with agricultural diagnostics services are always passed to farmers. Where services are provided by the private sector, the farmers fully incur the cost while where services are provided by the Government and/or NGOs, the cost is often subsidized (FAO, 2005). The current system requires that an extension officer has to be physically present to observe the symptoms on the plant for the disease to be identified. The extension officers will then proceed to advise on the various management techniques which vary from modern scientific prescriptions to traditional management methods.

In the recent past, agricultural diagnostics has been challenged by several factors. Low budgetary allocation by the Government, reduced effectiveness of extension, high cost and increased adulteration of key inputs, pre- and post-harvest crop losses, limited capital and access to affordable credit, low and declining soil fertility, inappropriate legal and regulatory framework, inadequate infrastructure and issuance of conflicting information by the different players are some of the factors. These challenges have made it almost impossible for the extension workers to deliver their services efficiently, effectively and in a timely manner (GoK, 2010).

1.1.3 Research, extension and agricultural diagnostics

Kenya has several research institutions ranging from public and private universities and national research centers. Research has been undertaken on crop and animal diseases, their symptoms and their management options by a team of specialists in these institutions. These specialists document their work and publish books, reports, journal and newsletters among others. Extension officers on the other hand are not in continuous contact with researchers to improve their knowledge and uptake of the new disease management options. The information flow from the researches through the extension officers to the farmers is also prone to distortion (Shamma 1954). In addition, extension deliver is hindered by poor infrastructure, understaffing, low budgetary and allocation among others. This has made the technical efficiency in agricultural diagnostics nearly impossible to achieve. (GoK, 2010)

1.1.4 Need for efficiency in agricultural diagnostic

Crop and animal productivity can be enhanced through diagnosis, management, prevention and control of diseases. Diseases affect the normal function of the body system, leading to health effect and reduced productivity. The estimation of crop loss due to pests and diseases is a complex subject. It is in fact, difficult to assess the loss caused by the individual pest as a particular crop may be infested by the pest complex in the farmers' field conditions. Further, extent of crop loss either physical or financial depends on the variety, stage of crop growth, pest population and weather conditions. Nevertheless, the crop loss estimates have been made and updated regularly at global level. The worldwide yield loss due to various types of pest was estimated at as: 37.4 per cent in rice, 28.2 per cent in wheat, 31.2 per cent in maize and 26.3 per cent in soybean (Oerke, 2006).

Maize crop forms the largest consumed staple food in Kenya with more than 60percent of consumers depending on it. Maize is also used as animal feeds, where it acts as the source of carbohydrates and roughages. It is for these reasons that maize was chosen for this study.

1.1.5 Potential of information and communication technologies in agricultural diagnostics

Information Communication Technologies (ICTs) refer to technologies that facilitate the creation, processing and transfer of information across space and time. ICT enables rapid, efficient and comprehensive performance of tasks and facilitate the flow of large volumes of information to a wide audience across numerous geographical locations. Though ICTs are not a panacea to agricultural production, they have the potential of bridging the information gap for rural farmers with respect to innovative practices, accessing markets and acting as an effective tool for policy advocacy.

Several studies have been conducted on diseases of plants and animals. A number of these diseases have been identified and management measures described/recommended with proven efficacy. Plant pathologists have been trained on theoretical and practical identification and management of plant diseases. New knowledge has also been gathered through experience by practicing agricultural experts. The facilitation of the flow of this information from the experts to the farmers and among the experts themselves is weak and is hindered by the challenges listed earlier in this chapter (GoK, 2010).

Current Government policies embrace the use of ICT in all sectors of the economy. The ICT initiatives include: training on computer use in academic curricula; exception of import duty on computers, mobile phones and other ICT related products; establishment of internet network through fiber optic cables across the country; establishment of the nationwide global system of mobile (GSM) network among others. These initiatives create a great potential for application of ICT in agricultural diagnostics.

ICT can therefore be used to provide a platform which captures both implicit and explicit knowledge of plant diseases and their management options from both experts and famers, store, retrieve, share, support decision making and provide access to all the stake holders in the agricultural industry. With the current ratio of extension officer to farmer at 1:1500, the movement of extension agents from farmer to farmer is expensive, time consuming and hindered by factors such as poor infrastructure. Expert System (ES) which can also be referred to as Artificial Intelligent (AI) system is a type of information system capable of performing the art of decision making as human. ES have the ability to provide diagnostic services and propose management solutions to farmers online. With such a platform, an expert will be able to attend to more than one farmer at the same time without necessarily having to move from one farmer to the other (Africa Science News Saturday, 16 November, 2013).

1.1.6 Information systems in ICT

"An information system is a collection of hardware, software, data, people and procedures that are designed to generate information that supports the day-to-day, short-range and long-range activities of users in an organization. Information systems generally are classified into five categories: office information systems, transaction processing systems, management information systems, decision support systems and expert systems. An Office Information System (OIS) is an information system that uses hardware, software and networks to enhance work flow and facilitate communications among employees. A Transaction Processing System (TPS) is an information system that captures and processes data generated during an organization's day-to-day transactions. A transaction is a business activity such as a deposit, payment, order or reservation. A Management Information System (MIS) is an information system that generates accurate, timely and organized information so that managers and other users can make decisions, solve problems, supervise activities and track progress" (Yaser, 2014).

A Decision Support System (DSS) is an information system designed to help users reach a decision when a decision-making situation arises. An expert system is an information system that captures and stores the knowledge of human experts and then imitates human reasoning and decision-making processes for those who have less expertise. Expert systems are composed of two main components: a knowledge base and inference rules. A knowledge base is the combined subject knowledge and experiences of the human experts. The inference rules are a set of logical judgments applied to the knowledge base each time a user describes a situation to the expert system (Yaser, 2014). ICT therefore provides a potential solution to agricultural diagnostics through its expert system/artificial intelligent systems which can be made to support farmers with both plant and animal disease diagnostics. Artificial intelligent system could be applied to bridge the gap where man power is insufficient and/or inadequate.

1.1.7 Artificial Intelligence Systems

Artificial intelligence (AI) is an area of computer science that emphasizes the creation of intelligent machines that work and reacts like humans. Some of the activities computers with artificial intelligence are designed for include speech recognition, learning, planning, problem solving.

Artificial intelligence is a branch of computer science that aims to create intelligent machines. It has become an essential part of the technology industry. The core problems of artificial intelligence include programming computers for certain traits such as: knowledge, reasoning, problem solving, perception, learning, planning and ability to manipulate and move objects.

Knowledge engineering is a core part of AI research. Machines can often act and react like humans only if they have abundant information relating to the world. Artificial intelligence must have access to objects, categories, properties and relations between all of them to implement knowledge engineering. Initiating common sense, reasoning and problem-solving power in machines is a difficult and tedious approach.

Machine learning is another core part of AI. Learning without any kind of supervision requires an ability to identify patterns in streams of inputs, whereas learning with adequate supervision involves classification and numerical regressions. Classification determines the category an object belongs to and regression deals with obtaining a set of numerical input or output examples, thereby discovering functions enabling the generation of suitable outputs from respective inputs. Mathematical analysis of machine learning algorithms and their performance is a well-defined branch of theoretical computer science often referred to as computational learning theory.

Machine perception deals with the capability to use sensory inputs to deduce the different aspects of the world, while computer vision is the power to analyze visual inputs with few sub-problems such as facial, object and speech recognition.

Robotics is also a major field related to AI. Robots require intelligence to handle tasks such as object manipulation and navigation, along with sub-problems of localization, motion planning and mapping.

Major Components of AI

An AI consists of three major modules:

- The knowledge base
- The inference engine
- Working memory

This portioning is deduced from how human expert problem solving works.

Knowledge Base

The highly specialized knowledge of the problem area is located in the knowledgebase. This module contains problem facts, rules, concepts and relationships. The first step to build the knowledge base is to gather the knowledge from human experts. After this step, the knowledge must be coded in a form which is useful for automatic processing. Several techniques of knowledge representation are available including a rule based representation and case based representation.

Working Memory

The working memory contains the facts about a problem that are collected during one consultation of the expert system. When a new problem has to be solved, the user enters information about the problem in the working memory. The expert system then uses this information together with the facts in the knowledge base to infer new facts. The content of the working memory can also consist of facts that have been collected from external storage like databases, spreadsheets, or sensors, beside the information that is taken from knowledge base.

Inference Engine

The reasoning of the expert is molded in the knowledge processor, usually named the inference engine. The engine uses knowledge base as the source of information for reasoning. Together with the other available information to draw conclusions and or give recommendations as to how specific problem can be solved. Another task for the inference engine is to reason with uncertain data. The certainty associated with a value is usually described by a numeric value, and various mathematical rules are employed to derive the joint confidence across sets of values.

Artificial intelligent systems have been used in manufacturing industries' lines such as robot for loading, offloading and packaging among others. However, the use of artificial intelligent systems in agriculture extension and more specifically for diagnostics has not been done.

Pest's diagnostics features can provide a good Knowledge base for an artificial intelligent system. An inference engine and a working memory can be modeled using the information systems development methodologies. With a combination of the three, an artificial intelligent system for diagnostics of maize pests can be developed.

1.2 Statement of the Problem

The pests which affect maize, their symptoms and curative measures are known. Continues research is being done about emerging Maize pest, symptoms and the curative measures. The research about maize pests is will supported by the good research institution infrastructures in Kenya ranging from public universities, national research institutions, donna funded research institutions and private universities. The information on the maize pests are documented published and is available in the libraries. The role of transferring this information to the farmers is mandated by the Government to the extension officers. Some NGO's have also employed their own extension officers to support in offering the services.

However, the transfer of this information has not been efficient. Production of maize in Kenya has been slowed down by pest infestation. This has been attributed to several factors namely: poor road infrastructure in the rural areas, low staff to farmer ratio and low budgetary allocation to agriculture. For the more, the extension officer to farmer ratio in Kenya is 1:1500 as opposed to the recommended FAO ratio of 1:400. In addition, these factors have led to high operation cost for extension officers, inability of extension officers to visit all famers and offer diagnostic services on time. The fact that information from researches passes through extension officer to farmers, also provided an avenue for information distortion. This makes it impossible for all the farmers to access diagnostics services in good time and space, which greatly challenges attainment of efficiency on Pest diagnostic services. Several studies on farmers' access to public and private extension services have revealed that the village level extension agent is the most effective source of information for farmers, but certainly not the most efficient in terms of cost and coverage (Arokoyo et al., 2002).

On the other hand, the Government has embraced the use of information communication technologies all across the country. The laying of the fiber optic cable in several parts of the country, removal of import duty on all ICT tools, inclusion of basic computing in the educational curriculum in primary and secondary schools and intention to supply all pupils joining class one with free laptop computers, provides a viable platform for the use of ICTs in all sectors of the economy.

Despite the opportunities presented by the efforts in the ICT sector, little has been done to offer Pest diagnostic services through ICT infrastructure. Information system in ICT can be used to provide agricultural extension services to farmers with a view to improve communication between farmers, extension agents and the researchers. Agricultural diagnostics is an important area which requires the use of ICT to improve communication. This study was therefore designed to fill the gap in knowledge on the possible use of artificial intelligence system for offering diagnostic services to farmers.

1.3 Justification of study

Research conducted in agricultural sciences has focused on production of crops. However, scientific data on the application of information and communication technologies in agricultural diagnostics is scant. Existing knowledge and practices among farmers, extension workers and researchers in Kenya is currently scattered in various information resource centers and with experts. This scenario highlights significant logistical and technical challenges in access and application of such vital data by various actors. In order to bridge this gap, it is necessary to embrace the use of modern information and communication technologies to improve communication of agricultural practices. It is therefore recommended to develop an artificial intelligent system to facilitate collection, storage, dissemination and application of knowledge and practice for efficient and effective prevention, control and management of diseases affecting crops.

The Government budgetary allocation to agriculture has been increasing at a decreasing rate. (Kenya National Bureau of Statistics, 2014)Although the population of farmers has increased, the number of extension officers has stagnated. Currently, the ratio of extension officers to farmers is at 1: 1500. This implies that with reduced budgetary allocation, increasing number of farmers and a declining number of extension officers, it is impossible for the extension officer to effectively reach all farmers and offer diagnostic services in a timely and cost effective manner. It is therefore important to develop an alternative approach to deliver the much needed extension services efficiently and cost effectively. This study was therefore designed to look into the provision of diagnostics services remotely using artificial intelligent systems.

1.4 General Objective

To determine how artificial intelligent system can be used for agricultural diagnostics and management of maize diseases in Kenya.

1.4.1 Specific objectives

1. To determine the requirements by farmers and extension officers for an artificial intelligent based diagnostic system for diagnostics and management of Maize pest.
2. To develop an electronic database on existing knowledge and practices related to Maize pests.
3. To formulate an artificial intelligent model for diagnostics and management of Maize pest
4. To develop and test a prototype for implementing the proposed model for diagnostics and management of Maize pest.

1.5 Research questions

1. What are the requirements of user in an automated maize diagnostic system?
2. What are the various maize crop diseases and pests, what are their symptoms, management options and how can an electronic database be developed to hold this information?

3. What are the existing artificial intelligence generic architectures of diagnostic systems and which is the best way through which the modules can be integrated to suit agricultural diagnostics?
4. What is the procedure of developing the model and what are the success and failure indicators of the model?

1.6 Scope of study

This was an agricultural based study that involved the use of ICT for disease diagnostics and management in maize. The study investigated the Diseases of maize and their management, through expert systems and their development and the user requirement in automation of the diagnostic system.

Definition of terms

Pest: means diseases, nutritional deficiency and insect infestation.

CHAPTER TWO

2.0 LITERATURE REVIEW

This study was a multi-disciplinary study touching on various academic areas ranging from agriculture and its economic contributions, agricultural extension, crop protection, communication and computerized information systems development. This section provides a comprehensive literature review and highlights the gaps which exist on the above mentioned sectors.

2.1 Agriculture in Kenya

The agricultural sector in Kenya has recently recoded improved performance especially in important commodities and enterprises such as horticulture, tea, dairy and maize. The agricultural sector is reviving and is on a trajectory of further development. However, challenges remain in some commodities such as coffee, sugar, pyrethrum and exploiting livestock and fisheries potential. Emerging constraints to agricultural growth need to be addressed. Challenges and constraints facing the sector vary with commodity and region. The effects of some of these challenges and constraints were accelerated by the worldwide food price crisis and its underlying drivers in 2008. Some of the general challenges include inadequate budgetary allocation; reduced effectiveness of extension services; low absorption of modern technology; high cost and increased adulteration of key inputs; pre- and post-harvest crop losses; livestock losses to diseases, pests and insecurity; limited capital and access to affordable credit; low and declining soil fertility; Inappropriate legal and regulatory framework; Inadequate disaster preparedness and response and inadequate infrastructure (GoK, 2010).

Some of the challenges outlined above are a pointer to the fact that Kenya has inadequate human resource capacity. This could be attributed to first, insufficient budgetary allocation which leads to reduced operation budgets and hence inability of extension officers to access all farmers. Secondly was reduced effectiveness of extension services due to inappropriate methods. The information flow from researchers to farmers through extension officers provides a room for distortion. Thirdly, pre- and post-harvest crop losses due to mainly lack of correct and timely diagnostic information services which is brought about by high extension officer to farmer ratio.

Lastly, heavy livestock losses to diseases and pests due to low surveillance and understaffing (GoK, 2010).

Several of the above challenges are information and knowledge related. The agricultural sector extension service plays a key role in disseminating knowledge, technologies, agricultural information and linking farmers with other actors in the economy. Extension service is one of the critical change medium required in transforming subsistence farming to modern, commercial and smart agriculture. The transformation is required to promote household food security, improve income and reduce poverty.

2.2 Agricultural extension

Extension approaches in Kenya include Focal Area Approach (FAA)– (Use of common interest groups (CIGs); Farmer Field Schools – Farmer to Farmer Extension; Commodity-based approach - commercial enterprises; Multidisciplinary Mobile Extension Teams especially in arid and semi arid areas.(FAO, 2011). Despite the various extension approaches employed by the private and public sector, several challenges exist. These include reduced staffing and funding for operations and maintenance (GoK, 2010), extension and dissemination of conflicting messages (World Bank 2011), unnecessary competition and duplication of efforts and lack of synergy (World Bank 2011).

An agricultural system can be considered sustainable when it satisfies producers' needs and preserves the natural resources for the present and subsequent generations. Development of the system should be based on three pillars: economic feasibility, social fairness and environmental sustainability (Carlos, 2006). Given the challenges facing the delivery of extension services in Kenya, the country is still far from achieving sustainability.

2.3 Agricultural extension and challenges related to maize production

"Maize is the most important staple food in sub-Saharan Africa and is the main food crop in Kenya. It contributes 3 percent of Kenya's Gross Domestic Product (GDP) and 21 percent of the total value of primary agricultural commodities. Maize thrives in regions where the rainfall average falls between 900-1700 mm, but can grow in as little as 500 mm or as much as 2500 mm rainfall. Grown on an estimated 1.4 million hectares in Kenya by large-scale farmers (25 percent) and smallholders (75 percent), it is a commercial and subsistence crop" (World Bank, 2012). Heavy losses of Maize through pests and diseases, by the farmers, have been witnessed in the past. These losses are witnessed throughout the maize value chain from planting through to post harvest. Diseases related to nutrient deficiencies reduce the maize plant vigor right from germination to maturity hence reduced productivity. Pathogenic diseases affect maize plant during growth thus reduced productivity at maturity. Insects affect the maize plant during growth and maize grain after harvesting. These reduce productivity and increases post harvest losses to the maize farming enterprises.

2.4 Communication models

Agricultural extension involves communication between farmers, extension officers and researchers. It is therefore important to review literature on communication models and types. Agricultural diagnostics being one of the extension services is no exception.

Shannon (1948) laid out the basic elements of communication:

- An information source that produces a message
- A transmitter that operates on the message to create a signal which can be sent through a channel
- A channel, which is the medium over which the signal, carrying the information that composes the message, is sent
- A receiver, which transforms the signal back into the message intended for delivery
- A destination, which can be a person or a machine, for whom or which the message is intended. (Shannon, 1948)

The figure below represent Shannon's module

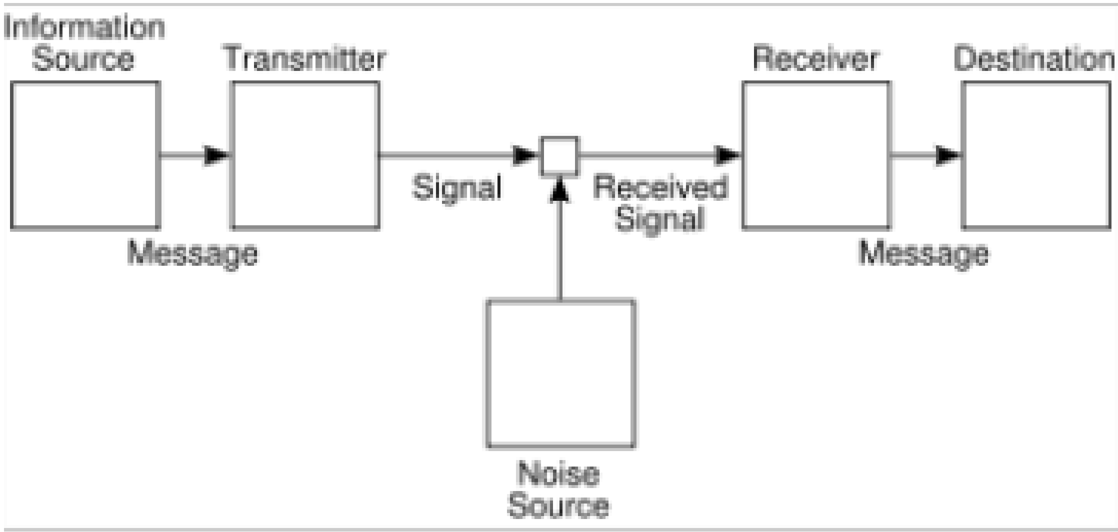


Figure 2.1: Shannon's diagram of a general system, which shows the process of information that produces a message (Shannon, 1948)

Shannon (1948) indicated that the three ways of overcoming barriers to effective communication. He stated that designing and delivering message so that it gets the attention of intended audience, relating to common experiences between the source and destination, and offering a way to meet personality needs appropriate to the group situation the receiver is in at the time you want that receiver to respond. Noise represent any external distortion of the information in transmission.

The model presented by Shannon however lacks the feedback mechanism. Without feedback, the sender will not know whether the receiver got the information or not. Because of this reason, Schramm (1954) modified the model by bringing in three new concepts which included feedback; individual’s knowledge, experience and cultural background.

From the two models, the elements of communication were developed which included source, sender, channel, receiver, destination feedback and entropic elements.

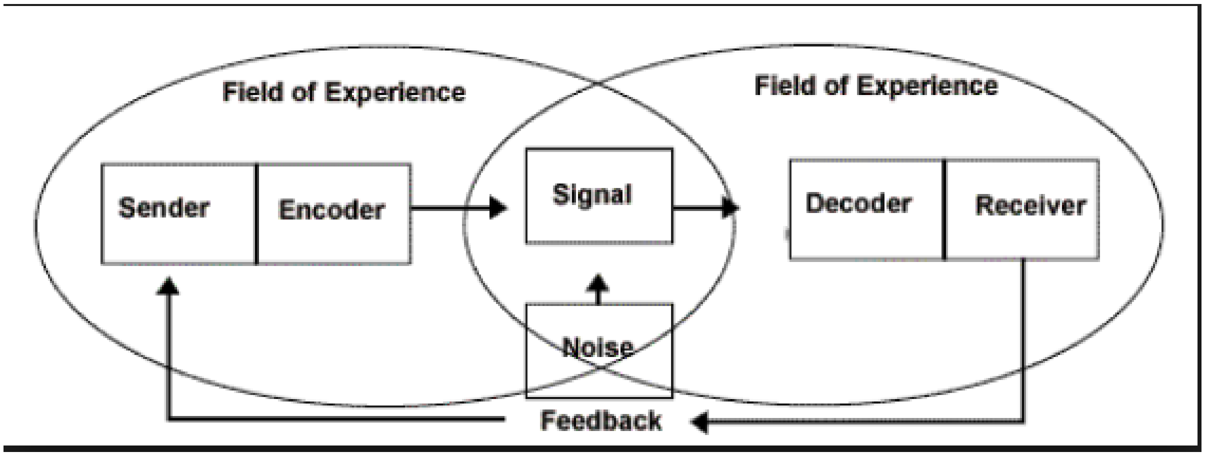


Figure 2.2: Communication module by Schramm, (Schramm, 1954).

Communication in extension involves the transfer of information from the researchers through the extension officers to the farmers. In the case of extension, the respective model is presented in figure 2.3 below.

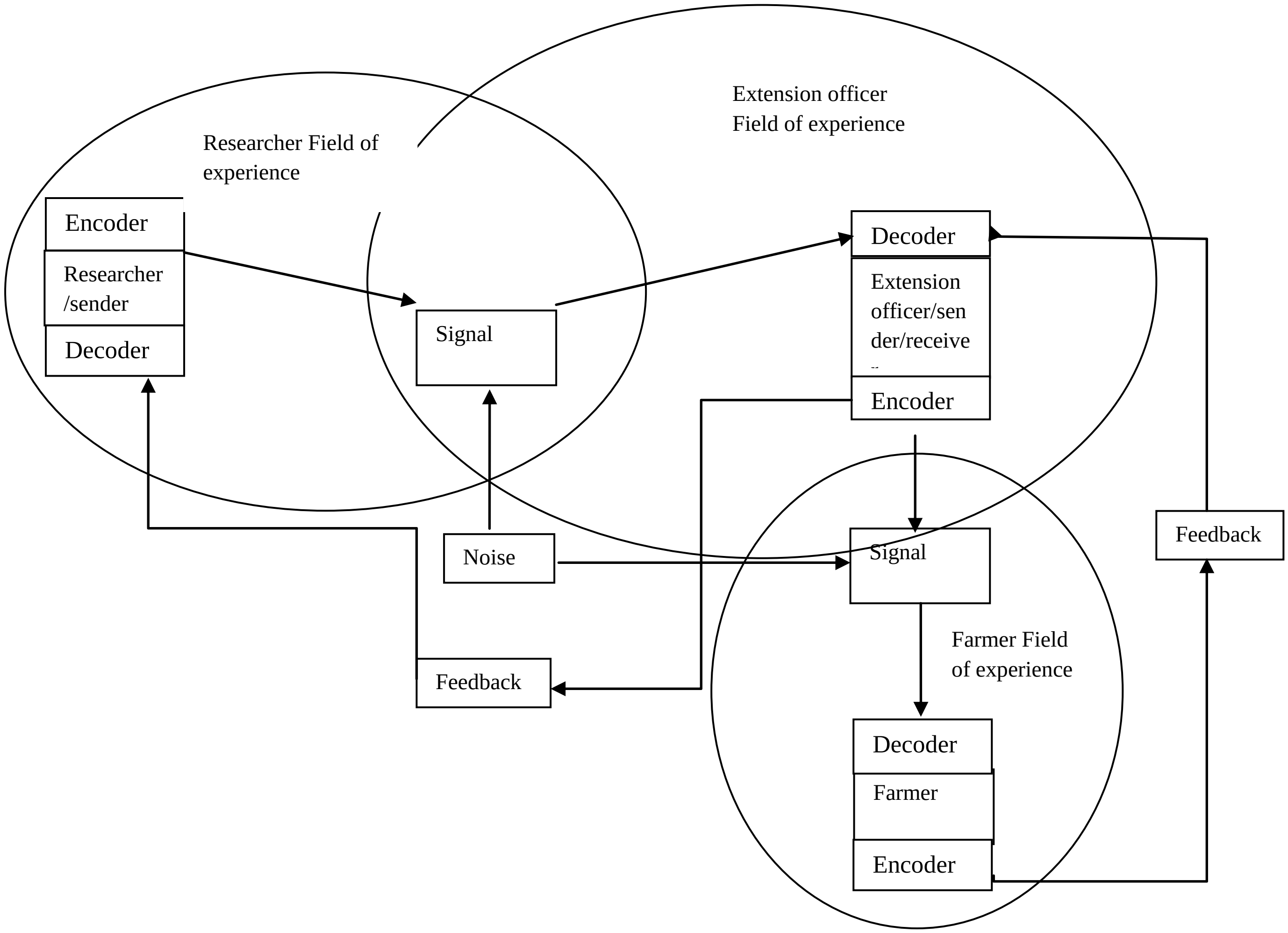


Figure 2.3: Communication module in agricultural extension in Kenya (source: Author).

As shown in the model, extension officer play a vital role in disseminating diagnostics information. However, given the communication process as stated by Schramm (1954), the process of encoding by the researcher and decoding by the extension officer is important. Extension officers must decode the information as intended by the researchers. Moving along the communication line, the repeated encoding by the extension officer and decoding by the farmer must also be right for the intended information to get to the farmers. However, this is not always the case as the long chain poses a challenge to effective communication in the agricultural extension. Effective communication is considered to have clarity in form and format, credibility from source, correct and satisfactory in content and context, through channels accessible to the intended audience, and the audience should be capable to decode the information within their field of experience. Given the factors for effective communication, the more the players in the communication channel, the less effective communication can be achieved. It is therefore important to undertake a study which will bridge this gap by bringing researchers into communication with farmers directly.

2.5 Information system development methods

There are various methods which can be followed by a system analyst and designer to develop an artificial intelligent system. This section highlights the various methods available.

2.5.1 Waterfall model

The waterfall model highlights processes which developers have to follow. These process are categories in phase namely Requirements specification (Requirements analysis); Software design; Implementation and Integration; Testing (or Validation); Deployment (or Installation) and Maintenance. In a strict Waterfall model, after each phase is finished, it proceeds to the next one. Reviews may occur before moving to the next phase which allows for the possibility of changes (which may involve a formal change control process). Reviews may also be employed to ensure that the phase is indeed complete; the phase-completion criteria are often referred to as a "gate" that the project must pass through to move to the next phase. Waterfall discourages revisiting and revising any prior phase once it is complete. This "inflexibility" in a pure Waterfall model has been a source of criticism by supporters of other more "flexible" models (Kent, 2000).

2.5.2 Spiral model

Figure 2.4 presents the spiral model for information systems development

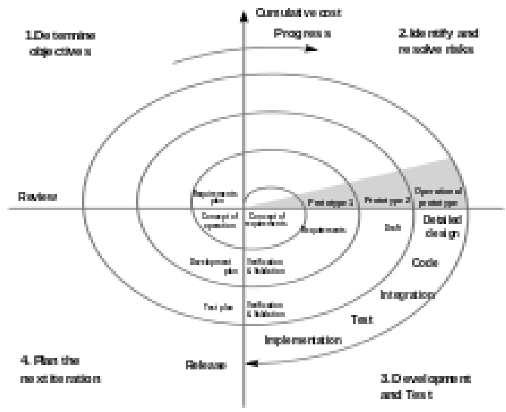


Figure 2.4: Spiral model (Boehm, 1988).

The key characteristic of a Spiral model is risk management at regular stages in the development cycle. In 1988, Boehm (1988) published a formal software system development "spiral model," which combines some key aspect of the waterfall model and rapid prototyping methodologies, but provided emphasis in a key area many felt had been neglected by other methodologies: deliberate iterative risk analysis, particularly suited to large-scale complex systems.

The Spiral is visualized as a process passing through some number of iterations, with the four quadrant diagram representative of the following activities: Formulate plans to: identify software targets, implement the program, clarify the project development restrictions; Risk analysis: an analytical assessment of selected programs, to consider how to identify and eliminate risk; Implementation of the project: the implementation of software development and verification

Risk-driven spiral model, emphasizing the conditions of options and constraints in order to support software reuse, software quality can help as a special goal of integration into the product development. However, the spiral model has some restrictive conditions, as follows: The spiral model emphasizes risk analysis, and thus requires customers to accept this analysis and act on it. This requires both trust in the developer as well as the willingness to spend more to fix the issues, which is the reason why this model is often used for large-scale internal software development; If the implementation of risk analysis will greatly affect the profits of the project, the spiral model should not be used; Software developers have to actively look for possible risks, and analyze it accurately for the spiral model to work (Kent, 2000).

The first stage is to formulate a plan to achieve the objectives with these constraints, and then strive to find and remove all potential risks through careful analysis and, if necessary, by constructing a prototype. If some risks cannot be ruled out, the customer has to decide whether to terminate the project or to ignore the risks and continue anyway. Finally, the results are evaluated and the design of the next phase begins (Kent, 2000).

2.5.3 Agile development

Agile software development uses iterative development as a basis but advocates a lighter and more people-centric viewpoint than traditional approaches. Agile processes fundamentally incorporate iteration and the continuous feedback that it provides to successively refine and deliver a software system.

There are many variations of agile processes: In extreme programming (XP), the phases are carried out in extremely small (or "continuous") steps compared to the older, "batch" processes. The (intentionally incomplete) first pass through the steps might take a day or a week, rather than the months or years of each complete step in the Waterfall model. First, one writes automated tests, to provide concrete goals for development. Next is coding (by a pair of programmers), which is complete when all the tests pass, and the programmers cannot think of any more tests that are needed. Design and architecture emerge from refactoring, and come after coding. The same people who do the coding do design. (Only the last feature — merging design and code — is common to *all* the other agile processes.) The incomplete but functional system is deployed or demonstrated for (some subset of) the users (at least one of which is on the development team). At this point, the practitioners start again on writing tests for the next most important part of the system (Kent, 2000).

2.5.4 Rapid application development

Rapid application development (RAD) is a software development methodology that uses minimal planning in favor of rapid prototyping. The "planning" of software developed using RAD is interleaved with writing the software itself. The lack of extensive pre-planning generally allows software to be written much faster, and makes it easier to change requirements. RAD involves methods like iterative development and software prototyping. According to Whitten

(2004), it is a merger of various structured techniques, especially data-driven Information Engineering, with prototyping techniques to accelerate software systems development (Whitten, 2003).

In rapid application development, structured techniques and prototyping are especially used to define users' requirements and to design the final system. The development process starts with the development of preliminary data models and business process models using structured techniques. In the next stage, requirements are verified using prototyping, eventually to refine the data and process models. These stages are repeated iteratively; further development results in a combined business requirements and technical design statement to be used for constructing new systems (Whitten, 2003).

This study therefore will use the traditional waterfall system development model because of the nature of this project and the advantages the model has over all other models.

2.6 Information System development and engineering Research methodologies

Artificial intelligent systems are one of types of information systems. To develop an artificial intelligent system for diagnostics and management of maize diseases, it was important to review the various research methodologies in this field and select the appropriate one for this case. “Information systems are modern entities that are distinctive in at least three respects. Firstly, the computer hardware and software artifacts, on which they are based, are tools like no other in the history of mankind. Not only can information and communications technologies (ICT) enable the automation of intricate work processes but they also provide support for sophisticated ‘knowledge work’. Secondly, information systems have a socio-technical composition with hardware, software, people and processes integrated into a complex, purposeful whole. Thirdly, ICT products and their use are evolving at an unparalleled rate, with increases in power and capability matched by decreasing costs. Information Systems (IS) as a field of study, draws its significance from the uniqueness of computer-based information and communication tools and their place in shaping recent human, social and organizational history. IS researchers are distinguished by the fact that they have the difficult and challenging responsibility of understanding, creating and using information systems to best effect” (Hassan, 2004).

“To reach maturity as a discipline in its own right, the new field of IS borrows research approaches from a wide variety of older disciplines, the closest comparative fields being the engineering traditions and the design sciences. Engineering is a traditional discipline concerning the construction and use of artifacts. The design sciences aim, not only to develop knowledge for the design and realization of artifacts, but also to improve the understanding of how to solve the social and organizational problems for which the artifact is designed.”(Hassan, 2004)

“According to Simon (1981) “design sciences do not tell how things are but how they ought to be to attain some ends”. Similarly, advances in the field of IS result from a better understanding of how to develop and use ICT-based tools and what impact they have on the way we work, and live. The question then arises, as posed by Gregor (2002): what constitutes a contribution to knowledge when research is of this type?

Papers describing such research typically contain “no hypotheses, no experimental design and no data analysis” (ibid p13) and so often pose a dilemma for reviewers. This does not necessarily invalidate this type of research and the challenge is to conduct and report it in ways that identify the vigour and contribution of the research making it acceptable to journal editors and reviewers.

Due to their distinctive nature, information systems development can be a knowledge creating activity, when those systems relate to emergent knowledge processes (EKP) (Markus et al 2002), and that, in those cases, information systems development is a legitimate research method. In the process of this type of information systems development, not only is knowledge created about the development process itself but also a deeper understanding emerges about the organizational problem that the system is designed to solve.” (Hassan, 2004).

The characteristic of IS that distinguishes it from other management fields in the social sciences is that it concerns the use of “artifacts in human machine systems” (Gregor 2002). Conversely, the characteristic that distinguishes IS from more technical fields, such as Computer Science and Information Technology, is its concern for the human elements in organizational and social systems (Hassan, 2004).

A systems development method (SDM) for data collection, analysis and theory building has the reflective and iterative attributes often associated with participatory action research, combining research and practice in such a way that action brings about some situational improvement and research increases the broader understanding of the issue. However, there are two particular characteristics that distinguish SDM from the general action research approach. Firstly, in SDM there are always three inter-related domains where this research method can generate knowledge, those of: (a) the techniques of systems development, (b) the properties of system itself, and (c) the situation where the system is to be used. Secondly, the research project is both constrained by the limits that current information technology places on the development of systems and is enabled by the uniqueness of this technology, which can, as a tool, mediate human learning and communication. (Hassan, 2004)

SDM also has qualities found in grounded approaches to research. A grounded approach enables IS research to incorporate the criticality of organizational context in shaping technology use in organizations. Grounded theory is an inductive, discovery methodology with the aims of generating a descriptive and explanatory theory while iteratively gathering rich data from one or more sites. Concepts are suggested by the data rather than imposed from outside and are organized through the identification of recurring themes into theory. SDM however differs from traditional grounded theory research in the way data is coded and categorized (Hassan, 2004).

The SDM has five stages which include: concept design, constructing the architecture of the system, Prototyping and Product development (Hassan, 2004).

The term engineering-type research is mentioned by Burstein and Gregor (1999) who claim that this type of IS research method is not always recognized as such and is comparatively poorly understood. Engineering is relevant to IS research that studies the design, delivery, use and impact of information and communications technology (ICT) in organizations and society. However, ICT can be considered more than physical artifacts or tools but rather ones that incorporate logic, in the form of software, and interact with people in a way no previous artifact has done. Information systems are both physical and mental tools so that in IS construction can be considered a form of constructivism that relates closely to SDM. In the context of learning and development, constructivism is a theory, which came out of the work of Piaget (2009) and is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. Each of us generates our own rules and mental models, which we use to make sense of our experiences, much in the same way as models are constructed though the processes of systems analysis and design (Hassan, 2004).

2.7 Artificial intelligent (Expert) systems development methodologies

Shu (2004) conducted a survey of expert systems (ES) development using a literature review and classification of articles from 1995 to 2004 with a keyword index and article abstract in order to explore how ES methodologies and applications have developed during this period. Based on the scope of 166 articles from 78 academic journals (retrieved from five online database) of ES applications, her paper surveyed and classified ES methodologies using the following eleven categories: rule-based systems, knowledge-based systems, neural networks, fuzzy ESs, object-oriented methodology, case-based reasoning, system architecture, intelligent agent systems, database methodology, modeling, and ontology together with their applications for different research and problem domains. Discussion presented, indicated the followings future development directions for ES methodologies and applications: (1) ES methodologies are tending to develop towards expertise orientation and ES applications development is a problem-oriented domain. (2) It is suggested that different social science methodologies, such as psychology, cognitive science, and human behavior could implement ES as another kind of methodology. (3) The ability to continually change and obtain new understanding is the driving power of ES methodologies, and should be the ES application of future works (Shu, 2004).

Based on the reviewed technologies, three methodologies are identified. Commonalities and differences among the methods are also identified. Figure 2.5 below shows the diagrammatical presentation. Information system analysis and design method was adopted for this research the artificial intelligent system development.

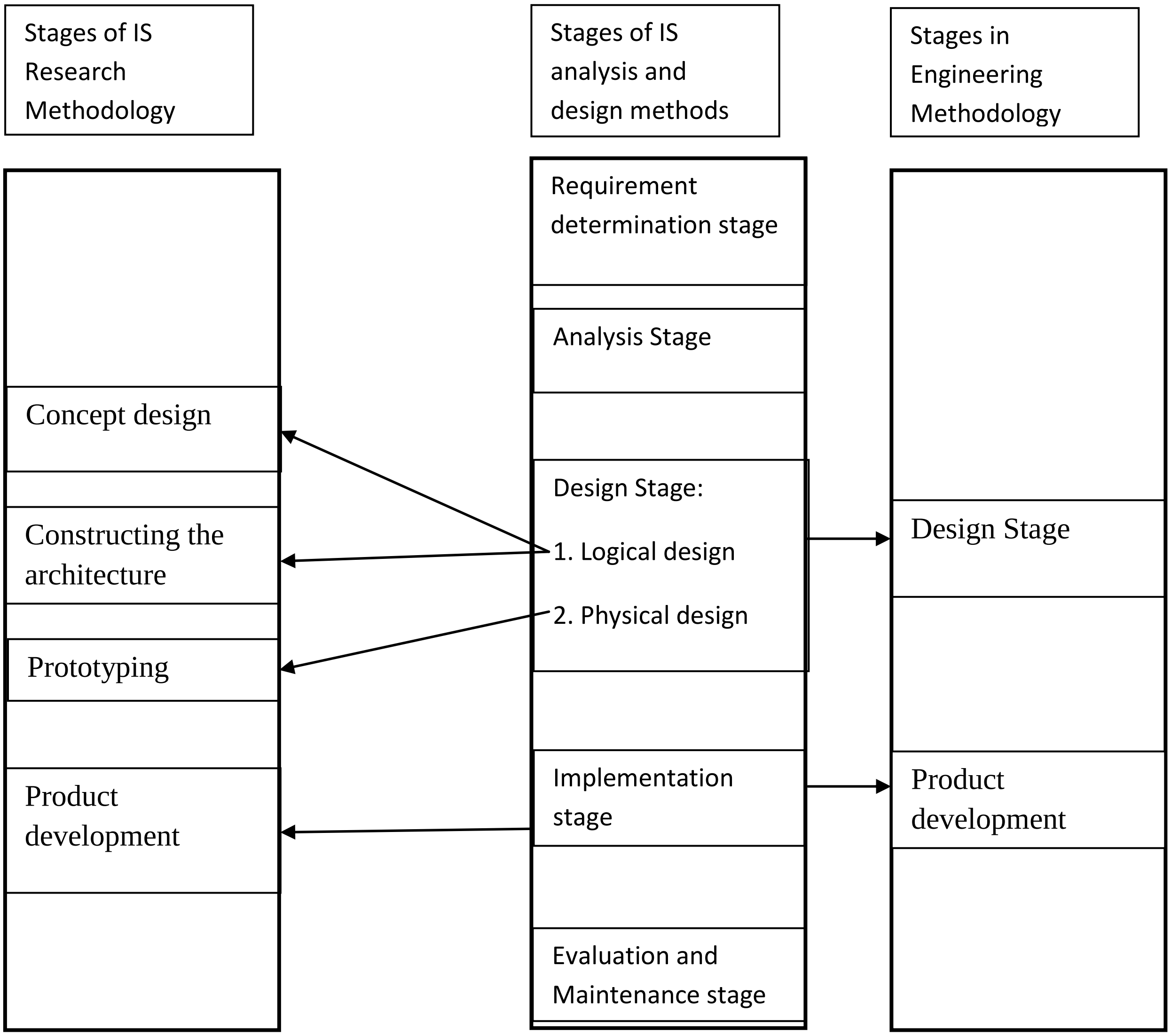


Figure 2.5: Similarities in methodologies in IS Development research and Information systems analysis and design (source: Author).

From the diagram, IS analysis and design method has all the stages in information system research methodology and in the engineering methodology. It also has the requirement determination stage includes the human social and economic aspects of the intended users and the analysis stage analyzes the human aspect and finds appropriate technologies for the system design stages. Because of this, the information system analysis and design was considered as the appropriate technology for the study.

2.8 Existing information systems in Kenya

ICT in Kenya is growing at a rapid rate. The penetration of mobile service in Kenya reached 64.2 percent by 2012 (Okyere, 2012). Kenya's high mobile penetration rate and subscription number indicates that mobile technology is a promising business opportunity, and an indispensible tool for empowering the country's citizens, especially its rural poor. The services widely used include use of *MPesa* which is a mobile money transfer service owned by safaricom and launched in 2007. It allows users to use their mobile phones to send, receive and transfer money; *MFarm*, an agribusiness software solution which was started in 2010 and offers information to farmers on farming and market information to improve their productivity through sending an SMS (short messaging service) to 20225; *iCOW.* This is an SMS and voice-based mobile application launched in 2013 and used by dairy farmers to access information on the cows' gestation period, veterinary information and record keeping; *Airtel Kilimo* is a unique and innovative service aimed at providing phone-based agricultural information, advice and support to smallholder farmers over Airtel's mobile network, launched in 2011. This service is utilizing Africa's mobile network and technologies to bridge the knowledge gap in rural areas. The service can be subscribed on *760# for free SMS subscription where a customer is charged KSh3 per SMS and on Interactive Voice Response (IVR) for KSh3 per minute (Maritz, 2011).

Another ICT program is the Kenya Agricultural Commodity Exchange (KACE), established in 1997, which has offers and bids. These services are prominently displayed on blackboard and are disseminated via SMS and Internet. KACE collects, updates, analyses and provides reliable and timely market information and intelligence on a wide range of crop and livestock commodities, targeting actors in commodity value chains, with particular attention to smallholder farmers and small scale agribusinesses (KACE, 2011). The components of the KACE links are: market resource centers, mobile phone short messaging service (SMS), interactive voice response service, internet database system, radio and the KACE headquarters central hub in Nairobi. All these applications helps in accessing information on daily wholesale buying prices for over 20 commodities as well as offers to sell and bids to buy (KACE, 2011).

Mobile phones are also used to distribute agricultural insurance products to farmers, most of whom cannot afford conventional insurance. A product called *Kilimo Salama*, Swahili for 'safe agriculture', enables smallholder farmers in Kenya to insure their agricultural inputs against adverse weather conditions, such as drought or too much rain. Developed by UAP Insurance, the Syngenta Foundation for Sustainable Agriculture and Safaricom, *Kilimo Salama* allows smallholder farmers to insure their inputs and produce. To be covered under the scheme, farmers only need to pay an extra 5percent for a bag of seed, fertilizer or other inputs.

Mobile technology plays a central role in the scheme as it is used both for registration of new policies as well as for payouts (Okeene , 2012). *Kilimo Salama* is distributed mostly through agro dealers that have been equipped with a camera phone that scans a special bar code at the time of purchase, which immediately registers the policy with UAP Insurance over Safaricom mobile data network. This innovative application then sends a SMS message confirming the insurance policy to the farmer's handset. Payouts are determined by automated weather stations that monitor the rainfall. Based on the stations' measurements and a predefined formula of crop rainfall needs, payouts are automatically made to farmers using Safaricom mobile money transfer service, *M-Pesa*. Farmers do not have to fill out any claim forms. Since its official launch in 2010, the scheme has already made payouts to numerous farmers (Okyere, 2012). It is expected that products like *Kilimo Salama* will increase productivity since only about half of Kenyan farmers invest in improved seeds and soil inputs (Okyere, 2012). A key reason for the low demand is the fear among farmers that poor conditions, such as drought, will render their investment worthless, robbing them of both their crops and their savings.

The literature indicates systems in various agricultural value chains; however, none of the existing systems provide agricultural diagnostics. In addition, the SMS based systems have limited words since an SMS cannot take more than 150 letters. Because of this reason, huge information on diagnostics and prescription might not fit through the existing systems. On the other hand, the existing systems are not user centered but only technologically centre. It is important to develop systems which are user driven for ease of adoption.

Mittal (2009) studied the role of mobile technology in improving small farm productivity in India by looking at the potential solution mobile phones could have in information asymmetry in agricultural sector. The study used focus group discussions and in-depth interviews with farmers to find answers to the use and impact of mobile phones and mobile-enabled services on agricultural productivity. The results showed that although mobile phones can act as catalyst to improving farm productivity and rural incomes, the quality of information, timeliness of information and trustworthiness of information are the three important aspects that have to be delivered to the farmers to meet their needs and expectations. This implies that the major factors for adoption of the technology were timeliness, quality of information and trust (Mittal, 2009).

2.9 Conclusion of literature review and the gap identified

The literature identified several gaps in Kenya agriculture which includes low budgetary allocation, ineffective extension services, low adoption of modern technologies; pre and post harvest crop losses to diseases and pests, inadequate disaster preparedness, high cost and increased adulteration of farm inputs, low and declining soil fertility and inadequate infrastructure. The literature review identified several gaps in the extension system in Kenya which includes reduced staffing and funding for operation and maintenance, dissemination of conflicting messages, reduced mobility due to poor road infrastructure, and low usage of modern communication technologies in extension among others.

The literature review identified the various types of research and indicated that evaluative and developmental research are two research approaches directed toward solving problems (Ackoff, 2005). The developmental type of research "involves the search for (and perhaps construction or synthesis of) instructions" that yield a better course of action (Ackoff, 2005). Developmental research has largely been ignored by some researchers. However, without research efforts directed toward developing new solutions and systems, there would be little opportunity for evaluative research. The literature review further demonstrated information system development as a credited research methodology. This study adopted the information system development research methodology for the development of the artificial intelligent system. The literature review identified the use of modern ICTs in the medical field, where ICTs have been used successfully to support diagnosis of disease. However, these ICTs have only been used to provide information to physicians (and not the patient) that eventually makes decisions on diagnosis and management. This study was designed to develop an artificial intelligent system that uses the symptoms observed by farmers to diagnose disease and provide necessary prescription to be administered.

The literature review also highlighted the importance of maize crop to the Kenyan economy and society at large, the challenges affecting maize production in relation to disease diagnostics and management. The findings/outcomes of this study will eliminate most of the challenges through provision of information to farmers. The study aimed at providing a fully functional prototype of an agricultural computer aided diagnostic system for Maize diseases. The study was guided by several theories/ models. The theory guiding the study was the system theory. The umbrella methodology for the study was the system development research methodology. Within the system development research methodology, traditional waterfall system development model was used to develop the system.

The literature identified the gap in the existing agricultural extension communication model. The literature identified the long communication chain which hinders the achievement of effective communication.

2.10 Conceptual Framework

Figure 2.6 below presents the conceptual framework for finding the user requirement and how the analysis of the requirement guided the development of the artificial intelligent system

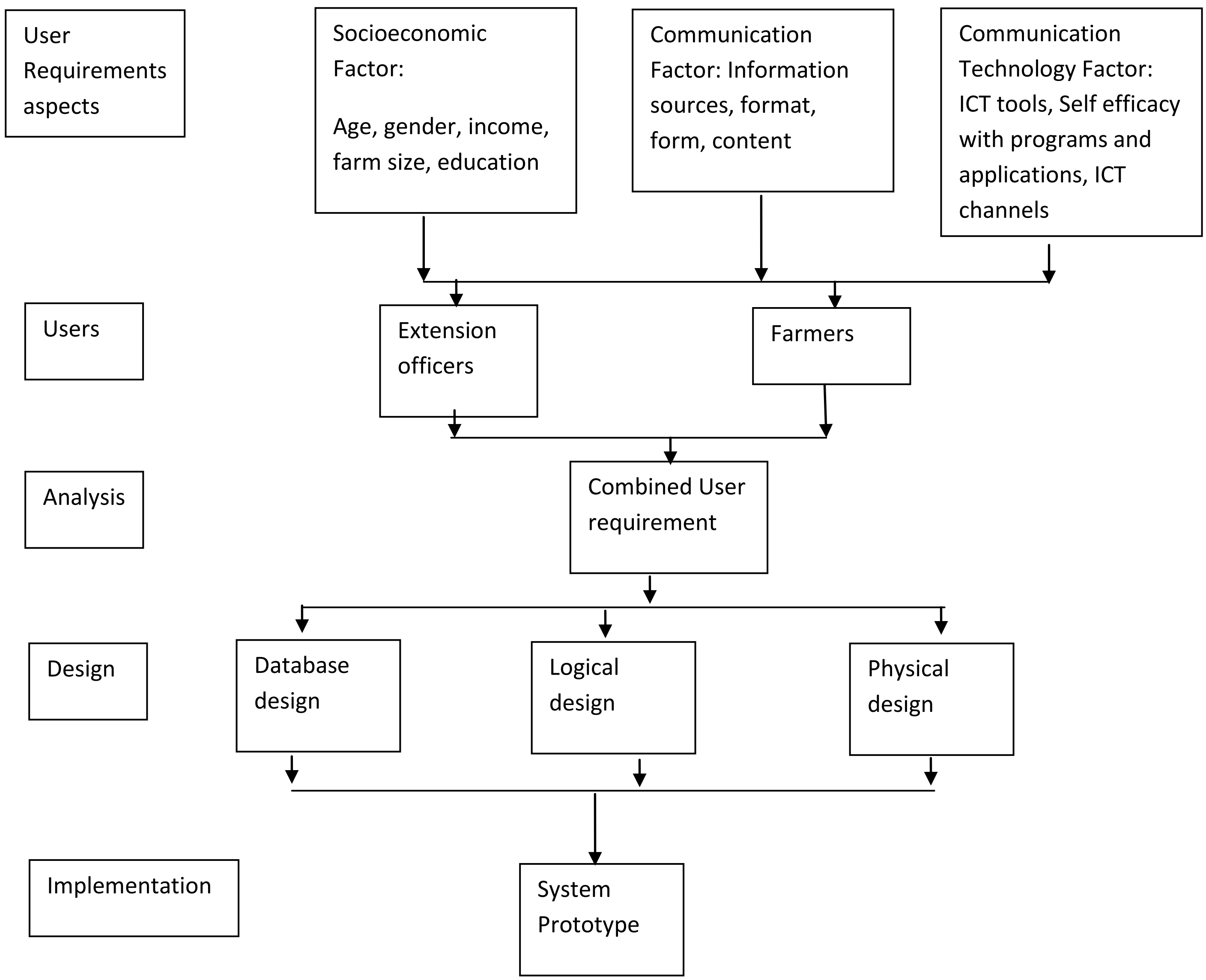


Figure 2.6: Conceptual framework for system prototype development (source Author).

The development of the artificial intelligent system started with gathering the requirement of users. The requirements are categorized into three namely socioeconomic, communication and communication technologies. There were two expected user which were the extension officers and the maize farmers. An analysis of the requirement was done and combined for the two users.

This formed the requirements of users. The analysed and concluded requirement of users was then used to guide the three major design processes namely data modeling (database design), Process and logic modeling (logical design) and the physical design. Upon the completion of the modeling, a prototype was developed to implement the designed model.

Figure 2.7 present a conceptual framework for achievement of an effective artificial intelligent system. It shows that to achieve an effective and efficient system which has ease of adoption and usage, user centric philosophy must be incorporated. The module is a modification of Unified theory of acceptance and use of technology (UTAUT) by Venkatsh (2000). It highlights that to achieve an effective and efficient system, information regarding the socioeconomics demographics, technology usage efficacy, communication factors and ICT factors must be used to guide the development of the system.

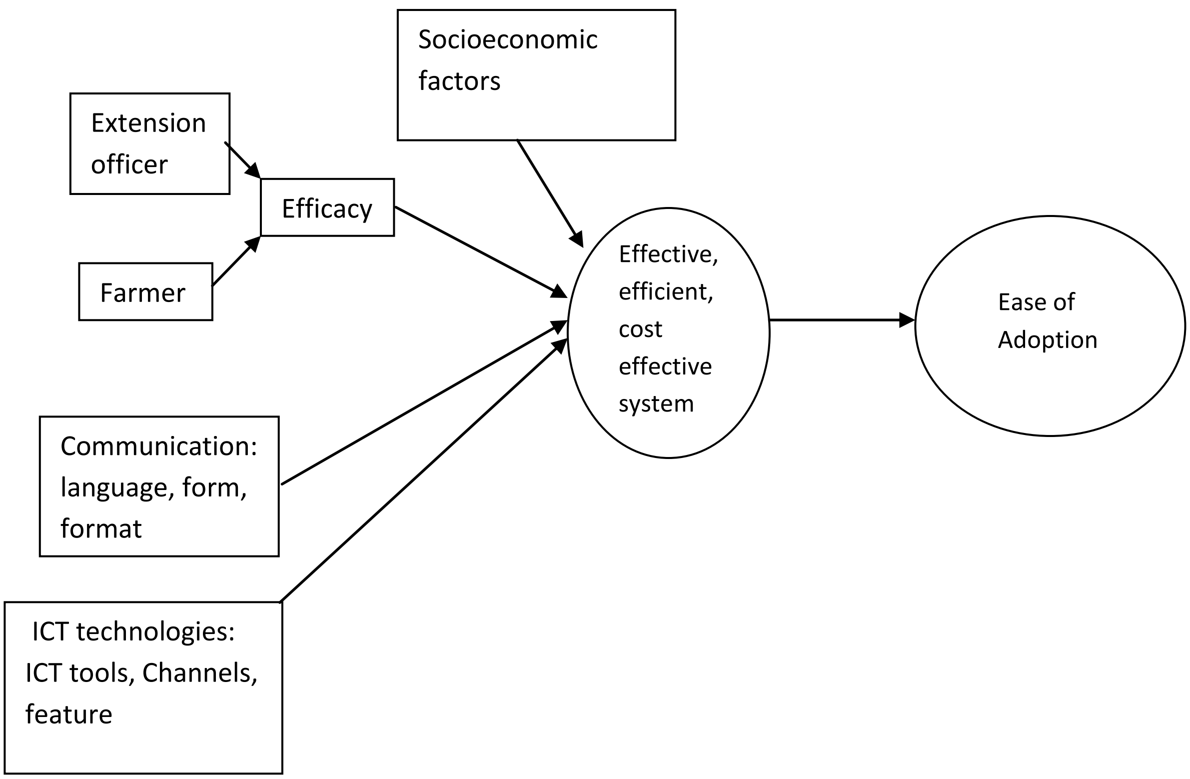


Figure 2.7: Conceptual framework for achieving an effective system and ease of adoption (source Author)

2.11 Brief of the overall Methodology of the Entire Study

The study was a multi-disciplinary which led to the use of several methodologies from various disciplines. The methodology is divided into four sections depending on the objective of the study to be achieved. The four sections included:

1. **User requirement determination**

The two users of the artificial intelligent system were identified as extension officers and farmers.

Methodology for extension officer requirement

The study was conducted in Uasin Gishu County, which is one of the forty seven counties in Kenya and the second largest maize producing county. It is located in the former Rift Valley Province. It extends between longitudes 340 50' and 340 57' East and latitude of 00 3' South to 00 1' North. The total area of the county stands at 2,955.3 km^2 (1,141.0 sq mi) whereas the total population of the county stands at 894,179 people and 202,291 households according to 2009 census. **(**http://www.scribd.com/doc/36672705/Kenya-Census-2009). Uasin Gishu County enjoys two rainy seasons with an annual rainfall ranging between 900 to 1200 mm. Seated on a plateau; the county has a cool and temperate climate, with annual temperatures ranging between 8.4 °C and 27 °C. The wet season in Uasin Gishu County is experienced between the months of April and May while the dry season comes between January and February due to favorable climate to maize production, high numbers of experienced maize farmers and extension officers, frequency of maize pests and disease occurrences in the area, the county was chosen for this study. The county has six sub counties with each sub county having three extension officers.

The population targeted by the study was the extension officers within the county. The research design was a case study in Uasin Gishu County and a case of maize diagnostics. These formed a representative area and crop for Kenya farmers.

Purposive sampling was used to identify the extension officers. All extension officers were interviewed hence total population in the case of the extension officers. Primary data was collected using interview guides (see Appendix I A) and analysed using SPSS. Descriptive statistics was used in the analysis.

User requirements for farmer

The study was also conducted in Uasin Gishu County. The county was purposively selected due to its favorable climate to maize production, the large number of experienced maize farmers and extension officers and the high prevalence/incidence of pests and diseases affecting maize occurrence.

Data was collected using interview guide (Appendix I B). The study sample size was estimated using the formula proposed by Mugenda and Mugenda (2003):

$$n = \frac{Z^2 pq}{d^2}$$

Where;

n = the desired sample size for N>10,000,

Z = constant associated with the required confidence level; in this study = 95percent, value= 1.96,

p = proportion of the population that possessed the target characteristics. The characteristics included farmers growing maize and farmer lacking extension services. Since this was not known, it was estimated to be 50percent= 0.5,

q = 1-p= 0.5 and

d = the level of precision estimated to be 10percent= 0.1

$$n= [1.96^2 *0.5*0.5] /0.1^2= 96.04$$

The sample size arrived at was 96 households (rounded to the nearest whole number).

Systematic random sampling technique was applied to select the households. A list of 11000 maize farming households provided by the county Government formed the sampling frame.

The sampling interval (k) was determined using the formula $k = N/n$, where **N** is the population size and **n** is the sample size. The sampling interval, k was therefore **11000/96= 114.5=115**. The first respondent who was the head was randomly selected. List of maize farming households, which was provided by the extension officer. By use of the formula, $K = n + k$, where **K** is the next household to be included in the sample, **n** is the previous member included and **k** is the sampling interval (Mugenda and Mugenda, 2003). The K^{th} household was determined and the process repeated until a sample size of 96 was achieved. In this study the second household was **1+115=116**; the third was **116+115=231**, and so on until the sample size was achieved.

A total of 90 farmers were successfully interviewed. As six respondents did not finish the interview, their interview guides were incomplete and therefore were not included in the analysis. Each farmer represented a household. Primary data was collected using an interview guide. Data was analysed using SPSS version 16.

2. Database development Methodology

This was a desk-top research which involved a collection of data from secondary sources. Physical and electronic libraries were visited. The target population was the publications on maize diseases and pests. The study involved the whole population as literature was collected from many books, journal and newsletters among other secondary sources. The information about pests and diseases collected included the name, symptoms, part where the symptoms appears, management options, specific chemical/drug to be administered, quantity and frequency of application and the photographs of each symptoms. This was collected using a check list form as the data collection tool. (Appendix II)

Maize pests were categorized into three, namely pathogenic diseases, nutritional deficiency and pest's infestations. There were several steps followed to achieve this objective. The steps were as follows

Identification of maize pests and diseases

This involved reading from most published work on plant pests and diseases and identifying the various pests and diseases which can attack maize crops. It also involved reading on the various soil nutrients deficiencies and their symptoms.

Collection of data on maize pests, diseases and nutritional deficiencies

Data collection tool in appendix II was used to gather information on most conditions, their symptoms and management option. Secondary data was collected and compiled in a spreadsheet

Determination of purpose of the database

This helped in determining the information that needed to be stored and tracked. It was at this process where access points were determined and database securities were put in place.

Determination of the tables needed

Decision on what information was to be kept in each table of the relational database management system. Each table will hold information about one subject.

Determination of the fields needed

Decision on what information will be kept in each table and how small that information was made at this point

Determination of the relationships of the tables

Looking at each table and deciding how the data in it is related to the other tables. Addition of the necessary tables and/or fields to clarify these relationships was done at this stage.

Refining and testing the design

Creating the tables and entering some data. Testing to see if the system could produce the reports required. If not, re-evaluation of the design was done.

Population

The population for this objective was publications on maize diseases and pests, their symptoms and management options. The publications comprised of journals, books, newsletters, magazines, internet among others.

3. Modeling of the artificial intelligent system

Secondary data was collected on the models of the existing system which are closely related to the intended artificial intelligent system. Analysis of the models was done to determine their strengths and weaknesses. The modules were also analysed to certain the possibility of each driving the intended artificial intelligent system for maize disease diagnostics and management.

This was a desktop research which involved collection of secondary data about the already existing systems models. The purpose of this was to be able to develop or understand a theoretical framework, indentify and study any related existing systems with an aim to broadening the scope of perceiving the problem and indentifying any deficiencies and also, to identify algorithms used and their implementation.

4. System development

Object oriented analysis and design is the design approach that was adapted during the design of the system.

Object-oriented analysis and design (OODA) is a software engineering approach that models a system as a group of interacting objects. Each object represents some entity of interest in the system being modeled, and characterized by its class, its state (data elements) and its behavior.

Object oriented analysis (OOA) applies object modeling techniques to analyze the functional requirements for a system. Object-oriented design (OOD) elaborates the analysis models to produce implementation specifications.

The outcome of object oriented analysis is a description of what the system is functionally required to do, in a form of a conceptual model.

Object oriented design (OOD) transform the conceptual model produced in object-oriented analysis to take account of the constraints imposed by the architecture and any non-functional requirements. The concepts in the analysis model are mapped onto implementation classes and interfaces. The result is model of the solution domain, a detailed description of how the system is to be built.

CHAPTER THREE

3.0 EXTENSION OFFICERS' REQUIREMENTS IN AN ARTIFICIAL INTELLIGENT SYSTEM FOR DIAGNOSIS OF MAIZE DISEASE, KENYA

3.1 Abstract

A study was conducted to determine the most frequently used agricultural diagnostic information source by extension officers, the content, the formats and form, the ICT tools, channels and features which extension offers have high self- efficiency with for the development an ideal artificial intelligent system. The study was conducted in Uasin Gishu County, Kenya where the population targeted was extension officers within the county. The research design was a case study in Uasin Gishu County and a case of maize diagnostics which formed the representative area and crop for Kenya farmers respectively. All extension officers were interviewed and data obtained analyzed using SPSS.

The study revealed that extension officers gathered information mostly from seminars conducted by the Government; they were interested in accessing full information on diseases and pests including their scientific and common names, symptoms, management options and prescriptions. Thus, a system was to be developed that would require an administrator to search, collect and input new diseases and pests diagnostics information into the system. The information accessed by the extension officers in relation to disease diagnostics is to be included in the actual system development. The final content of information given to the extension officers by the system must be in a printable format and must be accessed through Webpage and internet based application.

Keywords: Diagnostic, Artificial intelligent system, Uasin Gishu, Extension officers

3.2 Introduction

System requirements are one of the key prerequisites to system development. The development of a artificial intelligent system for agricultural diagnostics is no exception. Currently, agricultural diagnostics services are provided by extension officers. However, some players might have different alternatives to the extension sources. Extension officers have to move from one farmer to the other as they observe the affected plants and make diagnostic and management decisions. This has proven to be time consuming and costly. The current ratio of extension officers to farmers is 1:1500. This makes it impossible for extension officers to reach all farmers.

Extension services are largely funded by the Government and complemented by NGOs who serve their specific projects. Reduced budgetary allocation to agriculture and poor road infrastructure within the rural areas; have challenged efficiency and effective delivery of in diagnostic services. It was therefore necessary to explore alternative approaches for providing agricultural diagnostic services, in a global arena characterized by the development challenges and advancements in ICT innovation

Substantial financial resources have been allocated to improve ICT infrastructure in the country. These improvements include enhanced ICT connectivity through the laying of fiber optic cables, aggressive development of mobile phone networks by service providers such as Safaricom, Airtel and others and adoption of usage of mobile phones (80percent ownership and adoption) in many sectors of the economy. It is therefore important to automate services in the different sectors of the national economic..

Automation of services requires a good understanding of the various socio-economic factors affecting extension officers and the ICT tools, channels and features perceived as useful and easy to use. This study reviewed current diagnostics information sources by extension officers, the available ICT tools, channels, features/technologies for accessing and sharing information.

The ICT tools were mobile phones, computers, television and radio. The ICT channels were frequently modulated (FM) waves, GSM, internet and television waves. Expected outcome was an improved likelihood of adopting the system. After completing the artificial intelligent system development, the system will be user-centered. The findings of this study will guide development of automated artificial intelligent information's systems for agricultural diagnostic in Kenya, previously not reported in published scientific literature..

3.3 Statement of the problem

Despite the deployment of extension officers to offer agricultural diagnostic services to farmers, the ratio of extension officers to farmers still stands at 1:1500 farmers. In addition, there are challenges encountered including: inadequate budgetary allocation to agriculture, which eventually trickles down to the low budgetary allocation to the operations and movement of extension officer to offer services to the farmers. Moreover, Kenya is characterized by poor road infrastructure which raises the cost of ware and tare and making some areas inaccessible to extension officers.

On the other hand, service providers in the telecommunication industry such as Safaricom have expanded their networks to over 80percent of the country. The Government has facilitated internet connectivity through fiber optic cables to major towns. The policy of provision of computers to every child joining class one, is projected to transform the destiny of future generations in terms of ICT education and application in all sectors of the economy,..

This study therefore seeks to establish technological efficacy of extension officers to guide the development of an artificial intelligent system for agricultural diagnostics.

3.4 Justification of the Study

Technology acceptance model is based on two factors namely: perceived usefulness and perceived ease of use. Upon compliance with these requirements, the adoption and usage of the technology is increased. This study aimed to understand the perceived ease of use to guide the development of an artificial intelligent system. The perceived usefulness will be determined after the development of the system.

3.5 Objective of the study

To determine the requirements of extension officers in an artificial intelligent system for diagnostics and management of pests and diseases affecting maize in Kenya

Specific Objective

a) To determine the most frequently used agricultural diagnostic information source by extension officers and how socio-economic factor plays.
b) To determine the content of information which the extension officer would like to receive for full satisfaction, on agricultural diagnostics.
c) To determine the formats and form the extension officers would like to receive and send the information.
d) To determine the ICT tools, channels and features in which the extension officers have high self-efficiency.

3.6 Research question

What are the requirements of extension officers in an artificial intelligent system for maize disease diagnostics and management?

Specific Research Questions

a) What are the most used agricultural diagnostic information sources by extension officer and how does socio-economic factor play?
b) What is the content of information on diagnostics considered satisfactory by extension officers and how does socio-economic factor play?
c) What is the format and form that extension officers would like to receive the diagnostics information?
d) Which ICT tools, channels and feature extension officers consider easy to use and they are used to working with?

3.7 Literature review

Extension officers play a very important role in the provision of diagnostic services to farmers. Extension approaches in Kenya includes: Focal Area Approach (FAA)– (Use of common interest groups (CIGs); Farmer Field Schools – Farmer to farmer extension; Commodity-based approach - commercial enterprises; Multidisciplinary Mobile Extension Teams especially in arid and semi arid land areas.Despite the various extension approaches employed by the private and public sector, several challenges still exist. These challenges include: reduced staffing and funding for operations and maintenance among others in the public sector extension; dissemination of conflicting messages to the farmers; unnecessary competition, duplication of efforts, and general lack of synergy among the extension providers from the private sector.

These challenges have led to limited access to credible extension services in most parts of the country. Currently, the national extension staff to farmer ratio stands at 1:1,500 (Africa Science News Saturday, 16 November 2013). An agricultural system can only be considered sustainable when it satisfies producers' needs and preserves the natural resources for current and future generations. Its development should rest on three pillars: economic feasibility, social fairness and environmental sustainability (Carlos, 2006). This study sought to enhance provision of services by developing a computerized artificial intelligent information system that meets economic feasibility, social feasibility and environmental feasibility within the agricultural sector of Kenya.

Agricultural extension and challenges related to maize production

"Maize is the most important staple food in sub-Saharan Africa and is the main food crop in Kenya, representing 3 percent of Kenya's gross domestic product (GDP) and 21 percent of the total value of primary agricultural commodities. Maize thrives in regions where the rainfall average falls between 900-1700 mm, but can grow in as little as 500 mm or as much as 2500 mm rainfall. Grown on an estimated 1.4 million hectares in Kenya by large-scale farmers (25 percent) and smallholders (75 percent) it is both a commercial and subsistence crop."(World Bank, 2012) Heavy losses through pests and diseases, to maize farmers, have been witnessed in the past. These losses are witnessed throughout the maize value chain. Diseases related to nutrient deficiencies reduce the maize plan vigor right from germination to maturity hence reduced productivity. Pathogenic disease also affects the maize plant during growth hence reduced productivity at maturity. Entomological disease affects both the maize plant during growth and the maize grain after harvesting leading to heavy productivity reduction and post harvest losses. To guide artificial intelligent system which will bridge the gap, this study is seeking to understand the extension officer requirements in such a system with an intention to apply them on the actual system development.

Conceptual Framework

Figure 3.1 present the conceptual framework of this section. This is derived from the umbrella conceptual framework presented in figure 2.6. It shows that requirement of extension officers which included socioeconomic demographics, communication and information communication technology formed the extension officers' requirements which eventually formed the requirement analysis for system development

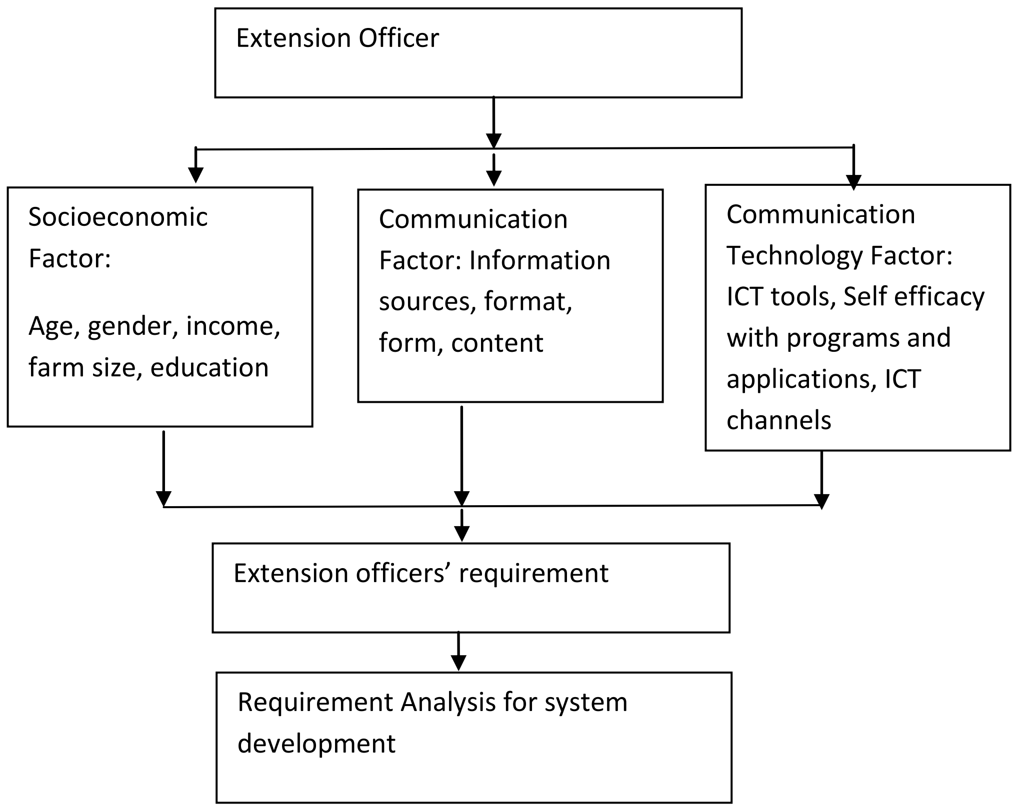


Figure 3.1. Conceptual framework

3.8 Methodology

The study was conducted in Uasin Gishu County, which is one of the forty seven counties in Kenya and the second largest maize producing county. It is located in the former Rift Valley Province. It extends between longitudes 340 50' and 340 57' East and latitude of 00 3' South to 00 1' North. The total area of the county stands at 2,955.3 km^2 (1,141.0 sq mi) whereas the total population of the county stands at 894,179 people and 202,291 households according to 2009 census. http://www.scribd.com/doc/36672705/Kenya-Census-2009. Uasin Gishu County enjoys two rainy seasons with an annual rainfall ranging between 900 to 1200 mm. Seated on a plateau; the county has a cool and temperate climate, with annual temperatures ranging between 8.4 °C and 27 °C. The wet season in Uasin Gishu County is experienced between the months of April and May while the dry season comes between January and February due to favorable climate to maize production, high numbers of experienced maize farmers and extension officers, frequency of maize disease and pests' occurrences in the area, the county was chosen for this study. The county has six sub counties with each sub county having three extension officers. .

The population targeted by the study was the extension officers within the county. The research design was a case study in Uasin Gishu County and a case of maize diagnostics. These formed a representative area and crop for Kenya farmers.

Purposive sampling was used to identify the extension officers. All extension officers were interviewed hence total population of eighteen extension officers provided by the county Government. Primary data was collected using interview guides (see appendix I A) and analysed using SPSS. Descriptive statistics was used in the analysis.

3.9 RESULTS AND DISCUSSIONS

3.9.1 Demographic information of the Extension officers

Eighteen extension officers were interviewed; the IR individual characteristics are shown on Table 3.1. There were nine males and nine females whose age range in years was thirty six to fifty one, with education of college certificate, diploma, bachelor, masters and post graduate diplomas. One responded did not disclose his/her education level.

Table 3.1: Individual characteristics

The table below represents the demographic characteristic of the extension officers who took part in the study

Characteristics		Frequency (N=18)	Percent
Gender	Male	9	50
	Female	9	50
Age	36-40	3	16.7
	41-45	6	33.3
	46-50	6	33.3
	51 and above	3	16.7
Education level	Bachelor degree	2	11.1
	College certificate	3	16.7
	Diploma	4	22.2
	Masters degree	5	27.8
	Post graduate diploma	3	16.7
	No response	1	5.6

Analysis of data presented in Table 3.1 revealed that 50percent of extension workers were female and 50percent male. 33.3percent of the extension officers are between 41 to 45 years of age, 33.3percent are of 46 to 50 years. Extension officers between the age of 36-40 years and those between 51 years and above formed 16.7percent each.

A majority of 27.8percent of the extension officers were holders of a master degree, 22.2percent with diploma, 16.7percent with Post graduate diploma, another 16.7percent with college certificates and 11.1percent with Bachelor degree only. 5.6percent (1/18) of the extension workers did not disclose their level of education during this study.

3.9.2 Sources of diagnostics information for extension officers

The extension officers were asked to indicate their current sources of information on agricultural diagnostics, using several options. Table3.2 represents the various options and the extension officers' responses. The respondents were allowed to select more than one option.

Table 3.2: Source of Information

Source	**Frequency**	**Percent**
Journal (if yes)	9	50
Internet (if yes)	2	11.1
Self (if yes)	14	77.8
Agro-vet shop (if yes)	10	55.6
Radio (if yes)	2	11.1
Television (if yes)	0	0.0
Mobile application (if yes)	2	11.1
Seminar (if yes)	18	100
Others		
Agricultural Officer	2	11.1
Extension Officer	2	11.1
Institute Officer	1	5.6

All(100percent) respondents agreed to getting information from seminars, 77.8percent also depend on their knowledge, 55.6percent depend on agro-vet, 50percent depend on journals, other sources of information was at 27.8percent (Agricultural officer 11.1percent, extension officer 11.1percent, and institutes officer 5.6percent). Internet, radio and mobile applications were each being used by 11.1percent of the respondents. The aim of understanding the sources of agricultural diagnostics is to identify the various sources of new information which is driving diagnostics and to incorporate these sources into the artificial intelligent system for agricultural diagnostics. The study finding revealed the need to deploy a systems manager charged with the responsibility of searching and collecting diagnostics information on new pests and diseases from seminars, agro vets, journals and extension officers and inputting into the artificial intelligent system.

Table 3.3: Correlation between information sources

Characteristics	Age	Gender	Education	Journal	Internet	Self	Agro vet shop	Radio	Mobile application
Age	1								
Gender	.290	1							
Education	-.147	-.201	1						
Journal	.058	-.111	-.040	1					
Internet	0.000	0.000	.100	0.000	1				
Self	0.000	0.000	-.247	-.267	.189	1			
Agro vet shop	.000	.224	.153	-.224	-.395	-.209	1		
Radio	-.369	0.000	-.157	-.354	-.125	.189	-.040	1	
Mobile application	.369	.354	-.157	.354	-.125	-.236	.316	-.125	1

There was no significant correlation between extension officers and their sources of information as shown in Table 3.3. This might be due to the fact that they are employed by the Government where they are taken through various similar trainings on accessing diagnostic information despite their social-economic, environmental and other human factors.

3.9.3 Diagnostic information content required by the extension officer

The various components of diagnostics information and the responses received from the extension officers are shown in Table 3.4.

Table3.4: Specific Information needed

Specific information	Frequency	Percent
Name of disease	18	100
Scientific name of disease	18	100
More symptoms	18	100
Management option	18	100
Name of chemical to apply and dosages	18	100
How to apply prescription	18	100
Where to purchase the chemical	18	100

The results of this study revealed that extension officers require all information related to the pests and diseases. There was 100percent agreement, for all the information content by the extension officers. This clearly indicates that during the actual system development, information accessed by the extension officers in relation to disease diagnostics must include the name of the disease, scientific name, all the symptoms, management options, and therapeutic products, how to apply the therapeutic product and where to purchase. This will ultimately influence the database design. The database must be designed such that it can accommodate the entire information requirement. It can therefore be concluded that the information content required by the extension officers in regard to disease diagnostics should include all aspects of disease symptoms, management option and the prescription.

3.9.4 Format preference of extension officers for receiving diagnostics information

Extension officers showed their level of preference for receiving diagnostic information as shown in Table 3.5.

Table 3.5: Information format preferred for receiving information

Form	Frequency	Percent
Printable format(Print and visual) (if yes)	9	50.0
Web page (print and visual) (if yes)	7	38.9
SIM Bases technology (if yes)	4	22.2
Email (print and visuals)(if yes)	1	5.6
Verbal phone call (if yes)	0	0.0
Verbal face to face communication (if yes)	0	0.0
SMS (print)(if yes)	0	0.0
USSD coded information(print) (if yes)	0	0.0

Fifty percent (50percent) of the respondents preferred receiving information in print form and printable format. Print form included written and pictures. Five point six percent (5.6percent) preferred receiving the information through email which also includes written and visual forms, thirty eight point nine percent (38.9percent) preferred receiving the information through a printable mobile and computer web based interfaces. Twenty two point two percent (22.2 percent) preferred receiving information through a mobile SIM based applications.

Therefore, the three significant information receiving form and format are print (written and audio visual) which included, email format and WebPages. It should be note that USSD coded information and SIM based application are both mobile interactive technologies and they constitute a third form. USSD and SIM applications are also written but are not printable. This information will guide the development of the user query interface and the form of delivering results by the system to the extension officers and farmers.

It was therefore deduced that the extension officer would prefer to receive written and visual information. It is also clear that the extension officers would prefer the information in a format which is printable. It may be concluded that the final information content given to the extension officer by the system must be in a printable format and must be accessed through Webpage.

Table 3.6: Correlation between individual characteristics and information format

	Age	**Gender**	**Education**	**Printed paper**	**Email**	**USSD coded information**	**SIM Bases technology**
Age	1						
Gender	.290	1					
Education	-.147	-.201	1				
Printed paper	-.406	-.111	.121	1			
Email	-.127	-.243	.244	-.243	1		
USSD coded information	.179	.342	-.106	-.342	-.193	1	
SIM Bases technology	0.000	-.267	.054	-.267	-.130	-.426	1

Analysis of data presented in Table 3.6 revealed no significant correlation between the various information formats which the extension officers would prefer to receive their information on agricultural diagnostics. This shows that no individual characteristic influences the respondents' choices on the various query interfaces they chose.

3.9.5 Preferred information form and format to Farmers by extension officers

Extension officers were presented with various forms and format of information for agricultural diagnostics and were asked to choose the form and format which they would prefer to deliver the diagnostic information to farmers. Their responses are shown in Table 3.7.

The study findings revealed that 66.7percent of extension officers preferred to deliver agricultural diagnostic information in printable and written formats. Other forms of delivery included Verbal phone call and verbal face to face formats with a preference rate of e 11.1percent each. However, only 5.6percent of the respondents preferred the webpage as a mode of delivery. WebPages can be also used as a user (delivery) interfaces to farmers for the printable written and visual formats. It is therefore important to use web based interface to deliver agricultural diagnostics information to farmers. This is because the preferred form and format is printable, written and visual. The web based user interface would be a convenient and appropriate mode for delivery of agricultural diagnostics information in a remote manner/format/location.

Table 3.7: Information form and format to the farmer

Preference	Frequency	Percent
Printable paper(print and visuals)	12	66.7
Verbal phone call(verbal only)	2	11.1
Verbal face to face communication (verbal only)	2	11.1
Email(Print and visuals)	2	11.1
Mobile phone application	2	11.1
SMS Bases	2	11.1
SMS(print)	1	5.6
Web page(print)	1	5.6

Table 3.8: Correlation between individual characteristics and communication form and format

Variables	Age	Gender	Education	Printed paper	phone call	face to face	Email	SMS	Web page	Mobile phone app	SMS Bases application
Age	1										
Gender	.290	1									
Education	-.147	-.201	1								
Printed paper	.194	.000	-.175	1							
Phone call	.527	.[b]	-.042	.667	1						
Face to face	-.219	.236	-.137	.110	-.688						
Email	.388	-.184	.173	-.060	-.982	.251	1				
SMS	-.209	-.240	-.121	.104	0.000	-.185	-.240	1			
Webpage	-1.000**	.[b]	1.000**	1.000**	.[b]	-1.000**	1.000**	.[b]	1		
Mobile phone app	.205	.121	.170	-.473	.189	-.718*	-.357	-.612	.[b]	1	
SMS Bases app	.186	-.185	.329	.271	.[b]	-.552	-.024	-.709*	.[b]	-.015	1

Significance: **. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed), b. cannot be computed because at least one of the variables is constant

There is a positive and significant relationship between web-based information format, printable format and email format (correlation coefficient of 1.0000). This is a clear indication that farmers who prefer web based information form and format also prefer email and printable format of information

3.9.6 ICT tools

ICT tools such as mobile phones, smart mobile phones, computers, radio and television which can be used to offer extension services remotely were presented to the extension officers and who were asked to identify the ICT tools they owned as shown in Table 3.9.This was to ensure that the ICT tool through which, the intended artificial intelligent system for is to be access, is one which the extension officers already own.

Table 3.9: ICT tools owned

ICT tools owned	Frequency	Percent
Mobile phone (if yes)	18	100.0
Radio (If yes)	18	100.0
Television set (If yes)	18	100.0
Smart Phone (If yes)	7	38.9
Computer (if yes)	5	27.8

ICT tools considered during this study are all common with the extension officers except computer. Only 27.8percent of the extension officers own a computer. On the other hand, all extension officers own mobile phones not all of them own smart phones, 38.9percentof them own smart phones.

The study findings revealed that all extension officers owned mobile phones, radios and TVs. However, not all of the respondents owned smart phones, this indicates that application based diagnostics system would not be appropriate to the entire extension officer apart from the 38.9percent who owns the smart phone. It is important to note that the mobile phones referred to had basic feature mobile phones with internet features. Therefore, the artificial intelligent system was modeled to be accessed through mobile phones.

Table 3.10: Correlation between individual characteristics and ICT Tools owned

Variables	Age	Gender	Education	Computer	Smartphone
Age	1				
Gender	.290	1			
Education	-.147	-.201	1		
Computer	.324	.372	.544*	1	
Smartphone	.417	.342	-.353	.523*	1

Significance: *. Correlation is significant at the 0.05 level (2-tailed)

The results of analysis of data presented in Table 3.10 revealed a significant positive correlation between extension officers who owned smart phones and those who owned computers. This implies that the owners of smart phone are also owners of computers hence the artificial intelligent system for diagnostic and management of Maize pests could also be accessed using computers.

3.9.7 Computer Uses

Table 3.11 presents results of the different uses of the extension officers interviewed in this study.

Table 3.11: Computer use

Uses	**Frequency**	**Percent**
Document preparation (if yes)	5	27.8
Accessing internet (if yes)	5	27.8
Sending and receiving emails (if yes)	4	22.2
Developing programs and applications (if yes)	1	5.6
Listening to music and accessing social media websites (if yes)	1	5.6
Transaction management (if yes)	0	0.0

Although the study findings revealed that 27.8percent of the extension officers owned a computer, respondents were asked to respond to what features they use in their computers. 27.8percent use their computers for document preparations (Microsoft office) such as word documents; excel file and PowerPoint presentations among others and for accessing internet (internet explorer and other web engines). 22.2percent also use their computers for sending and receiving emails. It can be deduced from the data that the respondents who use computer are 27.8percent and 22.2percent of them use it for internet access and sending and receiving emails respectively. 22.2percent is a significant portion of the population hence their requirements must be considered in the system development.

Accessing email and browsing the internet are features which fully depend on the internet. Browsing the internet involves the access of WebPages. Some emails are also accessed through web pages. The user interface must therefore be web-based for computer users since the computer owner's use their computer to access internet and to prepare documents. The web-based user interface will also be applicable to mobile phone users since all respondents had mobile phones which could be used to access internet.

Table 3.12: Correlation between individual characteristics and computer usage

Variables	Age	Gender	Education	Document preparation	Accessing internet	Sending and receiving emails	Developing programs and applications	music and accessing social media websites
Age	1							
Gender	.290	1						
Education	-.147	-.201	1					
Document preparation	.324	.372	-.544*	1				
Accessing internet	.324	.372	-.544*	1.000**	1			
Sending and receiving emails	.279	.535*	-.334	.862**	.862**	1		
Developing programs and applications	.127	-.243	-.459	.391	.391	-.130	1	
music and accessing social media site	.127	.243	-.107	.391	.391	.454	-.059	1

Significance: **. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed)

The results in table 3.12 shows the following three main findings: Significant strong positive correlation between accessing internet and document preparation (1.000), significant strong correlation between sending and receiving email and accessing internet (.862**), significant strong correlation between document preparation and sending and receiving email (.862**)

The results show that computer users currently use their computers for three major purposes. These are accessing the internet (web-pages), sending and receiving email (Internet based) and document preparation (print and visual files). It is worth noting the overlap which exists on the users which shows that it is the same user who actually uses their computers for the three reasons. It can be deduce that the extension officers, who already have computers, would require a diagnostic system which is web-based. The content of the web based system should be in print and visual forms and should also be in a printable format.

3.9.8 Mobile phone Usage

The extension officers were required to indicate what they used their phones for as shown in Table 3.13. The table presents the results of the different uses of a mobile phone which extension officers indicated as the features they already use.

Table 3.13: Mobile Phone Use

Use	Frequency	Percent
Making/receiving calls (if yes)	18	100
Sending and receiving SMS (if yes)	17	94.4
Accessing internet (if yes)	10	55.6
Accessing applications (if yes)	8	44.4
Sending and receiving emails (if yes)	6	33.3
Transaction management (if yes)	5	27.8
Listening to music and accessing social media websites (if yes)	4	22.2
WhatsApp and social media application access and communication (if yes)	2	11.1
Document preparation (if yes)	0	0.0

Extension officers were asked to choose the functions and features which they use their mobile for. Several choices were presented to the extension officers. All the extension officers use their mobile phones to make calls, none of the extension officers use was using their mobile phones for document preparation, 27.8percent use their mobile phones for making transactions such as M-Pesa, 55.6percent use their mobile phones for accessing the internet, 44.4percent use their phones for accessing applications, 94.4percent were utilizing the SMS facilities, 11.1percent were utilizing the social media access and communication applications(face book up) , 33.3percent were accessing and sending the emails and 22.2percent were accessing social media websites(face book website).

An interesting finding of this study was the fact that, verbal phone call was not preferred as a means to communicate diagnostics information to both the extension officer and farmers. Though making phone calls is the most utilized feature in mobile phones at one hundred percent (100percent), it cannot be put as a requirement for the system information delivery form and format. The use of mobile phones to access internet (web-pages) is preferred by 55.6percent of the respondent hence web based system interface is recommended for the system.

Table 3.14: Correlation between individual characteristics and mobile phone usage

Variables	Age	Gender	Education	Transaction mgt	Accessing internet	Accessing application	Sending & receiving SMS	WhatsApp& social media app.	Sending &receiving emails	Music & social media
Age	1									
Gender	.290	1								
Education	-.147	-.201	1							
Transaction management	.065	-.372	-.275	1						
Accessing internet	.234	0.000	.396	-.194	1					
Accessing applications	.234	.447	-.072	-.055	-.100	1				
Sending and receiving SMS	-.127	-.243	.107	.150	-.217	-.271	1			
WhatsApp& social media app.	0.000	-.354	-.028	.175	-.040	.040	.086	1		
Sending & receiving emails	.246	.236	-.313	.088	.395	.079	-.343	-.250	1	
music & social media websites	.279	0.000	.247	-.033	.209	.060	-.454	-.189	-.094	1

There is no significant correlation on the usage of mobile phone.

3.9.9 Use of input commands

Extension officers were requested to choose from a set of input/query technologies that they would prefer incase a system existed for them to retrieve information as shown in Table 3.15.

Table 3.15: Ease of use of input commands

Commands	**Frequency**	**Percent**
Web Based (if yes)	10	55.6
Mobile application (if yes)	6	33.3
SMS (if yes)	2	11.1
USSD code (if yes)	0	0.0

The study findings revealed that the Web based interactive input method was preferred at 55.6percent. Mobile application was also preferred at 33.3percent. USSD coded input method was not preferred. This implies that web based input/query forms would be appropriate of the proposed agricultural diagnostic intelligence system.

Table 3.16: Correlation between individual characteristics and input use commands

Variables	**Age**	**Gender**	**Education**	**Web based**	**Mobile app.**	**SMS**
Age	1					
Gender	.290	1				
Education	-.147	-.201	1			
Web based	.234	-.224	.315	1		
Mobile app.	.000	.236	-.228	-.791**	1	
SMS	-.369	0.000	-.157	-.395	-.250	1

Significance: **. Correlation is significant at the 0.01 level (2-tailed), The study findings revealed (0.791) a very strong negative but significant correlation between web based and mobile applications input/querying technologies. This implies that, those with smart phones and can install application would not prefer a web-based query system, while those with basic phones who are the majority at 60.2 percent prefer web-based application. It therefore means that web-based interface is still the preferred choice since those with smart phones have the ability to access web-based interface in addition to the ability to install applications.

3.9.10 ICT channels access

Respondents were presented with different ICT channels. The aim of this section was to establish a platform to transmit agricultural information was easily accessible to extension officers.

Table 3.17: Access to ICT channels

ICT Channels	Frequency	Percent
Internet (if yes)	18	100
(GSM) Global system for mobile communication (if yes)	18	100
Frequency modulated waves(radio waves) (if yes)	15	83.3
Analogue or digital television broadcasting waves (if yes)	15	83.3

Table 3.17 presents the frequency of farmers' preferences to the available ICT channels in Uasin Gishu County. The study findings revealed that Internet and GSM were available to all extension officers (100percent). FM and TV waves were also available to some extension officers. The GSM channel can be used for phone calls and sending SMS. It also provides internet channel (Safaricom internet services). This therefore means that GSM and internet channels would provide a wider geographical coverage than FM and TV waves. The implication of these observation was that the artificial intelligent system must use both GSM and internet channels to transfer agricultural diagnostics information.

Table 3.18: Correlation between individual characteristics and access to ICT channels

Variables	Age	Gender	Education	Internet	GSM	Radio Waves	TV waves
Age	1						
Gender	.290	1					
Education	-.147	-.201	1				
Internet	.545*	-.149	-.126	1			
GSM	.545*	-.149	-.126	1.000**	1		
Radio waves	.545*	-.149	-.126	0.833**	0.833**	1	
TV waves	.545*	-.149	-.126	0.833**	0.833**	1.000**	1

Significance: **. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed)

Table 3.18 presents result of correlation between individual characteristics and access to various ICT channels. The results revealed a very strong positive and significant correlation between access to GSM and internet channels among extension officers in the study. There was also a very strong positive and significant correlation between TV waves and Radio waves. There was, however very weak correlation between ICT channels and education. The other important observation was that GSM and internet channels have wider coverage. Additionally, channels with GSM also have internet. The artificial intelligent system to be developed therefore was to operate through internet channel.

CHAPTER FOUR

4.0 FARMERS' REQUIREMENTS IN AN ARTIFICIAL INTELLIGENT SYSTEM FOR DIAGNOSIS OF MAIZE DISEASES IN KENYA

4.1 Abstract

A study was conducted to determine the following: commonly used sources of agricultural diagnostic information by maize farmers, content of information which farmers would like to receive for full satisfaction on diagnostics, formats and form farmers prefer to receive the information and ICT tools, channels and features which farmers have high self- efficiency. These aspects were vital for developing of an artificial intelligent system for agricultural diagnostics. The study was conducted in Uasin Gishu County, Kenya where population targeted was maize farmers. A case study design was used in Uasin Gishu County. A case of maize diagnostics formed the representative area and crop for farmers in Kenya. Ninety (90) farmers were interviewed, Descriptive statistics was used to analyze data using SPSS version 16.

The study findings revealed that farmers gathered information mostly from extension officers, agro vet shops, from themselves, from internet, radio, televisions and mobile phones. Farmers preferred to access full information on pests and diseases regarding their scientific and common names, symptoms, management options and prescription, and where to purchase the prescription.

It was therefore desirable to develop a system with a system manager to search, collect and input new diseases and pests' diagnostics information. Information on the disease diagnostics is to be included in the system development. The final information content delivered by the system must be in a printable format and which must be accessible to farmers through Webpage and internet based application using mobile phones and computers as ICT tools.

Keywords: Diagnostic, Artificial intelligent system, Uasin Gishu, Maize Farmers

4.2 Introduction

4.2.1 Background

In order to develop a artificialintelligent system for agricultural diagnostics, it is necessary to determine farmers' needs. Agricultural diagnostic services are mainly provided by the extension officers. However different alternative models of delivering diagnostics services have emerged in the global arena.

Automation of this service requires an understanding of the various socioeconomic factors affecting farmers. It was also necessary to understand the available ICT tools, channels and features perceived as useful and easy to use.

This study was designed to determine the types of the available diagnostics information sources available to farmers and extension officers, the available ICT tools and channels as well as the accessible to the stakeholders and features/technologies which the stakeholders are comfortable to use to access and sharing extension information. The ICT tools were mobile phones, computers, television and radio. The ICT channels were frequency modulated waves (FM), GSM, Internet and Television waves. The application/features/evaluated in study were short message services (SMS), calling application, web-based mobile application, Unstructured Supplementary Service Data (USSD) code based application and SIM based application. An expected outcome of the study was improved likelihood of adoption of the completed diagnostic system.

4.2.2 Statement of the Problem

The Government has deployed extension officers for agricultural diagnostic services to farmers. However the ratio of extension officers to farmers is 1:1500; compared with the FAO recommended ration of 1:400(FAO 2011). Budgetary allocation is inadequate to support effective operations and movement of extension officers to meet farmers in the county. Poor road network and infrastructure further increases the logistical costs; rendering some areas inaccessible to the few extension officers. In spite of the many challenges service providers in the telecommunication industry have expanded their networks conveying over 80percent of the country. Government has facilitated internet access by connecting all major towns through the through the fiber optic cables. The Government is committed to its policy to provide laptop computers to all class one pupils. These trends will facilitate the upcoming generations to embrace knowledge and use of computers in all sectors of life, including agricultural extension will be used in this study.

4.2.3 Justification of the Study

The technology acceptance model based on two factors: perceived usefulness and perceived ease of use. It is compliance namely with meeting these two requirements, the adoption and usage of the technology is increased. This study aimed to understand the perceived ease of use, which guided the development of the system. The perceived usefulness will be determined after the development of the system and pilot testing the system among extension officers

4.2.4 Objective of the study

To determine the requirements by farmers for an ideal artificial intelligent system for diagnosis and management of Maize pests in Kenya

Specific Objective

The specific objectives of the study were;

1.) To determine the most common sources of agricultural diagnostic information source

2.) To describe how socio-economic factors affect the preferred sources of agricultural diagnostic information by farmers.

3.) To determine the ICT tools, channels and features preferred by farmers.

4.2.5 Research question

What are the requirements by farmers for an ideal artificial intelligent system for diagnosis and management of maize diseases?

Specific Research Questions

a) What are the most commonly used agricultural diagnostic information sources by farmers?
b) What content of information on agricultural diagnostics is considered satisfactory by farmers?
c) Which ICT tools, channels and features do farmers consider easy to use and are familiar with?

4.3 Literature Review

Communication in Agricultural extension

In chapter two item numbers 2.4, the literature review highlighted the communication modules by Shannon Shannon (1948) and Schramm (Schramm, 1954). It was identified that there is a gap in agricultural communication which leads to either farmers receiving distorted information or failing to receive the information. This is because transfer of information from researchers to farmers through the extension officers is highly influenced by: how the extension officer decoded the information from the researcher, how the extension officer encoded the information to the farmers, the noise interferences between extension officers and farmers, how the farmer will decode the information from the extension officer, the field of experience and social factors of the researcher and extension officer and the field of experience and social factors of the extension officer and the farmers.

Because of these factors, information in most cases gets to the farmers in such a way it was not fully intended for. Gaps therefore exist in the communication model for agricultural extension. This study will look into finding a solution which will link the farmers to the researcher directly without necessarily passing the information through the extension officers.

The figure 4.1 presents the communication module in agricultural extension and highlights the Gap which this study was to fill

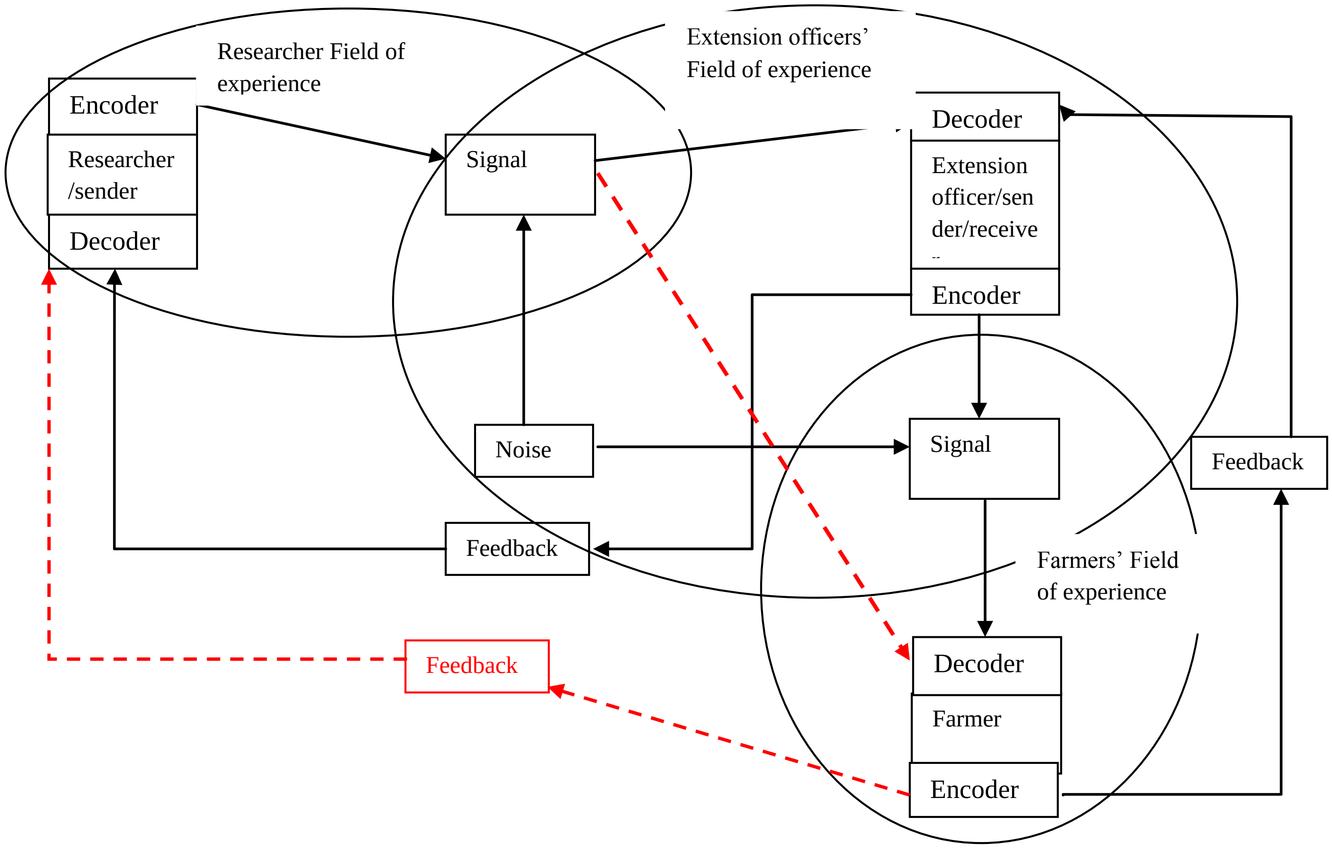


Figure 4.1: Gap in Communication module in agricultural extension in Kenya (source: Author)

Agricultural extension

Extension officers play an important role in provision of diagnostic services to farmers. Extension approaches in Kenya includes: Focal Area Approach (FAA)– (Use of common interest groups (CIGs); Farmer Field Schools – Farmer to farmer extension; Commodity-based approach - commercial enterprises; Multidisciplinary Mobile Extension Teams especially in arid and semi arid areas. Despite the various extension approaches employed by the private and public sector, several challenges are encountered in public sector. These challenges include: reduced staffing and funding for operations and maintenance of extension service delivery. In private sector the challenges include dissemination of conflicting messages, s; unnecessary competition, duplication of efforts, and general lack of synergy among extension service .

These challenges have led to limited access to credible extension services in most parts of the country. The national extension staff to farmer ratio is 1:1,500 (Africa Science News Saturday, 16 November 2013). An agricultural system is considered sustainable when it satisfies producers' needs and preserves natural resources for current and future generation. Development of the system should be based on three pillars: economic feasibility, social fairness and environmental sustainability (Carlos, 2006). This study was designed with the objective of enhancing provision of extension services, by developing a computerized artificial intelligent information system that meets economic,, social, and environmental feasibility. The system was designed to improve delivery of diagnostic and management services for maize diseases in Kenya.

Technology adoption Models

Several theoretical perspectives have been developed to understand how end users make decisions for to use of technology applications. Theories provide tools for understanding success or failure in the implementation processes of new information technology (IT) applications. The three most dominant theories in IT research are Innovation Diffusion Theory (IDT) (Rogers, 1995), Theory of Planned Behavior (TPB) (Ajzen et al., 1975), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003; 2012), the FITT framework (Ammenwerth et al., 2002) and the Technology Acceptance Model (TAM) (Davis 1989; Davis et al., 1989).

Technology Acceptance Model (TAM) (Davis, 1989; Davis et al., 1989) is possibly the most frequently used among all other theories (Ma et al., 2004; Kim et al., 2007; Yarbrough et al, 2007). The theory is based on principles adopted from Ajzen et al., (1975) attitude paradigm from psychology, which specifies how to measure the behavior-relevant components of attitudes, distinguishes between beliefs and attitudes and specifies how external stimuli are causally linked to beliefs, attitudes and behavior. The theoretical model on which TAM is based is the Theory of Reasoned Action (TRA). TRA is a general model which is concerned with individuals' intended behaviors.

According to the TRA, an individual's performance is determined by the individual's attitude and subjective norms concerning the behavior in question. In addition, an individual's beliefs and motivation interact with existing behavior (Ajzen et al., 1980). The Technology Acceptance Model (TAM) determines the user acceptance of any technology perceived usefulness (PU) and perceived ease of use (PEOU) factors. Perceived usefulness is defined as the degree to which an individual believes that using a particular system will enhance the task performance. Perceived ease of use (PEOU) defines as the degree to which an individual believes that using a particular system is free of physical and mental effort (Davis, 1989; Davis et al., 1989; Davis, 1993). The TAM suggests that the intention to accept technology is determined directly by attitude, perceived usefulness and perceived ease of use. According to the TAM, individuals' intention to use technology determines the actual use of the application and attitudes toward technology affect the intention (Davis et al., 1989; Davis and Venkatesh, 2004; Venkatesh et al., 2012).

Perceived usefulness and perceived ease factors are affected by various external variables such as level of education (Burton et al., 2005), gender (Venkatesh et al., 2000; Venkatesh et al., 2012), or organizational features such as training in computer use (Venkatesh, 1999; Venkatesh et al., 2012). The TAM theory is widely used in research contexts as well as with several types of technology applications (Chau *et al.*, 2001; Lee et al., 2006; Raitoharju, 2007; Yarbrough et al., 2007). The TAM uses TRA for generating explanations for the factors of technology acceptance that are transferable to different user populations and kinds of technologies.

Many different contexts and research constructions have confirmed the validity of the TAM model (Ma et al., 2004; King et al., 2006), including in health care industry (Chau et al., 2002a; 2002b; Chismar et al., 2003).

Venkatesh and Davis (2000) extended the original TAM model to explain perceived usefulness and usage intentions in terms of social influence and cognitive instrumental processes. The extended model, referred to as technology acceptance model 2 (TAM2), was tested in voluntary and mandatory settings. These results strongly supported TAM2 (Venkatesh and Davis (2000).

Due to this extensive modification of the TAM framework, it is only prudent to use its concept in coming up with a framework that will ensure complete and perfect adoption of agricultural diagnostic system systems; thus use of the Unified Theory of Acceptance and Use of Technology (UTAUT).

In this study, the TAM theory will be used to structure the research process. In addition it will enhance agricultural diagnostic system systems understanding acceptance and use of the proposed agricultural diagnostic system in the agricultural industry in Kenya.

Individual factors such as age, gender and technology skills are external variables in the study. Perceived usefulness is assessed by means of the content and benefits of the diagnostics system to farmers and the barriers and facilitators to the implementation of the system. The functionality of the application described perceived ease of use of the system. (Venkatesh et al, 2000)

Venkatesh et al, (2000) reated an integrated model called Unified theory of acceptance and use of technology (UTAUT), in which models previously used in information technology literature were merged. The UTAUT is made up of eight theoretical models: TRA, TAM, the motivational model, the theory of planned behavior (TPB), a model combining the TAM and TPB, the model of PBC utilization, the innovation diffusion theory and the social cognitive theory. The UTAUT helps managers assess the likelihood of success of new technologies as well as understand the drivers of technology acceptance. The UTAUT model identifies the determinants of user acceptance and usage behavior. Accordingly, there are four core determinants of intention to use and the usage of technology. Three are direct determinants of intention to use technology namely; performance expectancy, effort expectancy and social influence. On the other intention to use and facilitating conditions are two direct determinants of usage behavior. Venkatesh also identified four moderators of these key relationships namely gender, age, experience and voluntariness of used. (Venkatesh et al, 2000). This study investigated the three determinants of intention to use and moderating factors of gender age and specialty before the actual system development. This was to guide the development of the system and ease acceptance once the system is completed.

Performance expectancy is the extent to which users believe that medical diagnostic systems services will enhance their diagnostic efficiency. Conversely effort expectancy refers to the degree of ease with which user's access the agricultural diagnostic systems. There s to be similarities among the construct of performance expectancy and the perceived usefulness of TAM (Davis, 1989), perceived information quality (Venkatesh et al., 2003) and user satisfaction (Venkatesh et al., 2003). Also seem to be similarities among the construct of effort expectancy and perceived ease of use of TAM (Davis, 1989) and ICT skills and experience (Miyaki et al., 2001). Social influence refers to user's perception of significant others requiring them to use medical diagnostic systems whereas facilitating conditions relate to the extent that users believe organizational and technical infrastructure exist to support the use of medical diagnostic systems.

There seem to be similarities between the constructs of a social influence and saving/costs (Heek R 2006), perceived trust (Roca et al 2008) and awareness (Heeks R,2006).

Users will adopt a technology if they perceive it is helping them to improve their performance and consequently find it relevant in performing their tasks. Therefore, users performance contributes to enhancing perceived usefulness (Venkatesh et al., 2000; Venkatesh et al., 2003) the idea of job fit is also referred to as near term usefulness; which implies improved job performance or job satisfaction (Chau, 1996). Positively valued outcomes resulting from the use of technology will influence the users' beliefs about its usefulness (Davis, 1989).

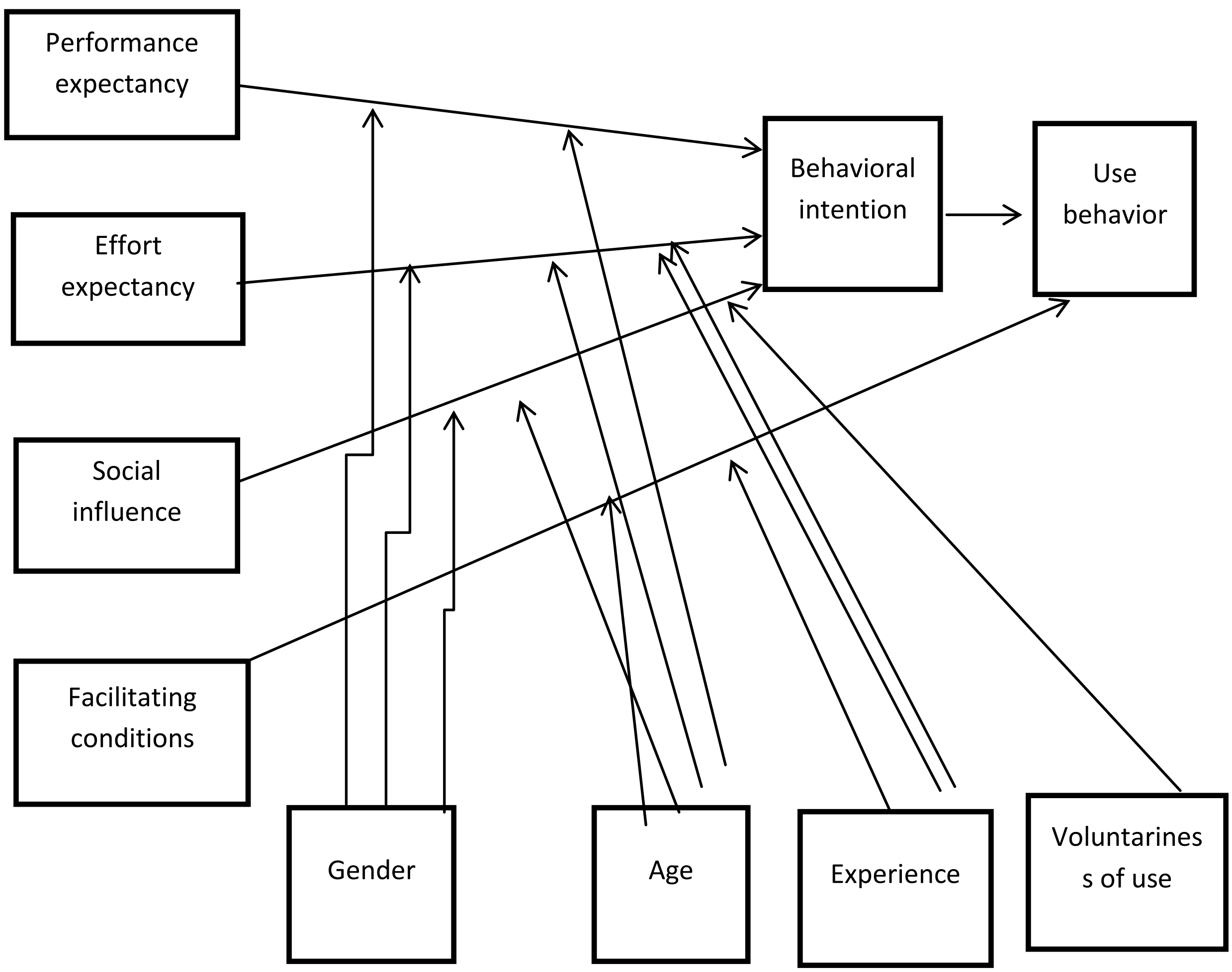


Figure 4.2:UTAUT model(Venkatesh et al, 2003)

The UTAUT model attempts to explain how individual differences influence technology use. More specifically, the relationship between perceived usefulness, ease of use and intention to use can be moderated by age gender and specialty (Venkatesh et al., 2003). To develop an artificial intelligent system for diagnostic and management of Maize diseases, the aspect of ease of use and the intention to use had to be incorporated to guide the design of the system. Farmers' requirements were to fill this gap. The conceptual framework below, showed how farmer requirement guided the artificial intelligent system design process.

Conceptual Framework

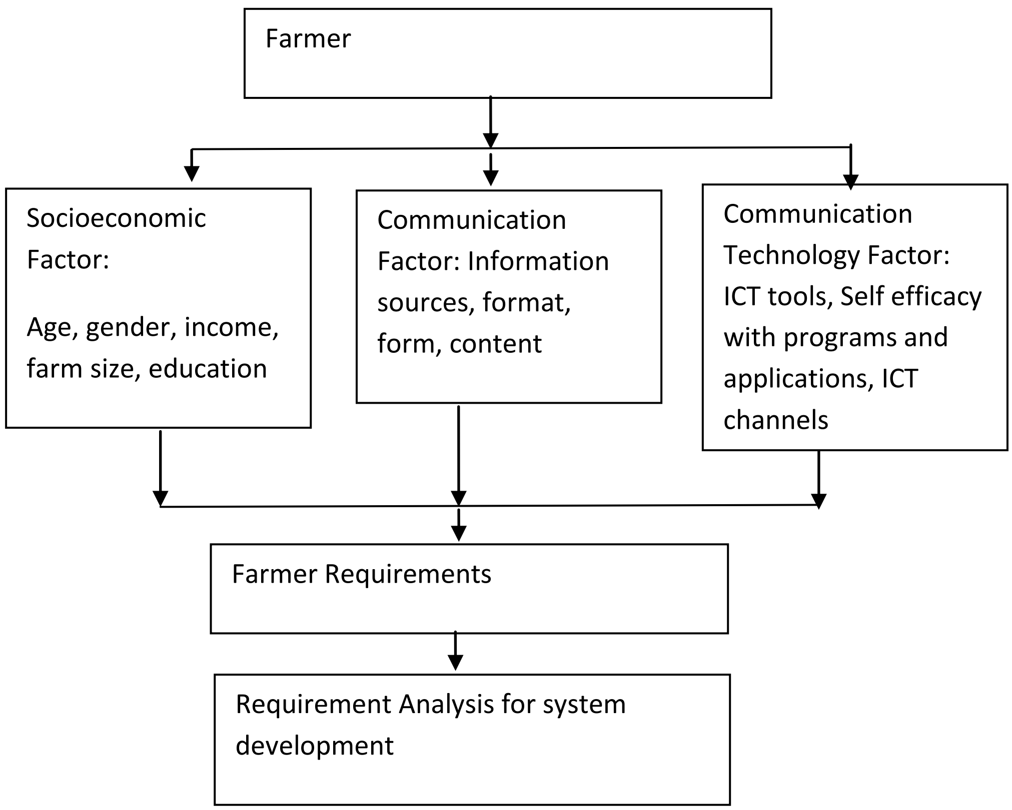


Figure 4.3: Conceptual Framework

4.4 Methodology

The study was conducted in Uasin Gishu County one of the 47 counties and the second largest maize producer in Kenya. The county extends between longitudes 340 50’ and 340 57’ East and latitude of 00 3’ South to 00 1’ North, anarea of 2,955.3 km^2 (1,141.0 sq m). The 2009 population census in was estimated at 894,179 people and 202,291 households. (http://www.scribd.com/doc/36672705/Kenya-Census-2009). There are two rainy seasons with an annual rainfall ranging between 900 to 1200 mm. Seated on a plateau; the county has a cool and temperate climate, with annual temperatures ranging between 8.4 °C and 27 °C. The wet season is experienced between April and May, while the dry season is encountered between January and February. The county was purposively selected due to its favorable climate to maize production, the large number of experienced maize farmers and extension officers and the high prevalence/incidence of diseases and pests affecting maize occurrence.

Data was collected using interview guide (appendix I B). The study sample size was estimated using the formula proposed by Mugenda and Mugenda (2003):

$$n = \frac{Z^2 pq}{d^2}$$

Where;

n = the desired sample size for N>10,000,

Z = constant associated with the required confidence level; in this study = 95 percent, value= 1.96,

p = proportion of the population that possessed the target characteristics. The target characteristics included maize farmer and maize farmer without access to extension services. Since this was not known, it was estimated to be 50percent= 0.5,

q = 1-p= 0.5 and

d = the level of precision estimated to be 10percent= 0.1

$$n= [1.96^2 *0.5*0.5] /0.1^2= 96.04$$

The sample size arrived at was 96 farmers (rounded to the nearest whole number).

Systematic random sampling technique was applied to select the households. The 11000 maize farming households formed the sampling frame.

The sampling interval (k) was determined using the formula $\boldsymbol{k = N/n}$**,** where **N** is the population size and **n** is the sample size. The sampling interval, k was therefore **11000/96= 114.5=115**. The first respondent who was the head was randomly selected. List of maize farming households, which was provided by the extension officer. By use of the formula, $\boldsymbol{K = n + k}$, where **K** is the next household to be included in the sample, **n** is the previous member included and **k** is the sampling interval (Mugenda and Mugenda, 2003). The K^{th} household was determined and the process repeated until a sample size of 96 was achieved. In this study the second household was **1+115=116**; the third was **116+115=231**, and so on until the sample size was achieved.

A total of 90 farmers were successfully interviewed. As six respondents did not finish the interview, their interview guides were incomplete and therefore were not included in the analysis. Each farmer represented a household. Primary data was collected using an interview guide. Data was analysed using SPSS version 16.

4.5 Results and Discussion

A total of 90 farmers were interviewed to determine demographic characteristics of the farmers, computing and mobile phone technology efficacy. Table 4.1 shows the various characteristics of the farmers who were interviewed.

Table 4.1: Demographic characteristics of farmers

Characteristics		Frequency (N=90)	Percent
Gender	Male	59	65.6
	Female	31	34.4
Age	26-30	10	11. 1
	31-35	18	20.0
	36-40	28	31.1
	41-45	15	16.7
	46-50	14	15.6
	51 and above	5	5.6
Level of Education	Primary school	41	45.6
	High School certificate	21	23.3
	College certificate	14	15.6
	Diploma	6	6.6
	Bachelors degree	6	6.6
	Masters degree	2	2.2
	Post graduate diploma	0	0
Farm size	10 acres and below	18	20.0
	11-20 acres	27	30.0
	21-30 acres	30	33.3
	31-40 acres	11	12.2
	41 and above	4	4.4
Mean annual income	Ksh.350,766.67		

Sixty six percent (59/90) of the farmers were male, while 34.4percent (31/90) were female. Majority (31.1percent) of the farmers were in the age between 36-40 years, 60 percent of the respondents were 40 years and below. Forty six percent ((41/90) of the respondents had primary school education, while 23.3percent had secondary school education. Sixty nine percent of the respondents had secondary and primary school education. 33.3percent of the respondents had between 21-30 acres of land. The average annual farmer income from maize was at Ksh 350,766.67 per farmer.

4.5.1 Current source of agricultural diagnostics information

Farmers were provided by various sources of agricultural diagnostic information and requested to select the various sources from where they received their information. More than one source of information could be chosen depending on where they have been getting their information. Table 4.2 shows the results.

Table 4.2: Source of Information for farmers

Source	Frequency(N=90)	Percent
Extension officer (if yes)	51	56.7
Radio (if yes)	50	55.6
Agro-vet shop (if yes)	43	47.8
Television (if yes)	31	34.4
Self (if yes)	29	32.2
Internet (if yes)	17	18.9
SMS (if yes)	9	10.0
Mobile Applications	1	1.1

Fifty six point seven percent (56.7percent) of the respondents access/obtain agricultural diagnostics information from extension officers, 55.6 percent from Radio and 47.8percent from Agro vets shops. Mobile phone, short messages (SMS) and mobile applications were used by 10percent and 1.1percent of respondents respectively.

Table4.3: Correlation coefficient between farmer characteristics and sources of information on agricultural diagnostics.

	Gender	Age	Education	Farm size	Annual Income	Extension officer	Internet	Self	Agro vet shop	Radio	TV	SMS	Mobile app.
Gender	1												
Age	.220*	1											
Education	-.027	.171	1										
Farm size	.040	.284**	.067	1									
Annual Income	.112	.190	-.117	.301**	1								
Extension office	-.121	-.125	-.063	.043	-.095	1							
Internet	.188	.223*	.142	-.193	-.013	-.208*	1						
Self	-.049	-.183	-.195	.040	.070	-.069	-.211*	1					
Agro vet shop	.102	-.104	-.055	-.062	.089	-.241*	-.234*	.007	1				
Radio	-.058	-.014	-.021	-.030	-.138	.030	.203	-.245*	-.443**	1			
TV	.016	-.019	.112	-.220*	-.201	-.121	.367**	-.200	-.319**	.648**	1		
SMS	-.008	-.135	-.042	.089	.073	.142	.028	-.151	-.319**	.298**	-.008	1	
Mobile app.	-.077	.017	.031	-.048	.022	-.121	.220*	-.073	-.101	.095	.146	-.035	1

***. Correlation is significant at the 0.05 level (2-tailed).**

****. Correlation is significant at the 0.01 level (2-tailed).**

The correlation of farmers who access agricultural diagnostic information from extension officers, internet and agro vet is negative as shown on Table 4.3. This implies that as the number of respondents who access agricultural diagnostics information from extension officer increases, the number of farmers who access the same information from the internet and agro vets within the same sample decreases.

There was a positive correlation between Internet, radio and television. Similarly to Agro vet, radio, television and SMS are positively correlated. Radio, TV and SMS are positively correlated. Implication: it is possible and easy to transform farmers who rely on television, radio and agro vet to using a mobile phone based information source. Farmers who depend on extension officers do not embrace any other source of information. This group could change to any other source of information through training by extension officers. An artificial intelligent system that is fully supported by extension officers as shown in the previous chapter would be valuable in moving these farmers to another technology will be easy. Moving farmers who rely on extension officers for information to internet based or mobile phone based information source would require greater efforts through training and using the extension officers as Trainers of Trainers.

4.5.2 Sufficient diagnostic information content

Farmers were presented with different content of agricultural diagnostics and disease management information. The farmers were requested to select the content of the diagnostic and disease management information which they considered sufficient. Table 4.4 represents their response.

Table 4.4: Distribution of the different content required by farmers in an agricultural diagnostics and pest management information system

Specific information	Frequency	Percent
Management option	80	88.9
Name of chemical to apply and dosages	72	80.0
More symptoms	69	76.7
Name of disease and pest	45	50.0
How to apply prescription	22	24.4
Where to purchase the chemical	18	20.0
Scientific name of disease and pest	17	18.9

Table 4.4 represents the results of different content required by farmers in an agricultural diagnostic system. The most common content preferred by farmers included management options (88.9percent), name of chemical to apply and dosages (80percent).More symptoms (76.7percent) and name of the diseases and pests.

Other minor content requested were; how to apply prescriptions (24.4percent), where to purchase the chemical (20.0percent) and scientific name of diseases and pests (18.9).

Table4.5: Correlation between farmer characteristics and specific information needed.

	Gender	Age	Education	Farm size	Annual Income	Name of disease and pest	Scientific name of disease & pest	More symptoms	Management option	Name of chemical to apply & dosages	How to apply	Where to purchase the chemical
Gender	1											
Age	.220*	1										
Education	-.027	.171	1									
Farm size	.040	.284**	.067	1								
Annual Income	.112	.190	-.117	.301**	1							
Name of the disease and pest	.070	-.130	-.282**	.021	.104	1						
Scientific name of the disease and pest	-.111	-.294**	-.027	.044	.072	.499**	1					
More symptoms	.013	-.089	-.176	-.237*	.153	.526**	.132	1				
Management option	-.041	-.006	-.123	-.036	-.040	.671**	.080	.495**	1			
Name of the chemical to apply and the dosages	-.164	-.182	-.222*	-.237*	-.027	.610**	.028	.318*	.588*	1		
How do apply the prescription	-.086	-.341**	-.559**	-.090	.076	.507**	.254*	.302*	.537**	.255*	1	
Where to purchase the chemical	-.070	-.243*	-.213*	.005	.071	.167	.255*	.079	-.177	.111	.556**	1
***. Correlation is significant at the 0.05 level (2-tailed).**												
****. Correlation is significant at the 0.01 level (2-tailed).**												

The results indicate a positive (.499**) correlation between the name of the diseases and pests and the scientific name of the diseases and pests. This means that, as the number of farmers who need to know the name of the disease increases, in the same respondent, the number of farmers who need to know the scientific name of the disease and the pest increase. There was a positive and significant correlation (.526**) between the name of the diseases and pests and their symptoms. This implies that as the number of the farmers who want to know the name of the pest and diseases affecting their crop increases, within the same population of respondents, the number of the farmers who needs to know more symptoms of the disease and/or pest also increases.

There was a strong and significant positive correlation between the name of the pest and/or disease and the management option. This implies that as the number of farmers who want to know the name of the diseases and/or pest increases, the number of farmers within the same respondent population, who want to know the management options also increases. The trend continues to include the name of the chemical to be applied and how to apply it. The two factors were positively and significantly correlated to the name of the disease. It is concluded that the farmer who wishes to know the name of the disease and/or pest also wishes to know the symptoms, management options, name of the chemical to apply and the dosage, and how to apply the prescribed treatment option (product).

The data in Table 4.3 indicates a positive correlation between the scientific name of the diseases and/or pest and how to apply the dosage and where to purchase the drugs/chemicals. This implies that as the number of the respondents who wish to know the scientific name of the disease and/or pest increases, the number of the farmers within the same respondents who wish to know how to apply the chemicals and/or dosage and where to purchases the chemical/drug also increases. It can be deduced that those farmers who wish to know the scientific name of the disease and/or pest also wish to know where to purchase the drugs/chemicals and how to apply it.

An additional finding was the fact that symptom is positively and significantly related to management options, name of the chemical to be applied and how to apply it. This shows that as the number of the respondents who wish to know more symptoms increases, the number of respondents within the same population who wish to know the management options, name of the chemicals to be used and how to apply the chemical also increases. Therefore, it can be deduced that farmers who wish to know more symptoms on the diseases and/or pests affecting their maize, would also wish to know the various management options, name of the chemical/drugs to apply and how to apply the prescribed chemical/drug.

Based on the study findings, it was concluded that farmers consider agricultural diagnostic information adequate only when the content includes the following; the name of the disease and/or, the scientific name of the disease and/pest, more symptoms of the disease and/or pest, the management options available to control, prevent and cure the disease and/or pest, the name of the chemical/drug to apply/administer, how to administer/apply the prescribed drug/chemical and where to purchase the chemical/drugs from.

4.5.3 ICT Tools

Different ICT tools were presented to farmers who were requested to choose those they owned. The objective was to determine the most commonly owned ICT tools by most famers and to select the tools through which agricultural diagnostic information can be provided. Table 4.6 shows the various ICT tools and percentage of the farmers who owned theses tools.

Table4.6: ICT Tools owned by farmers in Uasin Gishu County

ICT Tools owned	Frequency	Percent
Mobile phone (if yes)	88	97.8
Radio (If yes)	72	80.0
Smart Phone (If yes)	45	50.0
Television set (If yes)	36	40.0
Computer (if yes)	19	21.1

Data revealed that 97.8percent (88/90) of the farmers own mobile phones. Fifty percent (50percent (45/90) of the farmers have smart phones. This means that 47.8percent (97.8percent-50percent=88-45) have feature phone. The feature phones presented were those that had internet/ wireless Application protocol (WAP). Eighty percent (72/90) of farmers used radio as an ICT tool.. It can be deduced that transfer of agricultural diagnostics information through mobile phones will be the most preferred mode of communication. However, the above finding is not conclusive therefore it is important to obtain a deeper understanding of the correlation between the ICT tools for better conclusion. Table 4.7 below shows the correlation between the various ICT Tools and the farmer's personal characteristics.

Table 4.7: Correlation between farmer characteristics and ICT Tools owned.

	Gender	Age	Education	Farm size	Annual Income	Computer	Mobile phone	Smartphone	Radio	Television set
Gender	1									
Age	.220*	1								
Education	-.027	.171	1							
Farm size	.040	.284**	.067	1						
Annual Income	.112	.190	-.117	.301**	1					
Computer	.198	.143	.049	.069	-.016	1				
Mobile phone	.109	.031	.078	-.002	-.029	.078	1			
Smartphone	.070	.032	.114	-.268*	-.149	.027	.551**	1		
Radio	.012	.081	.153	.046	-.064	-.082	.713**	.456**	1	
Television set	-.019	-.017	.167	-.202	.008	-.033	.123	.181	.408**	1

***. Correlation is significant at the 0.05 level (2-tailed).**

****. Correlation is significant at the 0.01 level (2-tailed).**

The data analysis in Table 4.7 revealed that, computers have positive but weak correlation with mobile phones and smart phones. There was a weak negative correlation between radio and television. This implies that ownership of computers was not influenced by ownership of other ICT tools. However, from Table 4.6, 21.1percent of the respondents have computers, hence forming a significant portion of the population. It is therefore important to consider using computers in exchange of agricultural diagnostic information between farmers and extension officers.

Conversely, there was a positive and statistically significant correlation between ownership of mobile phones and ownership of smart phones and radio. This implies that as the number of the respondents who own mobile phones increases, among them, the number of those who also own smart phones and radios also increase. It was also observed that majority of farmers who owned mobile phones also had radios .This may be attributed to the fact that mobile phones contain radio as a feature within them. The study revealed that mobile phones are an important ICT tool used by farmers for communication. There was therefore a strong and significant positive correlation between use of radio and mobile phones. There was also a positive but not significant correlation between use of mobile phone and television. Radios had a positive and significant correlation with television.

These findings imply that conveying agricultural diagnostics information through mobile phones might be easily adopted by people who own mobile phones, smart phones radios and television sets. Mobile phones owned by respondents had internet/web application. It is therefore proposed that web based user interface would be appropriate even for the 21.1percentown f respondents who own computers.

4.5.4 Computer use by farmers

Despite the fact that only 21.1percent of the respondents own computers, farmers were asked if they interact with computers from elsewhere and what they actually do with the computers. The farmers were presented with the various functions of a computer. The aim of the study was to establish the self efficacy with the various functions of computers in order to identify the best mode of delivery of agricultural diagnostics information using computers. Table 4.8 shows the various computer uses and the results in percentages using computers per respondents.

Table 4.8: Computer uses by farmers in Uasin Gishu County

Uses	Frequency	Percent
Listening to music and accessing social media websites (if yes)	75	83.3
Accessing internet (if yes)	18	20.0
Document preparation (if yes)	17	18.9
Sending and receiving emails (if yes)	15	16.7
Developing programs and applications (if yes)	5	5.6
Transaction management (if yes)	3	3.3

Analysis of data presented in Table 4.8 revealed that, 3.3percent of the respondents use computers to listen to music and access social media websites. A significant (20percent) proportion of the respondents also use computers to access internet. This implies that information which is conveyed through computers should be web based for ease of adoption as the respondents self efficacy with web sites is high, given the experience gained by accessing social media and internet.

Table 4.9: Correlation between farmer characteristics and computer

	Gender	Age	Education	Farm size	Annual Income	Document preparation	Transaction mgt	Accessing internet	Sending and receiving emails	Developing programs and apps.	Listening music &accessing social media webs
Gender	1										
Age	.220*	1									
Education	-.027	.171	1								
Farm size	.040	.284**	.067	1							
Annual Income	.112	.190	-.117	.301**	1						
Document preparation	.248*	.161	.050	.044	-.029	1					
Transaction management	.126	.075	.055	.146	-.014	.385**	1				
Accessing internet	.164	.121	.042	.031	-.019	.894**	.217*	1			
Sending and receiving emails	.115	.072	.019	-.065	-.019	.774**	.083	.894**	1		
Developing programs and applications	.233*	.110	-.086	.025	-.065	.503**	.225*	.485**	.412**	1	
Listening to music and accessing social media websites	-.178	-.116	-.019	.065	-.060	-.089	.083	-.075	-.120	-.022	1

Analysis of data presented in Table 4.9 revealed that preparation of documents was positively and significantly correlated with access of internet, receiving and sending emails and developing of computer programs. Preparation of documents was also positively but not significantly correlated with transaction management. This implies that as the number of respondents who use computers to prepare documents increases, the number, in the same population of respondents, who use computers for accessing internet, sending and receiving email and developing applications also increases. Further, as the number of the respondents who use computers to execute transactions increases, the number of the respondents accessing internet and developing programs also increases but not significantly.

The data also showed a positive and significant correlation between accessing internet, developing programs, sending and receiving email. The overlap of factors shows that those who use computers for emails and developing programs also access the internet. This observation indicates that a web based agricultural diagnostics information system would facilitate access among farmers and extension officers.

4.5.5 Mobile phone uses

Analysis of data in Table 4.6 revealed that, 97.8percent of the respondents had mobile phones, 50percent of the respondents had smart phones and 47.8percent had feature phones. It was therefore important to understand the various functions of the mobile phones with which the respondent had high self efficacy. Table 4.10 represents the various functions of the mobile phones which were presented to the respondents. The respondents were required to choose the functions which they currently use not only for agricultural purposes but also in their day to day life. The aim was to establish the features which farmers have high self efficacy with. An additional aim was to determine the possibility of providing agricultural diagnostic information through a feature which the famers already know how to operate. The results were presented in Table 4.10 below.

Table 4.10: Mobile phone use

Use	Frequency	Percent
Making calls (if yes)	88	97.8
Sending and receiving SMS (if yes)	83	92.2
Accessing internet (if yes)	44	48.9
WhatsApp and social media application access and communication (if yes)	30	33.3
Transaction management (if yes)	28	31.1
Sending and receiving emails (if yes)	18	20.0
Listening to music and accessing social media websites (if yes)	7	7.8
Accessing applications (if yes)	4	4.4
Document preparation (if yes)	3	3.3

The results of the study revealed that (Table 4.10), frequently used function of a mobile phone among farmers (97.8percent). Sending and receiving short messages is also a frequently (92.2percent) used function by the farmers. Accessing internet is an equally well and was used by 48.9percent of the farmers. An additional finding of the study was the fact that the use of application and social media through mobile phone is also embraced by 33.3percent of the farmers interviewed.

The aim of this study was to identify the functions with high self efficacy among farmers and with the ability to be accessed remotely by several farmers at the same time. With the above results, it was therefore important to understand the correlation between the above results. Table 4.11 presents the correlation between the various mobile phone functions.

Table 4.11: Correlation between farmer characteristics and mobile phone use

	Gender	Age	Edu	Farm size	Annual Income	Calling	Doc preparation	Tran mngt	Access internet	Access apps	SMS	W&SA	Emails	Music
Gender	1													
Age	.220*	1												
Education	-.027	.171	1											
Farm size	.040	.284**	.067	1										
Annual Income	.112	.190	-.117	.301**	1									
Making and receiving calls	.109	.031	-.004	-.002	-.023	1								
Document preparation	-.004	.030	.021	-.142	-.070	.028	1							
Transaction management	.119	-.101	.094	-.127	-.161	.101	.143	1						
Accessing internet	.180	.158	.240*	-.134	.085	.447**	.066	.063	1					
Accessing applications	.071	.035	.063	-.048	-.046	.033	.861**	.088	.113	1				
Sending and receiving SMS	.123	.013	-.130	-.061	-.025	.238*	-.177	.106	.201	-.139	1			
Whatsapp and social media application access and communication	.182	.063	.106	-.124	.011	.053	.131	-.017	.440**	.191	.117	1		
Sending and receiving emails	.105	.162	.012	.134	.074	.775**	.062	.084	.345**	.162	.145	.118	1	
Listening to music and accessing social media websites	.051	.228*	.085	.099	-.006	.044	.408**	.074	.214*	.541**	.084	.147	.270*	1

Analysis of data in Table 4.11, revealed a positive and significant correlation between the use of mobile phone for calling and accessing internet. There was also a positive and significant correlation between the use of mobile phone for sending and receiving SMS and accessing internet. This implies that as the number of those who use the mobile phone for calling and sending short messages increases, within the same respondents the number of people using the mobile phone for accessing the internet also increases.

Based on the results in Table 4.10 showing call and SMS functions as the most used, it can be deduced that access to internet is also on the increase (capacity building). Inputs in technology transfer such as training would improve adoption of access to internet. An internet based agricultural diagnostics information system would therefore offer high farmers self efficacy, provide access remotely, and can be accessed by several people at the same time as opposed to calling and sending short messages who have limitations in terms of the number of people which can access at the same time and the volume of the content of information to be delivered.

4.5.6 User interface

The ease of use of any computer aided system begins with the user interface. The respondents were provided with various user interface input technologies in both mobile phones and computers. They were requested to choose the ones they considered easy to use, given the experience they possessed from using other systems with similar technologies in the society. Table 4.12 presents the results.

Table 4.12: Ease of use of input/query interfaces

Commands	**Frequency**	**Percent**
Web Based (if yes)	54	60.0
Mobile application (if yes)	26	28.9
USSD code (if yes)	24	26.7
SMS (if yes)	21	23.3

From Table 4.12, web based interface is preferred at 60percent. USSD cod interface, SMS based interface and mobile application are also significant at 26.7percent, 23.3percent and 28.9percent respectively. Based on the results, web based user interface will have a higher and quick adoption rate as the self efficacy of farmers with the interface technology is already high.

4.5.7 ICT channels available to farmers

Farmers were presented with various ICT channels and asked to identify those they had access to. The aim of the study was to identify the channel which can be used to deliver agricultural diagnostic information in a services remote area. Table 4.13 below represents the results.

Table4.13: Access to ICT channels

ICT Channels	Frequency	Percent
(GSM) Global system for mobile communication (if yes)	84	93.3
Frequency modulated (FM) waves(radio waves) (if yes)	83	92.2
Analogue or digital television broadcasting waves (if yes)	76	84.4
Internet (if yes)	44	48.9

GSM channel had the widest coverage at 93.3 percent. Internet on the other hand had the lowest coverage at 48.9 percent. The GSM channel had the ability to carry the internet channels through the mobile telephones; the two channels therefore go hand in hand. On the other hand, FM wave was the second largest channel at 92.2 percent. It is important to once again highlight that GSM has the ability to carry FM waves as well through mobile phones.

Based on the study findings, it can be concluded that GSM channels would be the most preferred communication channels as they provide a suitable platform for internet and radio channels.

Table4.14: Correlation between farmer characteristics and ICT channels

	Gender	Age	Education	Farm	Annual	Internet	GSM	Radio	TV

				size	**Income**			**Waves**	**waves**
Gender	1								
Age	.220*	1							
Education	-.027	.171	1						
Farm size	.040	.284**	.067	1					
Annual Income	.112	.190	-.117	.301**	1				
Internet	.133	.110	.228*	-.031	.077	1			
GSM	-.051	.104	.116	.132	-.051	.401*	1		
Radio waves	.100	.087	.090	.121	-.045	.261*	.655*	1	
TV waves	.053	.087	.106	.081	-.049	.358*	.619*	.500*	1
***. Correlation is significant at the 0.05 level (2-tailed).**									

Analysis of data in Table 4.14 revealed a strong positive and significant correlation between GSM, radio waves and TV waves. As GSM channels also provide a platform for internet channels, internet is a subset of GSM. GSM also provides a platform for radio waves and sometimes TV waves. Mobile phones have been produced with internet, Radio and TV enabled feature. Based on the study findings it is concluded that GSM channels provide the best channels for connecting the agricultural diagnostic system to the farmers and extension officers.

CHAPTER FIVE

5.0 ELECTRONIC DATABASE OF MAIZE PESTS AND THEIR MANAGEMENT OPTIONS

5.1 Abstract

Maize pests and diseases have had adverse effects on maize crops for a very long time. Farmers have experienced heavy losses due to the pests and diseases. On the other hand researchers have documented the pests and diseases, their symptoms, management options and the curative measures. However, this information continues to lie with the researchers and extension officer. The trick down of the information to farmers has not been realized as much due to several challenges which faces the extension service sector. The challenges include understaffing (extension officer to farmer ratio 1:1500), low budgetary allocation, and poor infrastructure among others. Despite the availability of the information on maize crop pests and diseases, there is no single repository for the same. In addition this information is available in hardcopy journals and books which has hindered the free and ease of access to this information.

A study was conducted to determine the known maize diseases and pests, their symptoms, management option, drug and chemical prescription for curing the disease, how to apply the drugs and where to get the drugs from. The study continued to design an electronic database for the maize diseases and pest as was collected for safe storage and ease of access.

An electronic database was later designed to allow for collection, storage and retrieval of the information electronically. This was later to act as the knowledge base for an artificial intelligent system for maize disease diagnostics. The database was later implemented using mySQL.

Keywords: Diagnostic, Artificial intelligent system, database, diseases and pests

5.2 Introduction

5.2.1 Background of the study

Artificial intelligent systems fully rely on a knowledge base which facilitates decision making. Information from researchers on maize diseases and pests has been extensively published in journals and books. The information is often shared in seminars to extension officers with the aim of improving knowledge,, skills, attitudes and competence on diseases and pests of maize. The ultimate expectation is to improve the agricultural diagnostic capacity of extension workers. The results of Chapter Three and Chapter Four revealed the recommended information content requirements for farmers. It is therefore necessary to design a study to consolidate all information on pests, diseases and their management options.

In order to make decisions like human beings, a system must rely on an electronic knowledge database. For ease of understanding and design of database, it is desirable to desegregate information on pests and diseases affecting maize. The first categorization is pest and diseases. Pests are living organisms which feed on parts of the crop for their survival. Diseases are caused by invisible micro organisms which alter the normal function of plants and animals. Diseases can be divided into several categories based on their causal micro-organisms. There are bacterial, fungal and viral diseases. Pests and diseases also affect different parts of the crop and at different stages of growth and development.

Diseases and pests have symptoms which are manifested when they attack crops at various stage of growth. The symptoms are also specific to certain parts of the crop. These characteristics lead to the symptoms, which facilitates decision making for diagnosis and determination of management option by the human experts. It was therefore necessary to develop an electronic database of all information held by humans. This would support decision making process of an artificial intelligent system for agricultural diagnostic purposes in Kenya, previously not documented in scientific literature.

5.2.2 Statement of the Problem

Although abundant information is available on research work on the pests and diseases affecting maize, the information is not easily accessible to farmers as it is stored in journals and books. Such information is normally relayed through extension officers to farmer. The extension officers are currently understaffed and unable to visit all the farmers to support the diagnostic services. The current ratio of extension officer to farmers is 1:1500 compared to FAO's recommended ratio of 1:400.

An artificial intelligent system was therefore recommended and developed to deliver the information. The system requires an electronic database of all the pests and diseases, to serve as knowledge base for diagnostic decision making in the management of maize production in Kenya

5.2.3 Justification of study

Extensive research previously conducted in agricultural sciences has focused on production of crops and animal resources .However, scientific data on the application of ICT's in agricultural diagnostic in Kenya is scanty. Knowledge and practice among farmers, extension workers and researchers in Kenya is available in different information resource centers and human experts. This scenario highlights the significant logistical and technological challenges facing various actors in the ease of access and application of such vital data.

In order to bridge this gap, it is necessary to validate the feasibility for diagnosis and management of pests and diseases of plants and animal importance, in use of modern information and communication technologies to improve communication of agricultural practices.

A study was therefore designed to develop an artificial intelligent system with an electronic database to facilitate collection, storage, dissemination and application of knowledge and practice for efficient and effective prevention, control and management of pests and diseases affecting maize crops in Kenya.

5.2.4 Objective

To develop an electronic database on existing knowledge and practices for agricultural diagnostics and management of maize pest's in Kenya.

Specific Objectives

a) To collect and compile data on existing knowledge of pests of Maize in Kenya.

b) To design an electronic database of the existing knowledge of pests of maize in Kenya.

5.2.5 Research Question

How can an electronic database on existing knowledge and practices, for agricultural diagnostics and management of maize diseases in Kenya be develop?

5.3 Literature Review

The CIMMYT Maize Program (2004) developed a guide for field identification of Maize diseases, intended for field use by agricultural technicians and maize farmers, the pocket-size manual carries descriptions and color photographs for more than 50 fungal, bacterial, viral, and mollicute diseases that affect the maize crop worldwide, with basic information on pathogens and symptoms. A diagnostic key facilitates quick identification of diseases and their effects. A nomenclature has been updated, which includes new diseases and information added, and improved photographs. (CIMMYT, 2004).

Plant library has a website https://www.plantvillage.com/en/topics/corn-maize/infos/diseases_and_pests_description_uses_propagation, which contains maize diseases and the symptoms in both description and pictures. However it does not provide users with the ability to query the website with little information, which they have and get more information on the disease. It also does not provide management solutions and the chemical to be applied. (Plant Library website https://www.plantvillage.com/en/topics/corn-maize/infos/diseases_and_pests_description_uses_propagation viewed at 10:39am on 17/6/2015)

According to the characteristics of maize disease knowledge, Ma et al (2013) used OWL DL language to build maize disease ontology and the reasoning rule of maize diseases was defined by using the expressive ability of SWRL rule language. Ma et al (2013) introduced several realizable reasoning functions and achieved the diagnostics reasoning for maize disease knowledge by Jess inference engine. The results indicated that constructing maize disease ontology and introducing SWRL rule into Maize diseases ontology provided an effective way for the construction of high-intelligent, sharable and reuse maize disease knowledge database and diagnostic rule database. (Ma *et al.*, 2013)

5.4 Methodology

A desk top research study design was used. Data was collected from secondary sources, including physical and electronic libraries. The target population was the publications on maize diseases and pests. The study involved the whole population as literature was collected from most books, journal and newsletters among other secondary sources. The information about pests and diseases collected included the name, symptoms, part where the symptoms appears, management options, specific chemicals and drug to be administered, the quantity and frequency of application and the photographs of each symptoms. Data was collected using a check list form as the data collection tool (Appendix II).Maize diseases were categorized into three sub categories namely pathogenic, nutritional deficiency and entomological diseases.

Identification of maize pests and diseases

The process was accomplished through the following stages; published scientific articles were reviewed to identify all pests and diseases of maize, soil nutrients deficiencies and their symptoms, as well as post-harvest..

Collection of data on maize pests, diseases and nutritional deficiencies

Data collection tool in appendix II was used to gather information on most conditions, their symptoms and management option. Secondary data was collected and compiled in a spreadsheet.

Determination of purpose of the database

The required information was determined stored and tracked. Access points were determined and database securities developed.

Determination of the tables needed

Decision on what information was to be kept in each Table of the relational database management system. Each table holds information about one subject.

Determination of the fields needed

Decision on what information will be kept in each Table and how small that information was made at this point.

Determination of the relationships of the tables

Each table was reviewed and a decision made on how the data is related to the other tables. Addition of the necessary tables and/or fields to clarify these relationships was done.

Refining and testing the design.

Creating the tables and entering some data. Testing to see if the system could produce the reports required. If not, re-evaluation of the design was done.

Population

The population for this objective was a myriad of publications on maize diseases and pests, their symptoms and management options. Publications comprised journals, books, newsletters, magazines, internet among others.

Sources and type of data

Data which was collected to fulfill this objective was secondary data. This was collected from journals, books, newsletters, internet, and magazine among other secondary sources of data.

Sampling Technique

All relevant materials were collected. This implies that most of the population was reached for data collection.

5.6 Results, discussions and database design

The data presented below indicates the diseases, their symptoms and management options to meet the information requirements of farmers and extension officers.

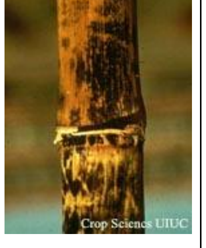
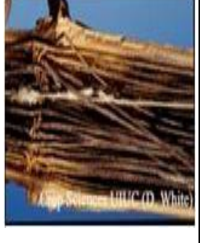
Table 5.1: Maize diseases and pests and the management options

Name of the disease	**Name of Pathogen/Insect/deficient Nutrient**	**Plant part Affected**	**Symptom**	**Picture**	**management option**	**Specific drug to be administered**	**Market Brand Name of the drugs**	**How to apply/administer**
Brown spot	*Physoderma maydis*	leaves	small chlorotic circular spots on the midrib and leaves		**Disease resistant germplasm, fungicide application**	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
		Stalks	brown lesions at node and internodes, rotting and lodging					
Common rust	*Puccinia sorghi*	leaves	small, elongate, powdery pustules over both surfaces		**Genetic Resistance plants Cultural Practices like crop rotation**	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foiar 50g/100l

			of the leaves					
Polysora rust (southern rust	*Puccinia polysora*	leaves	Light orange pustules on leaves. Pustules turn dark brown as plants approach maturity		**Genetic Resistance Cultural Practices** like cultivation and crop rotation do not affect common rust development.	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foiar 50g/100l
Tropical rust	*Physopella zeae*	leaves	Small Pustules found beneath the epidermis. Centre of pustule the lesion appears white to pale yellow.		**Genetic Resistance-** Resistant varieties are the most cost-effective means to manage common rust. **Cultural Practices**	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foiar 50g/100l
Turcicum Leaf Blight (TLB	*Exserohilum turcicum*	leaves	Slightly oval, water-soaked, small spots on leaves which become necrotic lesions.		**Plant resistance maize varieties**. **Rotating maize with non-host crops can reduce disease pressure**. **Fungicide application**	Tetraconazole 25percent EW	Domark 40 EW	Foliar spray 50-100ml/100L

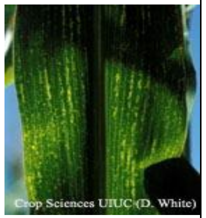
Anthracnose leaf blight	*Colletotrichum graminicola*	leaves	Water-soaked, oval lesions with tan centers with reddish-brown borders.		**Genetic Resistance** **Cultural Practices** Tillage can reduce the risk. Rotation to crops other than corn	Chlorothalonil 82.5percent WDG	Odeon 82.5percentWDG	Foliar spray 120-150/100L
Yellow leaf blight	*Mycosphaerella zeae-maydis*	leaves	Yellow coloration in a 'V' shaped pattern. In mature plants,lesions are narrow, necrotic, and parallel to veins.		**Resistant hybrids are commercially available**. **Tillage** can reduce risk when residue is incorporated in soil. Rotation to crops other than corn	Chlorothalonil 82.5percent WDG	Odeon 82.5percentWDG	Foliar spray 120-150/100L
Gray leaf spot	*Cercospora zeae-maydis, C. sorghivar. Maydis*	Leaves	Lesions begin as small, regular, elongated brown gray necrotic spots parallel to the veins		**Use of resistant cultivars** **Irrigation**. **Fungicides** are important for gray leaf spot control	Chlorothalonil 82.5percent WDG	Odeon 82.5percentWDG	Foliar spray 120-150/100L
Pythium stalk rot	*Pythium aphanidermatum*	Stalk	Basal internodes become soft, watersoaked, and dark, causing lodging.		Avoid planting too early when soils are wet and cold, Seed treatments may provide	Chlorothalonil 82.5percent WDG, Dipotassium phosphate 61percent	Odeon 82.5percentWDG, Agrifos 600	Foliar spray 120-150/100L, Soil drench 3-5.75L/Ha

		seedlings	Root tips or entire root system appear brown and become soft-rotted and water-soaked seedling blights.		protection for 10 to 14 days after planting**, improve soil drainage**			
Fusarium stalk rot	*Fusarium verticillioides*	Stalk	Wilting, dark-brow develop in lower int Phloem is dark bro browning of tissues,		**Genetic Resistance- Chemical / Biological Control/cultural** Fungicide applications. prevent Physical damage creating wounds	Carbendazim 50percent SC	Goldazim 500SC	soil drench 5-10L/ sq of 100mL/100Lsoln
		cobs	Ear infection begins as white mycelium which later turns reddish-pink, in infected kernels					
Head smut	*Sphacelotheca reiliana*	Tassel	Black masses of spores inside male florets; and in ear.		**Choose resistant varieties. Collect and destroy galls. Reduce infection points by avoiding injury of plant. Prevent damage from insect**	Copper oxychloride 50percent metallic Cu	AmiCop 50wp	foliar: 2.0-3.0kg/ha

Maize Smut	*Ustilago maydis*	tasseling and silking stages	Abnormal developi the tassels, masses spores in ear. The ear develops no grai		**Avoiding mechanical damage Controlling insect damage removing galls before they rupture to limit the spread A well-balanced fertilizer regime to reduce disease severit**y.	Copper oxychloride 50percent metallic Cu	AmiCop 50wp	foliar: 2.0-3.0kg/ha
Anthracnose stalk rot	*Colletotrichum graminicola*	stem	narrow, elongated dark lesions along the stem surface. Premature wilting due to the complete destruction of pith tissue,		**Use disease resistance hybrids Maintain balanced fertility Reduce plant stress Control the corn borer**	Copper hydroxide 50percent WP	Funguran -OH	Foliar spray 150-200g/100L
charcoal stalk rot	*Macrophomina phaseolina*	seedlings	abnormal drying of upper leaf tissue. At maturity, the internal parts of stems show a black discoloration.		**Use hybrids resistan**t **Minimize early senescence of stalk tissue Reduce moisture stress**	Chlorothalonil 82.5percentWDG	Odeon 82.5WDG	Foliar spray: 120-150ml/100L

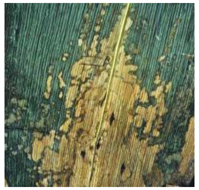
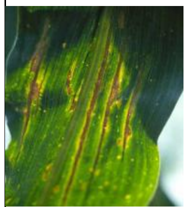
Peniculliu m ear rot	*Penicillium spp*	Ears	light blue-green powder grows between kernels and on cob surface . Bleaching of kernel		**Prevent injury to ears**	Carbendazim 50percent SC	Goldazi m 500SC	
Fusarium root rot	*Fusarium oxysporum*	roots	dark brown to black, discolored, decaying or completely rotted roots.		**Reduce plant stress Irrigation or tillage may be of some benefit. Use seed treated with fungicides.**	Carbendazim 50percent SC	Goldazi m 500SC	soil drench 5-10L/ sq of 100mL/100Ls oln
Aspergillus ear rots	*Aspergillus flavus, Aspergillus spp.*	Ears	Produces black, powdery masses of spores that cover both kernels and cob.		Reduce plant stress Irrigation or tillage may be of some benefit Insect control may be helpful Planting timed to reduce stress after pollination			

Bacterial stalk rot	*Erwinia chrysanthemi pv. Zeae*	stalk	Dark color, water soaking at the stalk. The bacterial decomposition produces an unpleasant odor		**Genetic Resistance** **Cultural Practices** cultivation to incorporate residue and avoiding excessive irrigation or flooding	AmiCop 50WP	copper oxychloride	Foliar: 2.0-3.0 Kg/Ha
Stiwart's wilt	*Erwinia stewartii*	leaves	Water soaked lesions, Stunting, wilting, death. Late infection cause severe leaf necrosis but does not lead to wilting		**Stewart's Wilt is a quarantined** pathogen requiring phytosanitary certification **Resistant hybrids** **foliar insecticides are effective in reducing Stewart's Wilt.**	Copper hydroxide 50percent WP	Funguran-OH	Painting: make a thick paste, Foliar spray: 150-200g/100L
Maize chlorotic mottle virus disease	Maize chlorotic mottle virus	leaves	Chlotoric spots on leaves, stunting, produce fewer and smaller ears. The male inflorescence is malformed		**Genetic Resistance** **Cultural Practices** **Crop rotation**. **Control of alternate host**			

maize dwarf mosaic virus disease	maize dwarf mosaic virus	whole plant	Distinct mosaic, irregularities in distribution of normal green color. At maturity, the foliage can turn purple or purple-red		**removal of the alternate host plants. Selecting corn varieties that are tolerant of the virus** and control **aphid population.**			
maize streak virus disease	maize streak virus	whole plant	small, round spots in young leaves. Spots enlarge parallel to leaf veins. Infection cause stunting, not develop cobs		**Grow resistant maize lines control insect vectors, practice crop rotation** . **Manure and basal/top dressing fertilizers can be applied to boost plant vigor**			
Maize lethal necrosis disease	maize chlorotic mottle virus (MCMV) and either maize dwarf mosaic virus (MDMV) or wheat streak mosaic virus (WSMV)	whole plant	Chlorosis on leaves and die at about flowering time. No ear development in plants infected during early stages		**Grow resistant lines, control insect vectors, and practice crop rotatio**n. **Manure and basal/top dressing fertilizers can be applied**			
Corn stunt	Corn stunt	Stalk			**Grow resistant lines**, **control insect vectors**, **practice crop rotation**. **Manure and basal/top dressing**			

			Stunting, shortened internodes, excessive root branching; leaf reddening, yellowing, chlorotic streaks at leaf bases		**fertilizers can be applied**			
Brown spot	*Physoderma maydis*	leaves	small chlorotic spots, in alternate bands of diseased and healthy tissue. Spots in mid-rib are circular and dark brown,		**Disease resistant germplasm . fungicide application** for management of Physoderma brown spot. **Accurate identification of this disease is important**,	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
		stalks	Nodes and internodes also show brown lesions.					
Downy mildews	Several species of the genera Peronosclerospora, Sclerospora, and Sclerophthora are responsible for downy mildews:	leaf	chlorotic striping, along with dwarfing. development of a downy growth on or under leaf surfaces		Disease **resistant germplasm**. **fungicides** application.	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
Maydis leaf blight	Cochliobolus heterostrophus	leaf	lesions appear small and diamond shaped. final lesion is rectangular resulting in burning of large areas of the leaves		-Use of **resistant cultivars** -avoid practices that **extend dew periods**. **Fungicide**s are important for gray leaf spot control	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l

Carbonum leaf spot	Cochliobolus carbonum	leaf	oval, zonate, brownish lesions. produces narrow, grayish lesions with a chlorotic border.		**Use of resistant cultivars, avoid practices that extend dew period**s. **Fungicides** are important for gray leaf spot control	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
		Ear	brownish lesion on ears which rot and turn black					
Anthracnose leaf blight	Colletotrichum graminicola	foliar	Irregular, oval, elongated lesions with yellow reddish brown margins.		Use of **resistant cultivars avoid, practices that extend dew periods**. **Fungicides** application are important	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
		stalk	stalk rot symptom					
Yellow leaf blight	*Phyllosticta maydis*	leaf	lesions are narrow, necrotic, and parallel to the veins. In older leaves, lesions produce blighting near the tip.		**Use of resistant cultivars** avoid, practices that extend dew periods. **Fungicides application** are	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l

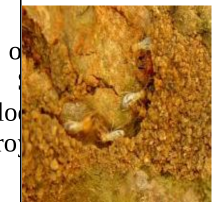
					important for gray leaf spot control			
Banded leaf and sheath blight	Rhizoctonia solani f. sp. Sasakii	leaves and sheaths	Symptoms are characteristic concentric spots that cover large areas of infected leaves and husks		**Plant resistance maize varietie**s. Rotating maize with non-host **Fungicide application**	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
Curvularia leaf spot	Curvularia lunata, C. pallescens, and C. maculans	leaf	small necrotic or chlorotic spots with a light colored halo.		Resistant maize varieties. crop rotation. Fungicide application	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
Septoria leaf blotch	Septoria maydis	leaf	small, light-green-to-yellow spots on the leaves. Lesions coalesce and produce severe blotching and necrosis		**Plant resistance maize varieties. crop rotation.** **Fungicide application** can effectively control the disease	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l
Macrospora leaf stripe	*Stenocarpella macrospora, syn. Diplodia macrospora*	leaf	necrotic lesions along the veins. These lesions resemble spotting produced by bacteria or by Exserohilum turcicum.		**Plant resistance maize varieties. Rotating maize with non-host crops** **reduce inoculum level** **Fungicide application**	copper oxychloride 50percent metalic Cu, Azoxystrobin 250g/l	Amicop 50wp, othello 250wgd	foliar: 2.0-3.0kg/ha, foliar 50g/100l

Fusarium and gibberella ear rots	*Fusarium graminearum* and *Fusarium moniliforme, syn. F. verticillioides*	ears	white mycelium which turn reddish-pink, in Infected kernels develop a cottony growth on the pericarp and germinate on the cob.		**Reduce plant stress** Irrigation or tillage may be of some benefit **Insect control may be helpful** **Planting may timed to reduce stress after pollination**	Copper oxychloride 50percent metallic Cu	AmiCop 50wp	foliar: 2.0-3.0kg/ha
Ergot, horse's tooth	Claviceps gigantean	ears	Infected kernels grow into large fungal structures. Sclerotia are pale colored, soft and slimy,		**Reduce plant stress** Irrigation or tillage **Insect control may be helpful** **Planting may timed to reduce stress after pollination**	Copper oxychloride 50percent metallic Cu	AmiCop 50wp	foliar: 2.0-3.0kg/ha
Botryodiplodia or black kernel rot	*Botryodiplodia theobromae*	ears	Affected ears develop deep black, shiny kernels and husk leaves turn black and be shredded.		**Reduce plant stress** Irrigation or tillage **Insect control may be helpful** **Planting may timed to reduce stress after pollination**	Copper oxychloride 50percent metallic Cu	AmiCop 50wp	foliar: 2.0-3.0kg/ha
		stalk	Abundant grayish black mycelia in rotten areas, confined mostly to the lower internodes above ground					

INSECT NAME	SCIENTIFIC NAME	PART AFFECTED	KEY SYMTOMS	picture	Management			
Seed Corn Maggot	*Hylemya platura*	corn seed	the maggots are present and boring into the seeds and seedlings		**insecticides** should be considered for early planted corn	Chloropyriphos 48percent EC	pyrinex 48 EC	Nest drench: 400ml/5L sq.m.
Seedcorn Beetles	*Agonoderus lecontei*	maize seed	Attack germinating maize seed and destroy the germ. Adults can be seen inside the damaged seed,or in the surrounding.		**use seed treatment containing insecticide**	Chloropyriphos 48percent EC	pyrinex 48 EC	Nest drench: 400ml/5L sq.m.
Wireworms	*Limonius agonus*	maize seedling	damage occurs to germinating seeds and seedling plants during cold. they also leave behind empty seed hulls		**solar baiting techniques** and **application of banded row or in furrow insecticide**	Chloropyriphos 48percent EC	pyrinex 48 EC	Nest drench: 400ml/5L sq.m.

White Grubs	*Phyllophaga* species	maize seedling	Pruning of the root system.		**Remove old plants, weeds before planting. Plough and harrow the field to expose eggs and grubs Proper drainage. Practise crop rotation.** **Use trap crops and / or repellent plants.**	imidacloprid	kohinor 200SL	DRENCH: 25ML/10L/MOULD HILL
Billbugs	*Nicentrites testaceipes*	seeds, roots, seedlings	White specks on leaves, which grow together under severe infestation.		control is warranted if significant number of plants are injured	imidacloprid	kohinor 200SL	DRENCH: 25ML/10L/MOULD HILL
Cutworms	*Agrotis ipsilon, Agrotis spp, Peridroma saucia,* *Chorizagrotis auxiliaries*	maize seedelings	Young cutworms cut maize seedlings at or a little below ground level, make small holes along the initial leaves,		**Inspect crop twice weekly. Chemical control is recommended. Apply pyrethroid sprays in bands over the rows**	chloryfos, imidacloprid	dusban, kohinor 200SL	20-40ML in 10-20 L, DRENCH: 25ML/10L/MOULD HILL

Corn Rootworm	*Diabrotica virgifera, Diabrotica undecimpunctata*	maize roots	Larvae feed on roots and reduce both plant stand and vigor.Root pruning		Chemical control is recommended. Apply pyrethroid sprays in bands over the rows	chloryfos, imidacloprid	dusban, kohinor 200SL	20-40ML in 10-20 L, DRENCH: 25ML/10L/MOULD HILL
African Stalk Borer	*Busseola fusca*	stalk	caterpillars feed on leaves and stems. The caterpillars kill growing points of plant, causing dead-heart		• Clear all remains of the previous crop • Plough deeply, • Plant early, • **Thiodan 3percent G** **• Dipterex 2.5percent G** **• Bulldock 0.05percent G**	Flumbediamide 480gL	Belt 480 SC	Foliar spray:7.5-10mL/100L
Maize Weevil	*Sitophilus zeamais*	maize grain	adult feeding and larvae tunneling within the grains. Ragged holes in individual grains.		insect control using **high temperature, Conserve natural enemies., fumigation**	dichlorvos 1.14kg/L	dichlorvos	10.5mL
Larger Grain Borer	*Prostephasnus truncates*	maize grain	Damage is by both adults and larvae. The beetle feeds on the most nutritious part of the maize kernel that is endosperm.		insect control using **high temperature, Conserve natural enemies., fumigation**	dichlorvos 1.14kg/L	dichlorvos	10.5mL

Arnyworm	*Spodoptera exempta*	leaves	appear suddenly wh numbers of moths into a region. caterpillars feeding leaves.		Chemical control e.g. **dimethoate or similar organophosphorous insecticide, Ambush.** Apply **a band spray along the edge of the field**	Lambdacyhalothr in 5percent EC	Lambdex 5percent EC	foliar spray: 35ml/100l
Leaf Hoppers	*Cicadulina mbila*	leaves	Affected plants can be recognised by their dark green color and thickening of the veins on the underside of the leaves.		inspect crops weekly Chemical control Host-plant resistance:	methomil 90percent SP	methomex 90SP	foliar: 40-50g/100L
The maize aphid or corn leaf aphid	*Rhopalosiphum maidis*	leaves	yellow mottling.		Conserve **natural enemies.**	diazinon 60percent EC	Diazol 60EC	foliar spray 100-150mL/100L
Termites	*Microtermes spp., Macrotermes spp., Allodontermes spp., and Odontotermes spp*	seedlings	Total defoliation o seedlings. damaged plants lo completely destro termites		**Dusban (Chloryrifos).** Other chemicals include **terminator, dusban , pyrinex, troban, endosulphan, malataf. Regent 3-G (Fipronil):**	chloryfos, imidacloprid	dusban, kohinor 200SL	20-40ML in 10-20 L, DRENCH: 25ML/10L/MOULD HILL

Angoumois grain moth	*Sitotroga cerealella*	grain	The larvae of Angoumois grain moth penetrate and feed inside maize grain.		**practise store hygiene. Keep temperature, humidity low . Prevent pest entry by sealing the store. Inspect and remove any infested maize**	dichlorvos 1.14kg/L	dichlorvo s	5.3ml/100L
Chafers	*Macrodactylus* spp	maize leaves, silks, and tassels	Beetles damage maize leaves, silks, and tassels. Pruning of the silks can affect seed set.		Plough and harrow the field to expose eggs and grubs Ensure proper drainage. Practise crop rotation. Use trap / repellent plants.	imidacloprid 20percent SL	kohinor 200SL	DRENCH: 25ML/10L/M OULD HILL
Spider mites	*Tetranychus spp. and Olygonichus spp*	maize plant	The presence of small, faint yellow blotches on the lower leaves Colonies of mites.		**Conserve natural enemies. Predatory mites and anthocorid bugs usually control spider mites**	dicofol210g/L+te tradifon 75g/L	acarin T	foliar spray: 150-200mL/100L

Corn Flea Beetle	*Chaetocnema pulicaria*	leaves	Small round holes and scraped or striped areas. Growth is retarded and leaves may wilt		**Conserve natural enemies. Predatory mites and anthocorid bugs usually control spider mites**	Beauveria bassiana (GHA stain)	Botanigu arg ES	Foliar spray 100-200 ml/100L
NUTRIENT DEFICIENCIES								
Nitrogen (N) Deficiencie s	Under-application of N fertilizer needs Underestimation of N release in manure Leaching of nitrate (rainfall/irrigation)	Maize plant	Yellow coloration in shaped p Pattern progresses fro end to leaf Pattern progresses lower to upper leaves		Appropriate fertilizer N application Analyze manure for N content Apply irrigation level appropriate for soil			

Phosphorous (P) Deficiencies	Under application of P fertilizer needs Cooler/wetter weather (environmental) Planted P inefficient hybrids Inherited tendency of some hybrids	maize plant	Purple coloration of lower leaves		Apply fertilizer P as a 'starter' application Avoid earliest planting dates Plant P efficient hybrids			
Potassium (K) Deficiencies	Under-application of K fertilizer needs Cooler/wetter weather (environmental) Planted K inefficient hybrids	maize plant	Yellow and coloration of leaf margins. Occurs first on lower May progress to leaves		Apply appropriate fertilizer K rate Plant K efficient hybrids			

Sulfur (S) Deficiencies	under-application of S fertilizer needs. reduced mineralization of organic -S to sulfate-S because of reduced soil temperatures or lower soil organic matter levels: Fields with eroded knolls and hillsides have lower organic matter than rest of the field Mineralization of organic-S to sulfate-S in fields under no-till cultivation is reduced compared to cultivated fields	maize plant	Yellow coloration in a striping or interveinal chlorosis pattern Generally found in younger leaves		Apply appropriate fertilizer S levels. Apply fertilizer in sulfate form as ammonium sulfate or ammonium thiosulfate .			
Zinc (Zn) Deficiencies	Under-application of Zn fertilizer needs Soil has high pH (>7.5)	maize plant	Yellow coloration in broad bands, Occurs in upper leaves, Occurs in leaf middle, may progress outward		Apply appropriate fertilizer Zn needs as starter fertilizer Avoid planting in very high pH soils			

Iron deficiency	under application of iron related fertilizers	maize plant	Symptoms are prominent interveinal chlorosis or necrosis; veins are prominent over length of leaf		Apply appropriate fertilizer iron needs as starter fertilizer (Iron-Chelates are recommended.			
Magnesium deficiency	under application of magnesium related fertilizers	maize plant	Green-yellow plants dark yellow interveina chlorosis advancing to rust-necrosis		Foliar applications Commercial Mg products Epsom salt solution Apply appropriate fertilizer magnesium			

Table 3.4, 4.4 and 4.5 presents results of the study showing the information content considered satisfactory by extension officers and farmers. The study findings indicated that farmers and the extension officers considered diagnostic information satisfactory only when the content includes the following; the name of the disease or pest; the scientific name of the diseases or pest; the symptoms; the management options; the chemicals to be applied; how to apply the curative measures and where to buy the drugs/chemicals. This information served as the database content.

Table 3.2, 3.3, 4.2, and 4.3 showed the various sources of diagnostic information used by extension officers and farmers. The respondents indicated that, some of their reliable information sources were journals, seminars, and their own knowledge.. Farmers on the other hand, indicated their study that their sources of diagnostics information as extension officers, radio, agro-vets and mobile phone. All (100percent) the extension officers received diagnostics information from seminars organized by the Government. Training in seminars was based on published research work. Fifty percent (50percent) of the extension officers also obtained the diagnostic information from journals. Seventy eight percent (77.8percent) supported the diagnostic work from their knowledge which they learnt in college and universities s. Learning at universities and colleges is informed by research publications. In addition, there is strong positive correlation between journals and seminars, seminars and own knowledge, and own knowledge and Journals. On the other hand 56.7percent of farmers obtained diagnostic information from extension officers, 55.6 percent from radio and 47.8percent from Agro-vet shops. The use of mobile phones short messages and mobile application is seen to be making gains at 10percent and 1.1percent respectively.

Extension officers largely relied on information obtained from published work. This information was used to guide the database design and content. Data that was considered satisfactory by farmers and extension officers informed the data base regarding diseases and pests to be collected. Consequently the data collected informed the database structural and the architectural designs. The various information sources which led to the conclusion of published research work and journals as the credible diagnostic information source, informed the reliable information source and the mandatory inclusion of system manager whose work is to collect the new information on Maize diseases and pest and their management options and continuously update in the database.

5.6.1 Database Design

With the data above, a database was designed as presented in figure 5.1. normalization of the data above led to the need to generate crop table, language crop table, language curative table, language new table, crop category table, language table, curative measures table, language preventive table, prevention category table, preventive measures table, language prevention category, and symptoms table. Primary and foreign key of each table was also identified and relationships established as shown.

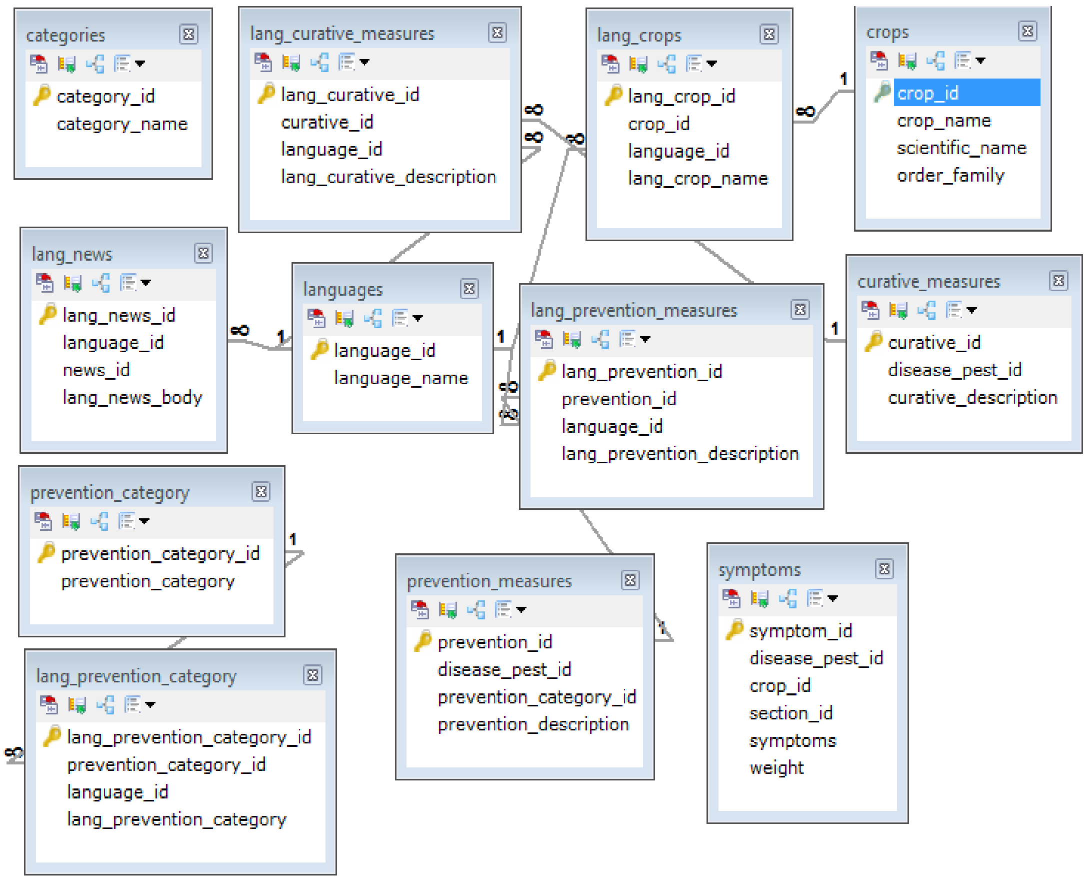


Figure 5.1: Database schema

Figure 5.2 present the database design.

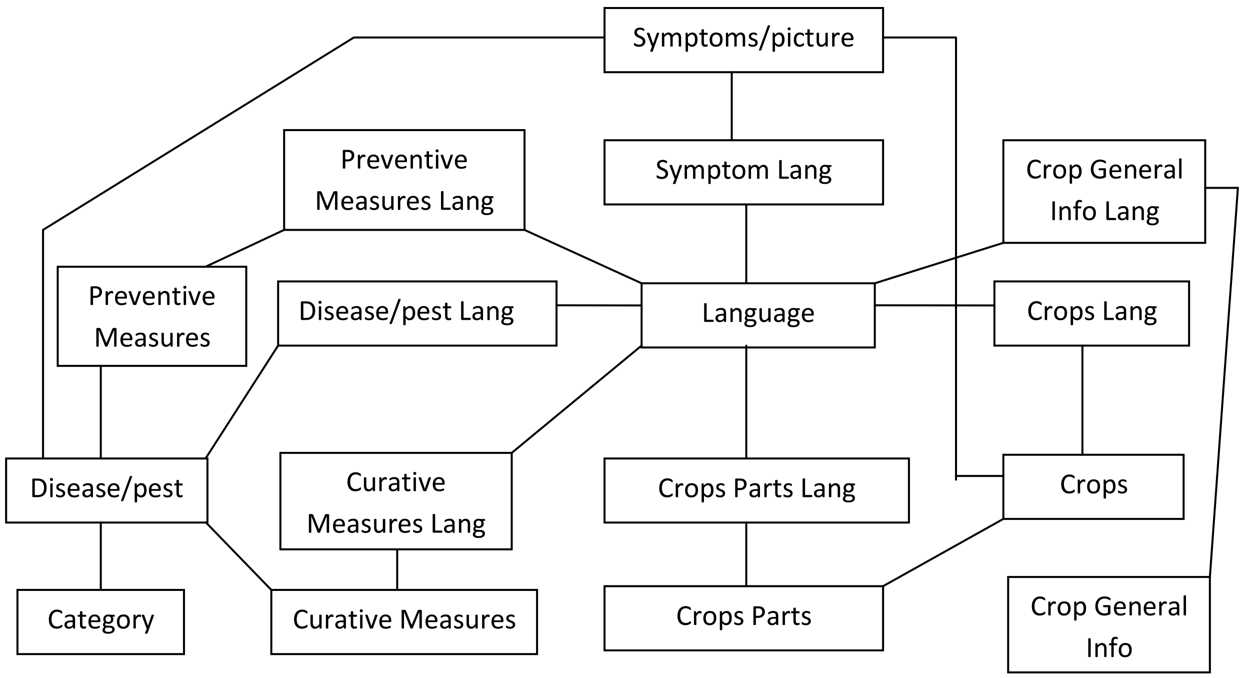
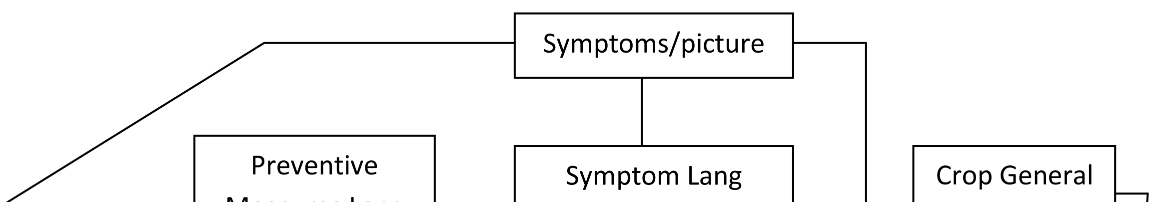


Figure 5.2: Database design diagram

Figure 5.3 presents the relational databased for the system. PK is used to Identify primary keys. FK is used to identify foreign keys. The arrows shows how the tables are related and connected.



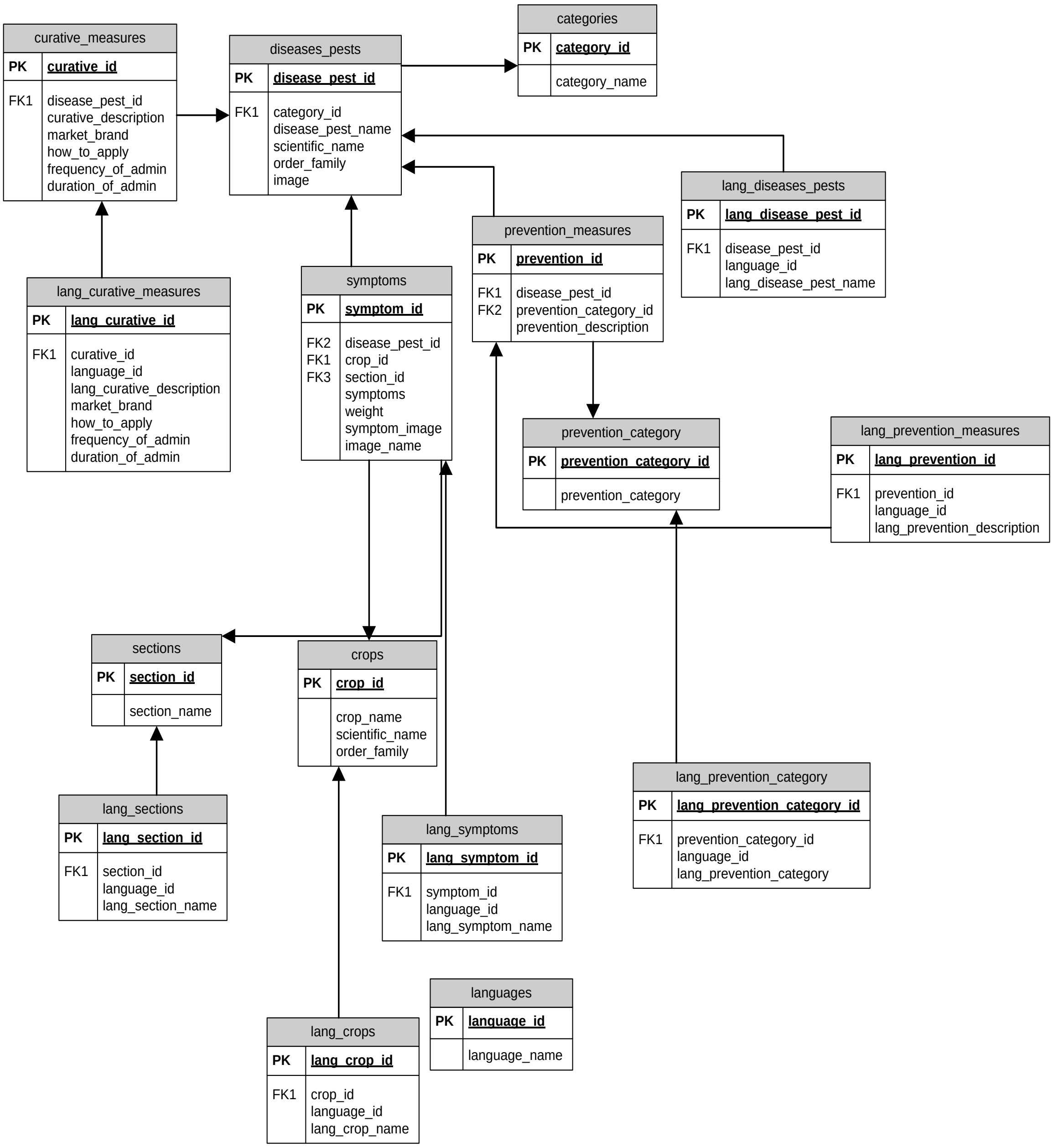


Figure 5.3: Database correlation table diagram and structure

Figure 5.4 presents the type of relationship between tables. Between curative measure table and langage curative measure table, the relationship is one to many and the vice verser is optional many to one. The relationship between disease pests table and curative measure table is one to many and the vise verser is optional many to one. These is the same to the rest of the relationships between the related tables.

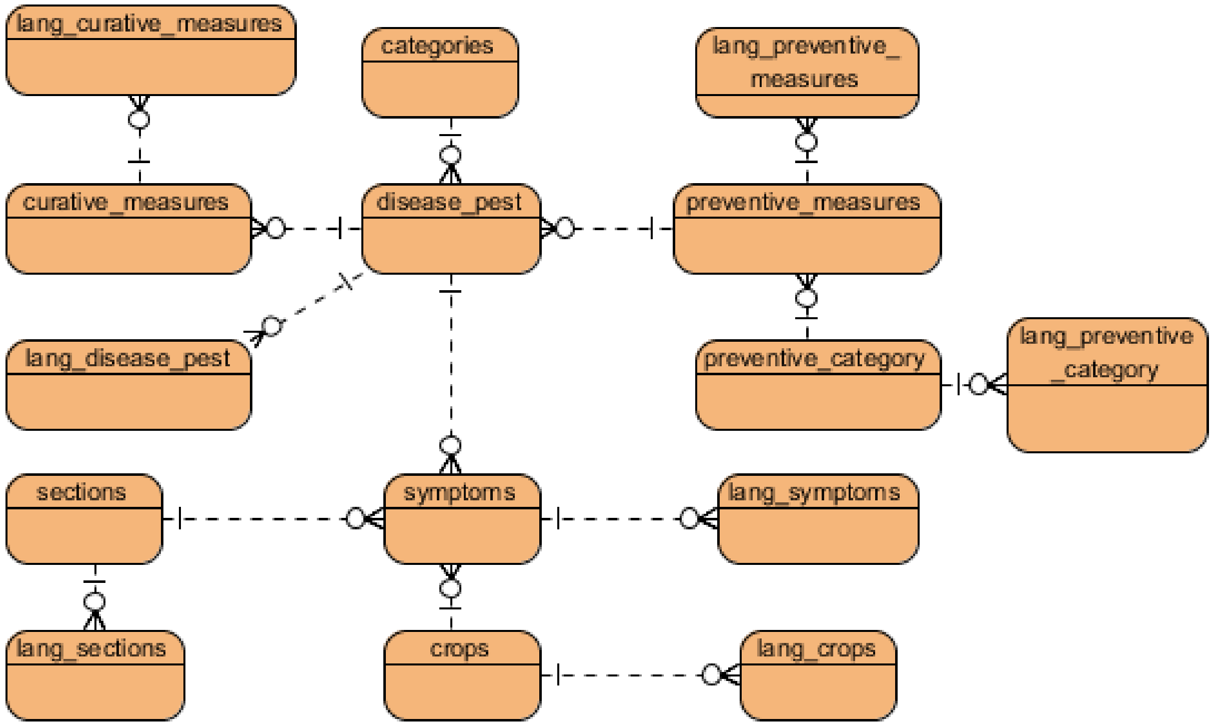


Figure 5.4: Entity relationship Diagram

5.6.2 Database Implementation tool requirements

For the implementation of the designed database, mySQL development language, was used.

CHAPTER SIX

6.0 MODELING OF THE ARTIFICIAL INTELIGENT SYSTEM

6.1 Abstract

Diagnostics of crops pests and diseases is one of the major roles of extension officer. It always involves extension officers going to visit the farms, viewing the symptoms on the crops and from their knowledge of pests and diseases, identifying the specific disease. The extension officer then proceeds to prescribe curative measures to the farmers for the plan based on their knowledge of existing management option. This service has however been hindered by under staffing of extension officer, low budgetary allocation to the agricultural sector, poor road infrastructure among other. Because of these challenges, there is always more often delay or some time complete failure in the delivery of the diagnostics services to farmers which eventually result into loose of crop productivity. With the advances made in ICT in Kenya and the development of several artificial intelligent system which can perform like humans on decision making, it was necessary to rethink the delivery of these services to the farmers in a more speedy, efficient and cost effective manner.

A study was done to establish a module which can drive an Artificial Intelligent System for Agricultural Diagnostics. The study involved a review of the modules of already existing system for diagnostics in both agriculture and human medicine. Some of the systems reviewed included Rice-Crop Doctor, Cattle Disease Diagnostic System (CaDDiS), Agricultural Pest Diagnosis Using Imaging Technologies, Mobile Interfaced Crop Diagnosis Expert System (MICDES), Computer assisted Medical diagnostic systems (CAMD) and Computer Aided Diagnostics (CAD) in Medical Imaging.

Given the user requirements in chapter 3&4 and the database in chapter 5 MICDES module was found to meet the output required. MOCDES module was adopted wholly without any alterations

Key Words: Diagnostics, Artificial intelligent system, modeling.

6.2 Introduction

A comprehensive farmer and extension officer requirements and the electronic database for maize diseases and their management provided by research work in chapter 3, 4 and 5, provides satisfactory information for the artificial intelligent system modeling.

An artificial intelligent is an application which contains the knowledge of a human expert about solving problems in a bounded environment. Such applications have been developed such as manufacturing, medicine, business procedures or engineering.

The most important goals of an expert system are:

- To conserve the knowledge of human experts.
- To provide help to laymen and experts in solving problems.
- To make information readily available that is difficult to recall.

6.2.1 Major Components of Artificial intelligent systems

An artificial intelligent system consists of three major modules:

- The knowledge base
- The inference engine
- Working memory

This portioning is deduced from how human expert problem solving works.

Knowledge Base

The highly specialized knowledge of the problem area is located in the knowledgebase. This module contains problem facts, rules, concepts and relationships. The first step to build the knowledge base is to gather the knowledge from human experts. After this step, the knowledge must be coded in a form which is useful for automatic processing. Several techniques of knowledge representation are available including a rule based representation and case based representation.

Working Memory

The working memory contains the facts about a problem that are collected during one consultation of the artificial intelligent system. When a new problem has to be solved, the user enters information about the problem in the working memory. The artificial intelligent system then uses this information together with the facts in the knowledge base to infer new facts. The content of the working memory can also consist of facts that have been collected from external storage like databases, spreadsheets, or sensors, beside the information that is taken from knowledge base.

Inference Engine

The reasoning of the expert is molded in the knowledge processor, usually named the inference engine. The engine uses knowledge base as the source of information for reasoning. Together with the other available information to draw conclusions and or give recommendations as to how specific problem can be solved.

Another task for the inference engine is to reason with uncertain data. The certainty associated with a value is usually described by a numeric value, and various mathematical rules are employed to derive the joint confidence across sets of values.

In this section the focus is given on the previously developed artificial intelligent systems which are used to disseminate information and SMS based systems.

6.2.2 Statement of the Problem

Knowledge on maize diseases and pests and related management options exists in an electronic database as developed in Chapter Five. Farmers and extension officers are in dire need of diagnostics service problems as demonstrated in Chapter One. Farmer and extension officer requirement for an ideal artificial intelligent system for diagnostics and management of maize disease has been documented in Chapter Three and Four. However, the module to guide the decision making process of the Artificial intelligent systems is lacking. A study was therefore designed to investigate the existing systems and develop a module to drive the decision process from the frameworks of the existing modules.

6.2.3 Justification of study

Artificial intelligent systems are expected to make decisions similar to human beings; given a knowledge base, inference engine and working memory as developed and reported in the previous chapter . The working memory and the knowledge base for this study exist and to complete the artificial intelligent system, an inference engine is required.

6.2.4 Objective

To formulate an artificial intelligent model for diagnosis and management of pests and diseases of Maize in Kenya

6.2.5 Research Question

What are the combination of models which will drive the artificial intelligent system for maize pest identification, disease diagnosis and management?

6.3 Literature review

Expert systems are artificial intelligence (AI) tools that capture the expertise of knowledge workers and provide advice to (usually) non-experts in a given domain. Thus, artificial intelligent systems constitute a subset of the class of AI systems primarily concerned with transferring knowledge from experts to novices. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

Knowledge representation systems

Knowledge representation systems, also called artificial intelligent systems, are computerized models that capture the knowledge of one or more human experts and store it in the framework that is most appropriately suited to the reasoning processes that the experts use in their problem-solving behavior. Such systems are created by a specialized systems analyst called a knowledge engineer, whose task is to interview the expert and/or observe his problem-solving behavior, then determine the most appropriate form(s) of knowledge representation to model the expert's problem-solving techniques. This process, called knowledge acquisition, is perhaps the most difficult and time-consuming aspect of artificial intelligent systems development. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

Knowledge acquisition requires both technical and people skills on the part of the knowledge engineer. The engineer must establish rapport with the domain expert, maintain a productive relationship during the interviewing process, and recognize the required mapping from the expert's explanations to the appropriate knowledge representation. The knowledge engineer then encodes the expert's knowledge into a knowledge base, which is a repository of the expert's knowledge in a particular representational structure. Some of the most common knowledge representations are described below. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

In addition to the knowledge base, an artificial intelligent system includes an automated reasoning mechanism called an inference engine that performs calculations and/or logical processes to produce the results of a particular problem-solving session. The explanation facility of an artificial intelligent system provides the user with an explanation of the reasoning process that was used to achieve the conclusion or recommendation. Each knowledge representation has a corresponding inference technique. Three very common knowledge representations are rule-based systems, frame-based systems, and case-based systems. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

Uncertainty in artificial intelligence

The types of problems that AI systems try to solve are often fraught with uncertainties. Sometimes experts are uncertain about the conclusions they may draw based on the facts that are presented to them. In addition, the facts themselves may not be clear-cut; they may be in error, incomplete, or ambiguous. Thus, AI systems must have the ability to reason and draw some inference even in the face of such uncertainties (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am). AI systems do this in many ways. Two common approaches are described below.

Rules with confidence factors

This approach to uncertainty combines probability with logic. It enhances rule-based systems with probability-like numbers that represent the confidence in either a fact or an inferred conclusion. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

The inference process propagates the uncertainties through to the conclusions, so that the artificial intelligent system tells the user not only what its recommendation is, but also the level of confidence in the recommendation. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

An artificial intelligent system using rules was found in the Department of Veterans Affairs within their OneVA initiative in the United stated of America, which seeks to improve service by implementing improved information technology. A component of this initiative was the creation of an "artificial intelligent system for the determination of potential benefits." This artificial intelligent system utilizes a rule-based approach that analyzes customer data to determine proper eligibility levels. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

Fuzzy logic systems

Fuzzy logic deals with linguistic ambiguity by mapping precise values (e.g., price, temperature, age in years) onto imprecise concepts (e.g., expensive, cold, young) via a membership function. The imprecise concept is called a fuzzy set, and the membership function measures the degree to which a precise value belongs in the fuzzy set. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

Fuzzy logic systems are used in many applications. They are commonly embedded in control systems, such as regulating automatic braking systems in cars and auto focusing in cameras. (http://www.referenceforbusiness.com/management/Em-Exp/Expert-Systems.htm, accessed on 27/8/2015 at 11:52am)

“Hwang et al (2001) noted that Cognitive compatibility plays an important role in the development of the human–computer interface. A good user interface will lead to better user/artificial intelligent system interaction and task performance. In his study, he examined what and how cognitive types affect problem-solving and analyzed the theoretical development of the relationship between human cognition and the use of intelligent machines in the domain of maintenance. The implementation of the knowledge acquisition (KA) presented the development process of the maintenance protocol which derived from using ICAM Definition0 (IDEF0) and Data Flow Diagram (DFD). From the maintenance process modeling, the formal representation of what the user does with the resulting interface can be defined. The knowledge base of the system was represented by a fault decision tree diagram, and was incorporated to communicate between the maintainers and the computer. Furthermore, they also evaluated and compared the effectiveness of artificial intelligent system interface with the traditional maintenance handbook. As a case study, a fault recovery artificial intelligent system for the Maintenance Department of the diesel engine bus system of Taipei City had been developed. Findings of the study showed important implications in artificial intelligent system interface design, including the specific features of changeability, traceability, plenitude, and qualitative description in this maintenance area" (Kuo *et al.*, 2001). This is similar to this study in that it considered the design of the user interface as a factor to technology user acceptance and uptake. This study also considered the user interface design as a factor for user acceptance. In this chapter, the research work focused on modeling the user interface based on the user requirement gathered in Chapter Three and Four.

Related Agricultural Artificial intelligent systems

6.5.1 Rice-Crop Doctor

National Institute of Agricultural Extension Management (MANAGE) has developed an artificial intelligent system to diagnose pests and diseases for rice crop and suggest preventive/curative measures. The rice crop doctor illustrates the use of expert-systems broadly in agriculture and rice production in particular .The system operates through development of a prototype, taking into consideration a few major pests and diseases and some deficiency problems limiting rice yield. Several diseases and pests were included in the system for identification and suggesting preventive and curative measures. The diseases included rice blast, brown spots, sheath blight, rice and zinc deficiency disease. The pests included are stem borers, rice gall midge, brown plant hopper, rice leaf folder, green leaf hopper and Gundhi bug (www.knowledgebank.irri.org/RiceDoctor/Process/Diagnosing_Field_Problems.htm).

Weakness

- Use of expensive equipment
- High level of literacy required for one to use the system hence ii cannot be used in the Kenyan context especially in the rural areas.
- Lacks portability.

6.5.2 Cattle Disease Diagnostic System (CaDDiS)

CaDDiS was designed to serve as a component of a larger decision support system which provide information to decision makers within the African agricultural community on the relative likelihood of a cow having different diseases given that you have observed that it exhibits particular clinical signs. (http://vie.dis.strath.ac.uk/vie/CaDDiS/docs/Home_Page.html (Viewed on 20/06/2015)) The objective of this decision support module was to facilitate better differential diagnosis of tropical diseases. The linking together of different types of techniques such as artificial intelligent systems, mathematical models, statistical analysis systems, hyper textualised media systems and databases to handle different types of information produced a system which had analytical and advisory potential.

CaDDiS is a Windows application consisting of an artificial intelligent system which uses the Bayesian Belief Networks methodology. It was developed using Microsoft Visual C++. The system is parameterized using data collected from 41 veterinary experts. This data was analyzed and converted into a suitable format for use in the belief network. Two different analyses were carried out, giving subtly different parameter values (http://vie.dis.strath.ac.uk/vie/CaDDiS/docs/Home_Page.html (Viewed on 20/06/2015)).

Weakness of CaDDiS

The weakness of the CaDDiS is the fact that it is not user research based and therefore does not have a user friendly interface. Consequently, the low level of literacy among farmers in the rural areas makes it impossible to use the CaDDiS.

6.5.3Agricultural Pest Diagnosis Using Imaging Technologies

The Distance Diagnostics through Digital Imaging project enhances the ability of the University of Georgia Cooperative Extension Service to evaluate and propose solutions for agricultural problems, including plant diseases and pests. The system operates through the use of digital imaging and the World Wide Web.

To reduce sample deterioration and speed of delivery and response, County Extension faculty were provided with and trained to use microscopes with image-capture devices, digital still cameras, and the appropriate computer equipment. The user can utilize this equipment package, known as “agricultural diagnostic imaging stations,” to photograph field symptoms, insects, foliage symptoms, and other identifying agents such as weeds and crop patterns.

Compound microscopes and stereoscopes, fitted with cameras and image-capture devices to facilitate digital imaging, are used for close-up examination of insects, diseased plants, weeds, horticultural material. This technology emphasizes proper pest and host plant sampling.

Once captured, images are uploaded via the World Wide Web (WWW). Once the user has committed the sample to the DDDI system, an electronic mail (e-mail) message is automatically generated and sent to the appropriate diagnostician informing that person that there is a sample available for identification. The diagnostician is designated by the system based upon responses provided by the user in key fields of the submission form. The diagnostician, having received e-mail notification, searches for and retrieves the sample based on the sample number provided in the e-mail. That person then evaluates the sample and formulates a reply.

Equipment

Each DDDI agricultural diagnostic imaging station consists of a computer, a printer, a hand-held digital camera, a compound microscope, a dissecting microscope, a video camera, a still-frame video capture device, and a collection of plant disease diagnostic compendia. The video camera is connected to the computer via the video capture device. This camera is mated with an adapter tube that can easily be moved from one microscope to the other. This allows the user to capture digital images from either source.

The Backend System

The DDDI system was developed on and runs under Microsoft Windows NT Server 4.0 and its WWW services are provided by Microsoft's Internet Information Server 4.0.

Weaknesses of the DDDI System

The system implemented in the Distance Diagnostics through Digital Imaging project requires that users must have access to internet, and email services. However, most farmers in rural areas in Kenya who can benefit from these services may have no access to computers. This system will not benefit them.

The equipment used to implement the above mentioned system is too expensive and complicated. These include computer, printers, a hand-held digital camera, a compound microscope, a dissecting microscope, video camera, for use by farmers in rural community. (Onsumo, 2009)

6.5.4 Mobile Interfaced Crop Diagnosis Expert System (MICDES)

"The MICDES is a prototype case-based reasoning expert system that enables farmers to get assistance with crop diagnostics and other extension services through the web via a dynamic website or through mobile phones. It is also voice enabled to support visually impaired people. Mobile Interfaced Crops Diagnosis Expert System (MICDES) was motivated by the lack of extension services to farmers in the rural areas of Kenya, a situation compounded by poor communication infrastructure. The system conceptualization, design and development were based on contextual inquiry putting the user and culture at the centre. The design, implementation and testing was done based on studies carried out on two rural agricultural self-help groups and schools in Kenya. The diagnoses currently performed are major tropical diseases and pests affecting rice, tomatoes, bananas and sweet potatoes. The system automatically alerts a human expert via SMS in cases where it fails to diagnose a case presented by the user". (Ochieng *et al.*, 2011)

Weakness

Contextual inquiry was based on the system conceptualization, design and development. This, however did not include farmer self efficacy with the various web based and mobile phone information access technologies, perceived ease of use and perceived usefulness.

In addition, it did not take into consideration the farmer information content requirements. The system only considered the professional information requirements.

The system query was based on textual statements. However, some farmers cannot read but have the ability to see. This implies that farmers without the ability to read cannot use the system.

6.5.5 Computer assisted Medical diagnostic systems (CAMD)

Computer assisted diagnostic systems are interactive computer programs designed to assist health professionals with decision making tasks. Several of such systems have been developed and are operational. Literature on some of these systems was reviewed.

6.5.6 Computer Aided Diagnostics (CAD) in Medical Imaging

Computer-aided diagnosis (CAD) has become one of the major research subjects in medical imaging and diagnostic radiology. Kunio (2007) in his article noted that, the motivation and philosophy for early development of CAD schemes were presented together with the current status and future potential of CAD in a picture archiving and communication systems (PACS) environment. With CAD, radiologists use the computer output as a “second opinion” and make the final decisions. CAD is a concept established by taking into account equally the roles of physicians and computers, whereas automated computer diagnosis is a concept based on computer algorithms only. With CAD, the performance by computers does not have to be comparable to or better than that by physicians, but needs to be complementary to that by physicians. In fact, a large number of CAD systems have been employed for assisting physicians in the early detection of breast cancers on mammograms. (Kunio,2007).

This study differs from that by with (Kunio 2007) in the sense that, the users of CAD system are physicians and not patients. Users of the system in this study were farmers and extension officers.. The farmers may be equated to patients in the CAD system case, while researchers and extension officers may be equated to the physician. The CAD used photographic images only, while this study seeks to come up with a system that would use both symptoms and images.

The user requirements were described in the previous chapters of this study. The MECDES is closer to what the farmers would like to have except for the weakness noted during the review. It was therefore recommended that the artificial intelligent system was to be developed based on the MECDES Module.

6.6 Theoretical framework

The system is modeled around Case-Based-Reasoning which is a problem solving paradigm that solves a new problem by remembering a previous similar situation and by reusing information and knowledge of that situation. CBR uses a database of problems to resolve new problems. The database can be built through the knowledge engineering (KE) process or can be collected from previous cases.

CBR doesn't need an explicit model of the problem domain. This makes elicitation – the process of extracting expert knowledge about some unknown quantity of interest only a question of collecting history from earlier cases.

The CBR was originally simulated by research into how people remember information and how they are in turn reminded of information. It was observed that people commonly solve problems by remembering how they solved similar in the past. CBR was developed as a methodology that judges a new problem by comparing it to already classified cases.

CBR retrieval engine retrieves the most similar case(s) from the case base and adapts the retrieved solution to fit the specifics of the target case. Hence to create a CBR system, you only need records of cases of previously solved problems. It is not necessary to know how these problems were solved in the first place.

In a problem solving system, each case would describe a problem and a solution to that problem. The engine solves new problems by adapting relevant cases from the library. CBR can learn from previous experiences. When a problem is solved, the case-based engine can add the problem description and the solution to the case library.

There are two basic kinds of CBR:

1. Interpretive
2. Problem solving

Interpretive CBR involves use of past cases, typically called precedents, to create an analysis and justification for the interpretation of the new case.

Problem solving CBR involves adapting a solution to a past problem, typically a design or plan, to meet the requirements of the new situation.

In the expert system there are widely used in many application areas. There are few type of problem solving paradigm such as control, design, diagnosis, instruction, interpretation, monitoring, planning, prediction, prescription, selection and simulation

MICDES System Previously Developed Using CBR Module

"The back-end architecture

MICDES system back-end is modeled around case-based reasoning which is a problem- solving paradigm that solves a new problem by remembering a previous similar situation and by reusing information and knowledge of that situation. MICDES uses a database of problems to resolve new problems. A case in MICDES is captured as crop name, crop part (i.e. roots, leaves, steam, fruits, etc.), symptom, disease/pest, curative and preventive measures of the corresponding disease.

MICDES retrieval of similar cases is based on nearest neighbor approach. This approach involves the assessment of similarity between stored cases and the new input case, based on matching a weighted sum of features. The biggest problem here is to determine the weights of the features but this problem was fixed by assigning weights of the symptoms based on the frequency of occurrence of a particular symptom. The greater the frequency of the symptom the less weight assigned to it. The limitations of this approach include problems in converging on the correct solution and retrieval times. In general the use of this method leads to the retrieval time increasing linearly with the number of cases. Therefore, this approach is more effective when the case base is relatively small. Several CBR implementation have used this method to retrieve matching cases, for example: the Compaq SMART system (Acorn and Walden, 1992) for a customer product support help desk, and ANON (Owens, 1993) for situation assessment in plan failure.

A typical algorithm for calculating nearest neighbor matching is the one used by Cognitive Systems Remind software reported in Kolodner (1993) where *w* is the importance weighting of a feature (or slot), *sim* is the similarity function, and *fI* and *fR* are the values for feature *i* in the input and retrieved cases respectively.

A nearest neighbor algorithm is as follows:

$$\frac{\sum_{i=1}^{n} w_i \times sim\left(f_i^I, f_i^R\right)}{\sum_{i=1}^{n} w_i}$$

MICDES consists of four modules:

1 *Retrieve*: During this process, MICDES searches the database to find the most approximate case matching to the current problem presented by the user. The retrieval starts with description and ends when the best matching previous case has been found.

2 *Reuse*: This process includes using the retrieved case and adapting it to the new situation. At the end of this process, the reasoning might propose a solution for each retrieved case, the corresponding strategy used and the results obtained are looked up.

3 *Revise*: When a case generated by the reuse phase is not correct, an opportunity for learning from failure a rises. The case solutions are evaluated via human expert feedback and if successful, learning from the success, otherwise repair the case solution using domain-specific knowledge.

4 *Retain*: This process enables MICDES to learn and create a new solution and a new case that should be added to the case base. It incorporates what is useful to retain from the new problem-solving episode into the existing knowledge. The learning from success or failure of the proposed solution is triggered by the outcome of the evaluation and possible repair. It involves selecting which information from the case to retain, in what form to retain it, how to index the case for later retrieval for similar problems, and how to integrate the new case in the memory structure." (Ochieng *et al.*, 20011)

The CBR models is presented in the figure below

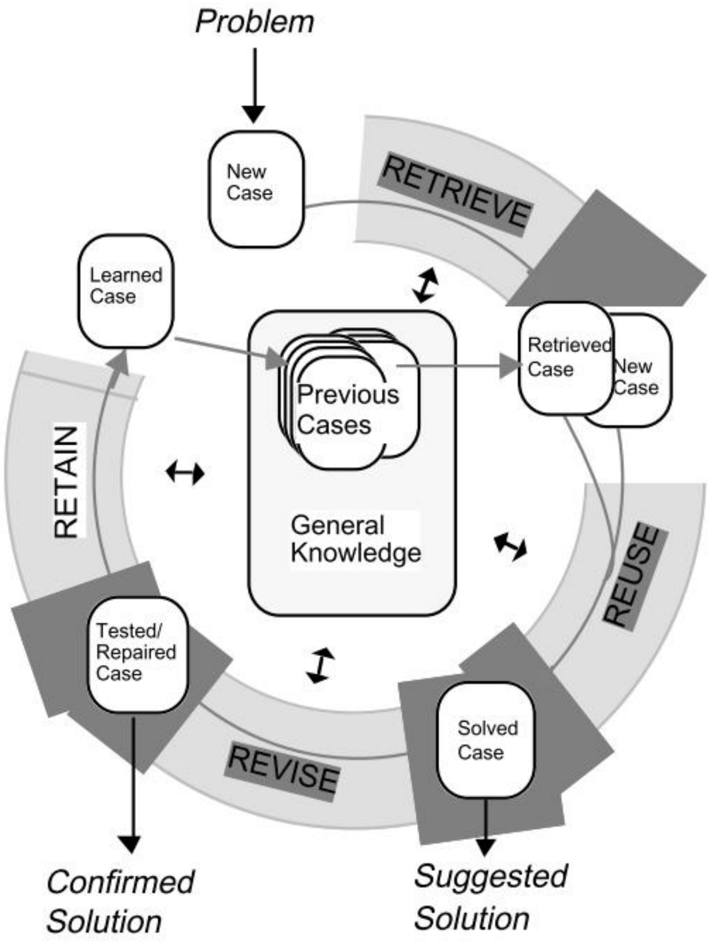


Figure 6.1: CBR Model diagram (Ochieng et al, 2011).

6.4 Methodology

Secondary data was collected on the models of existing system which are closely related to the intended artificial intelligent system. Analysis of the models was done to determine their strengths and weaknesses. The modules were also analysed to ascertain the possibility of each driving the intended artificial intelligent system for diagnosis and management of pests and diseases of maize.

A desktop research study design was used and involved collection of secondary data about on existing systems models. The objectives of the study were to understand and develop a theoretical framework and identify and study related existing systems. The expected outcome was to broaden the scope of perceiving the problem and to identify any deficiencies and to identify algorithms used and their implementation.

6.5 Results and Discussions

System Modeling

Artificial intelligent system for agricultural diagnostics for Maize had been identified as a powerful tool with extensive potential in agriculture. It will be an expert system that is composed of a knowledge base (cases), inference engine, and end user interface (accepting inputs, generating outputs).

The system has one major modules namely Diagnostic system module

Diagnostic System

The Diagnostic System will be divided into two components:

- The backend – Case based reasoning (CBR) system
- The frontend – Interfaces for accessing the backend

Backend (CBR)

Case-based Reasoning means to use previous experience in form of cases to understand and solve new problems. A case-based reasoning remembers former cases similar to the current problem and attempts to modify their solutions to fit for the current case. The underlying idea is the assumption that similar problems have similar solutions. Though this assumption is not always true, it holds for many practical domains.

The processes involved in CBR can be represented by a schematic cycle as shown in the figure below:

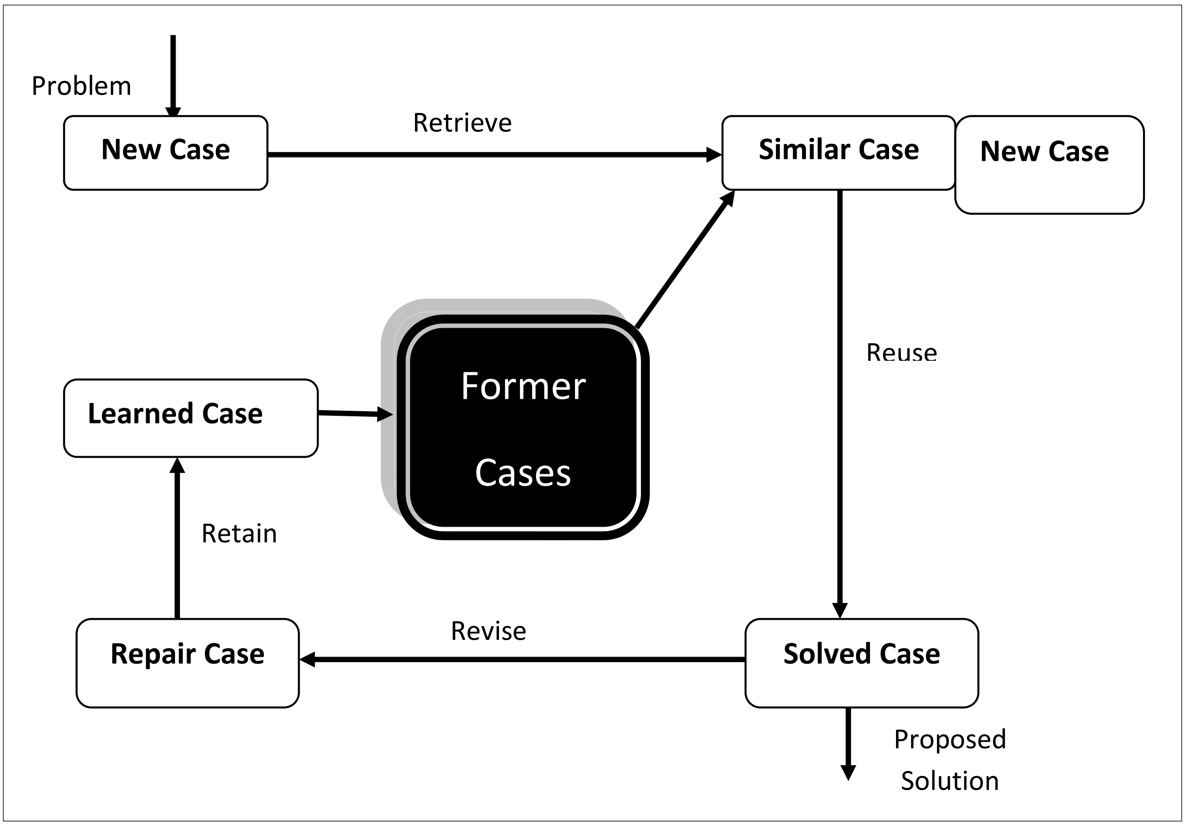


Figure 6.2: Backend Case based reasoning model (Onsumo, 2009).

CBR consist of four modules:

- RETRIEVE
- REUSE
- REVISE
- RETAIN

When a new problem is matched against cases in the case base and one or more similar cases are retrieved. A solution suggested by the matching cases is then reused and tested for success. Unless the retrieved case is a close match the solution will probably have to be revised producing a new case that can be retained and this will be done by the case Manager.

CBR directly addresses the following problems found in rule-based technology.

- CBR does not require an explicit domain model and so elicitation becomes a task of gathering case histories,
- Implementation is reduced to identifying significant features that describe a case, an easier task than creating an explicit model,
- By applying database techniques largely volumes of information can be managed, and

- CBR systems can learn by acquiring new knowledge as cases thus making maintenance easier.

Frontend

The proposed system will provide two modules through which users will interact with it and these include:

- WAP
- Website (response will be both in text format and speech)

Through these interfaces user diversities will be taken care of, making the system more accessible and acceptable to the users.

Website

The system provides a web interface through which users will key in a new problem. If a match to the posted problem is found the proposed solution will be presented in either text format or the text will be channeled to text to speech module which will synthesize the text to speech format. This will to some degree enable the visually impaired users interact with the system. The process is shown in the diagram below:

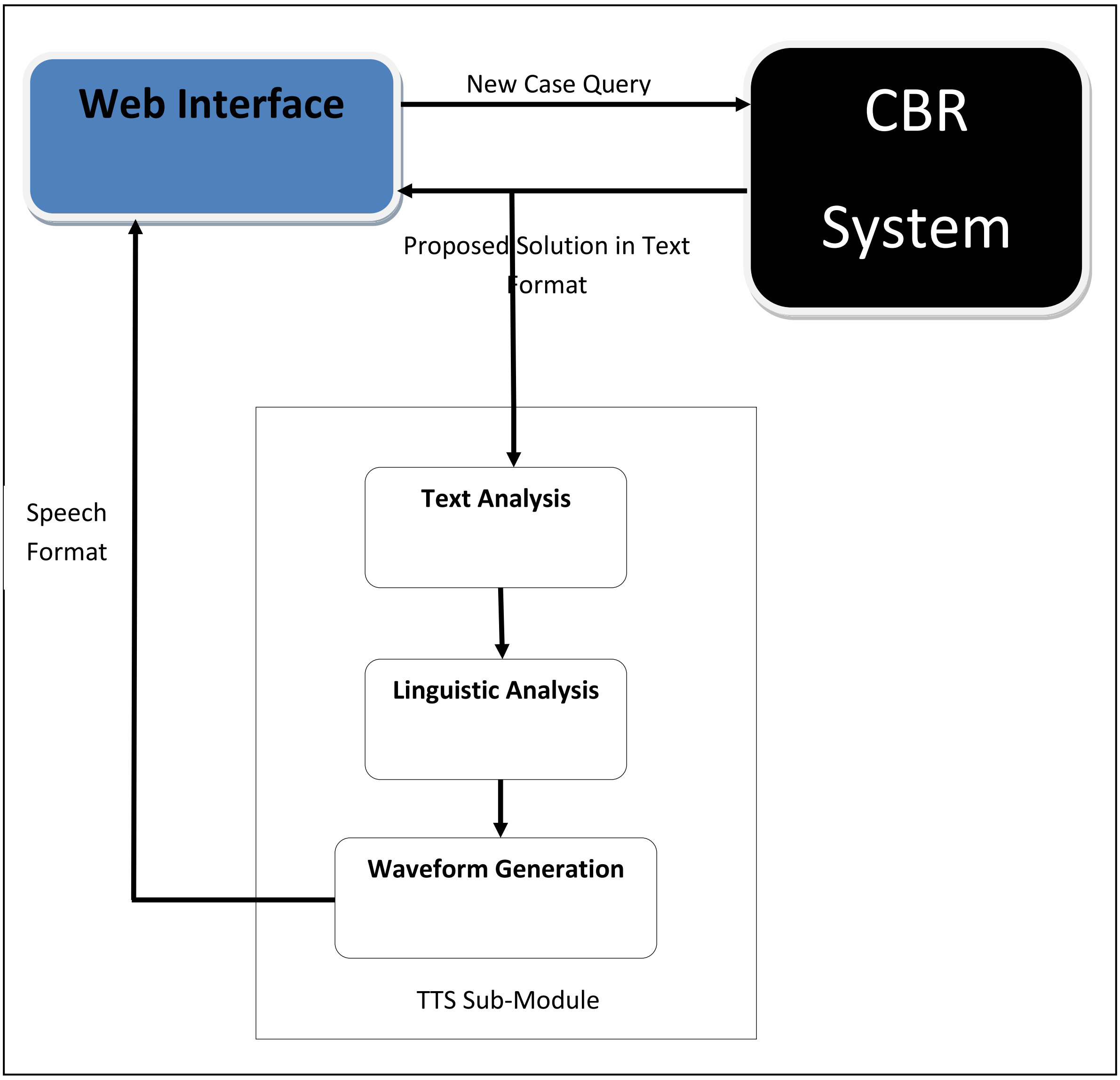


Figure 6.3: Speech to text model diagram (Ochieng et al 2011)

WAP (Wireless Application Protocol)

WAP is the technology which introduces the concept of the Internet as a wireless service platform. By using WAP, user can see Internet content in special text format on mobile phones. The figure below shows the components of WAP architecture and how it is used to access the Diagnostic System. The WAP device (mobile phone or PDA) communicate with the remote server directly or via intermediary proxies and gateways which may belong to mobile network operators or alternatively to service providers. In order to use WAP, users have to activate GPRS service on a mobile phone which supports WAP feature.

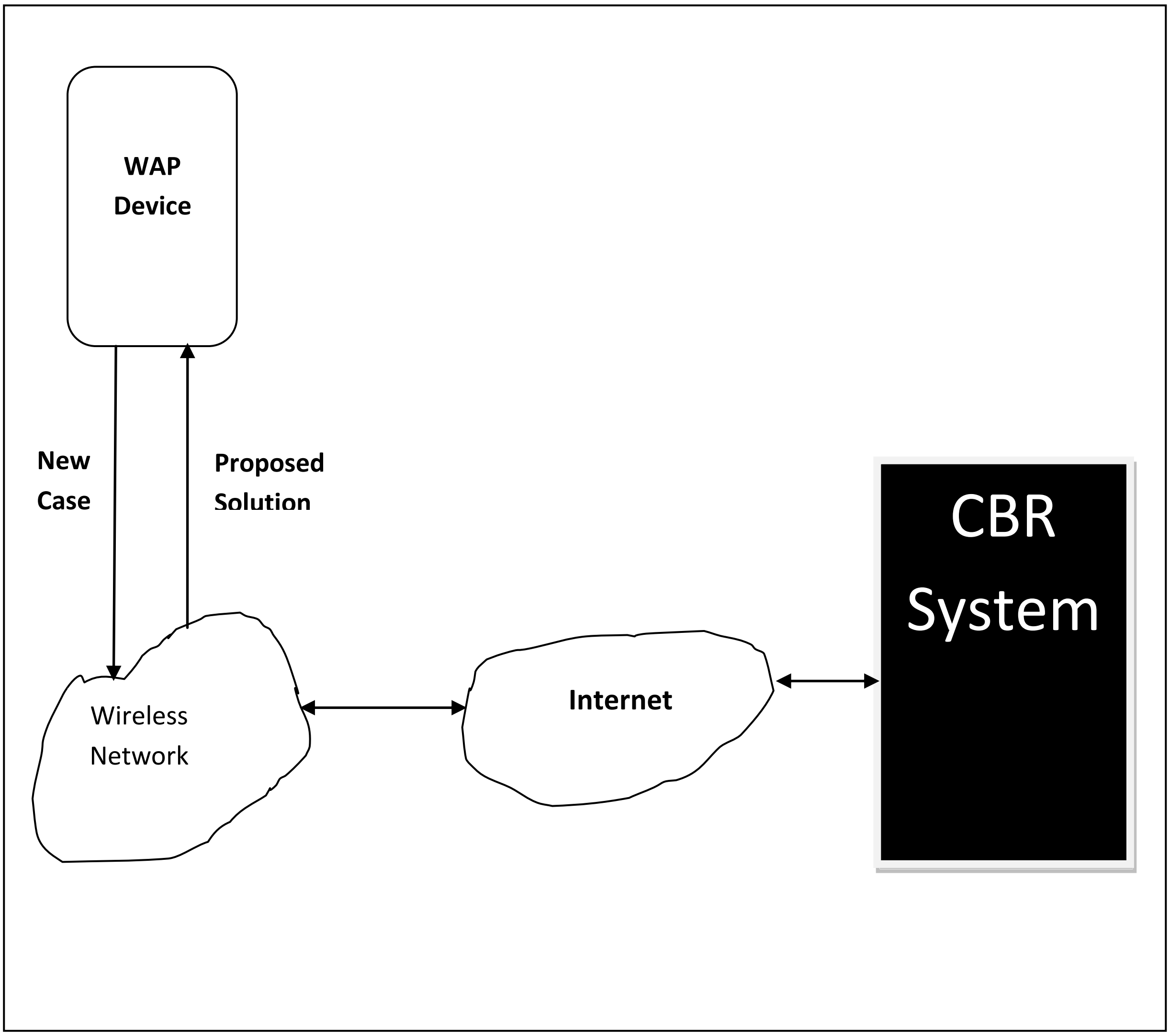


Figure 6.4: WAP model diagram (Onsumo, 2009)

The same module is capable of driving the required system however changes will only be made on the content of the information, ways of access and the format of the information.

CHAPTER SEVEN

7.0 DEVELOPMENT AND IMPLEMENTATION OF THE ARTIFICIAL INTELLIGENT SYSTEM FOR AGRICULTURAL DIAGNOSIS

7.1 Abstract

Artificial intelligent system for agricultural diagnosis, a case study of maize farmers in Uasin Gishu County is carry home expert system which is based on reasoning for diagnosing maize diseases using the previous resolved cases. The system supports multiple languages which include: English, Kiswahili and Kalenjin to make it more acceptable, usable and accessible. The system performs diagnosis of all known maize diseases and pests.

The system is accessible through the mobile devices for example WAP enabled mobile phones and dynamic website which is voice enabled to support the visually impaired people. The system has the ability to learn from the unsolved cases. The system alerts the expert when it fails to diagnose a case via email who then tries to solve the case so that the next time users present the same the system will be able to diagnose.

Artificial intelligent system for agricultural diagnosis, a case study for maize farmers has been implemented using PHP, SQL, HTML, JavaScript, Ajax, C++, ASP and XHTML and uses an open source database.

The realization of the system was through interaction with farmers and extension officers in Uasin Gishu county Kenya through interviews. A validation of the system was conducted to establish the soundness and completeness of the indicated solutions.

Key Words: Diagnosis, artificial intelligent system, Uasin Gishu, Maize, Farmers

7.2 Introduction

Agriculture contributing 24.5percent of the GDP (GoK, 2011) and provides employment to over 70percent of the population in rural areas. . The reforms in agricultural practices to boost production are, therefore, central to economic development.

Improvement in agricultural productivity requires increased allocation of qualified human and technical resources. Such resources will be utilized to enhance crop and animal breeding, production and as well as diagnosis and management of pest and diseases along the agricultural production value chain. This is however not effectively achieved due to the low budgetary allocations to agriculture at a time when the population of farmers are increasing.

A significant milestone in the use of IT as a means of improving the quality of life is evident in the advent of both internet and mobile technologies. The rapid adoption of these technologies, particularly the mobile phones, both in developed and developing nations over the past decade is an obvious sign that technology is impacting on people's lives (Onsumo 2009). With the recent developments in mobile phone technologies, Java 2 Micro-Edition for mobile devices, Python, XML, even Wireless Markup Language (WML), XHTML applications can be developed and deployed into mobile devices and further interfaced to an expert system e.g. via Wireless Application Protocol (WAP). Convergence of these technologies in the Internet and the field of expert systems have contributed in offering new ways of sharing and distributing knowledge.

Mobile phones on the other hand are becoming increasingly cheaper and more accessible in Kenya than Personal Computers (PCs) and the Internet. With a per capita income of $1,200, many Kenyans cannot afford computers, much less reliable Internet access. But Kenya has readily adopted the cell phone. The Communications Commission of Kenya (CCK) estimates over 10 million mobile phone subscribers out a national population of 40 million. There are nearly 100,000 new subscribers each month.

The ICTs such as internet, SMS and WAP have not been fully utilized for innovative and transformative ways to solve some of the problems including inadequate access to accurate and timely information on the pests and diseases affecting their crops. A study was designed with the objective of developing an artificial intelligent system for agricultural diagnostics and management of maize diseases to improve the desermination of information on disease diagnostic and management among farmers, experts and extension service providers.

7.2.1 Statement of the Problem

Agriculture is the backbone of economy in Kenya and over time agricultural production has evolved into a complex business requiring the accumulation and integration of knowledge and information from many diverse sources. Every year, farmers experience heavy losses in maize production due to diseases and pest which affect the crops throughout its lifestyle from planting to post harvest. With the population growth in Kenya and the reduced budgetary allocation to agriculture, the number of extension officer has been on the decline while the population of farmers has been on the increase. Currently the extension officer ratio stands at 1:1500 farmers. In addition, there has been an increase is the operation cost of extension officers fueled by poor road infrastructure among other factor. These challenges have made it impossible to efficiently and effectively deliver diagnostic services. The study therefore seeks to develop a system which will enhance delivery of agricultural diagnostics services to farmers remotely.

Objective

To develop an artificial intelligent systems for maize pests identification, disease diagnostic and management in Kenya

1.7.1 Specific Objectives

a) To provide access to diagnostics information on maize crop to farmers in the rural areas through the use of the mobile devices and a dynamic website.

b) To develop a phone interface for accessing the diagnostic expert system since most farmers have mobile devices.

c) To develop voice response interface to cater for user diversity especially the visually impaired people.

d) To avail the expertise in multiple languages that is understood by maize farmers in Uasin Gishu County.

e) To develop a diagnostic expert system using case- based reasoning to enable farmers have timely information on diseases/pests and their corresponding treatment and control measures that affect maize.

7.2.3 Justification of study

Abundant information on agricultural diagnostics is stored in publications and journals and therefore unavailable. The system will enables farmers to have readily available information about their crop diseases/pests and their corresponding curative and control measures, as the system will be accessed through WAP enabled mobile devices and a website.

With readily available information on crop diseases and their curative and control measures, farmers will be well armed to deal with diseases/pests affecting their crops in a timely manner, which will lead to high production of food. This will in turn increase food security in the country and also reduce Government budget on food importation.

With reduced budgetary allocation to agriculture, the Government will still be able to deliver diagnostics services to farmers efficiently and cost effectively.

7.2.4 Target Audience

The prime audiences of the system are maize farmers and extension officers in the rural areas. The system will facilitate access to diagnostic and management services for solving problems related to pests and diseases affecting maize in Kenya. The Government of Kenya can benefit indirectly in the sense that food production will improve increasing food security in the country, hence reducing the budget for importing food.

7.2.5 Scope of the study

The scope of the study was to develop and implement maize diseases/pests diagnostic system based on case-based reasoning where by previously solved cases are used to solve the current problems. The crop supported by the system is maize.

- The system supports several languages including English, Swahili and Kalenjin:

The system can be accessed through two user interfaces namely:

- Dynamic Website.
- WAP (Wireless Application Protocol).

Finally the system provides a speech module which converts text to speech

7.3 Methodology

Object oriented analysis and design was adapted for the system design.

Object-oriented analysis and design (OODA) is a software engineering approach that models a system as a group of interacting objects. Each object represents some entity of interest in the system being modeled, and is characterized by its class, state (data elements) and behavior.

Object oriented analysis (OOA) applies object modeling techniques to analyze the functional requirements for a system. Object-oriented design (OOD) elaborates the analysis models to produce implementation specifications.

The outcome of object oriented analysis is a description of what the system is functionally required to do, in a form of a conceptual model.

Object oriented design (OOD) transforms the conceptual model produced in object-oriented analysis to take account of the constraints imposed by the architecture and any non-functional requirements. The concepts in the analysis model are mapped onto implementation classes and interfaces. The result is model of the solution domain, a detailed description of how the system is to be built.

7.4 System Features

7.4.1 Case Based Reasoning

1 Capture problems and solutions

This module provides an interface which allows the system manager to key in problems, their corresponding solution and explanation as given by the expert. It also enables the manager to perform administrative tasks for the system.

Inputs

The parameters include: Case description (symptoms, disease names, images of the symptoms), Solutions to the described cases and explanation and locations on where to purchase the prescribed solution.

Operations

a) This module provides the user with an interface to capture each of the inputs specified above.
b) The module validates the captured input.
c) The module provides an interface for deleting the unwanted cases and updating the existing cases and their corresponding solutions.

Outputs

The module displays a message indicating that the status of the operation has been completed.

2 Processing user problems

This module allows users to post problems through two interfaces namely: WAP application and Website application

Inputs

User problem description in a case format.

Operations

a) **Retrieve –** Upon receiving the new case from the user, the case base reasoning searches the database to find the most approximate case to the current problem. The retrieval starts with description and ends when the best matching from previous case handled by the system.
b) **Reuse –** This is where the case based reasoning uses the retrieved case and adapting it to the new situation. The case based reasoning proposes a solution for each retrieved case, the corresponding strategy used and the results obtained are looked up, at the end of the process.
c) **Revise –** In case a case generated by the reuse phase is not correct, an opportunity for learning from failure a rises. The case solutions are evaluated via expert feedback and if successful, learning from the success, otherwise repair the case solution using domain-specific knowledge.
d) **Retain –** This process enables CBR to learn and create a new solution and a new case that should be added to the case base. It incorporates what is useful to retain from the new problem solving episode into the existing knowledge. The learning from success or failure of the proposed solution is triggered by the outcome of the evaluation and possible repair. It involves selecting which information from the case to retain, in what form to retain it, how to index the case for later retrieval from similar problems, and how to integrate the new case in the memory structure.

Output

Depending on the matching case the output will be the corresponding solution of the matched case.

3 Language module

The system supports multiple languages to cater for user diversity hence making it more accessible, usable and acceptable in the Kenyan context. The languages supported include:

- English
- Kiswahili
- Kalenjin

Inputs

The parameters include:

- Preferred language specified above with English being the default language.

Operations

a) The module provides the user with an interface to select the preferred language in a combo box. This makes the input validation easier as opposed to user keying in the preferred language.
b) The module changes the text from the current language to the selected one.

Outputs

The text is converted to the language selected by the user.

7.5.2 Speech synthesis Module

The artificial intelligent system for maize disease diagnostics and management supports the conversion of text to speech. This module comes in handy to visually impaired people which allow them to interact with the system to some degree.

Text processing

Inputs

Well formatted text.

Output

Speech.

Operation

The module captures the text and converts into speech.

7.4.3 Nonfunctional Requirements

Performance Requirements

The artificial intelligent system for maize disease diagnostic and management supports real time processing and communication.

Security Requirements

Access to the artificial intelligent system for maize diagnostic and management is limited to authenticated users whose roles have been defined at the database level.

Software Quality Attributes

Below are key expected software quality attributes of the artificial intelligent system for maize disease diagnostic and management.

Availability

The artificial intelligent system for maize disease diagnostic and management is expected to operate continuously from time of installation.

The artificial intelligent system for maize disease diagnostic and management is expected to run 24 hours a day, 7 days a week, 365.25 days a year and throughout its lifetime.

Reliability

The artificial intelligent system for maize disease diagnostic and management is expected to handle system failures elegantly**.**

Flexibility

The addition of new modules or upgrading of existing sub system should not cause interference with existing modules.

7.5 System Design

In this section, a detailed description of the design process involved in developing the artificial intelligent system for maize disease diagnostic and management is presented.

7.5.1 Use Case Diagram

Use case diagram was used to show the system functions which are performed by the various actors hence depicting the roles of every actors in the system. A use case diagram describes the system’s behavior upon receiving requests which originates from outside of the system. A user case therefore describes “who” can do “what” with the system.. The use case technique is used to capture a system's behavioral requirements by detailing scenario-driven threads through the functional requirements.

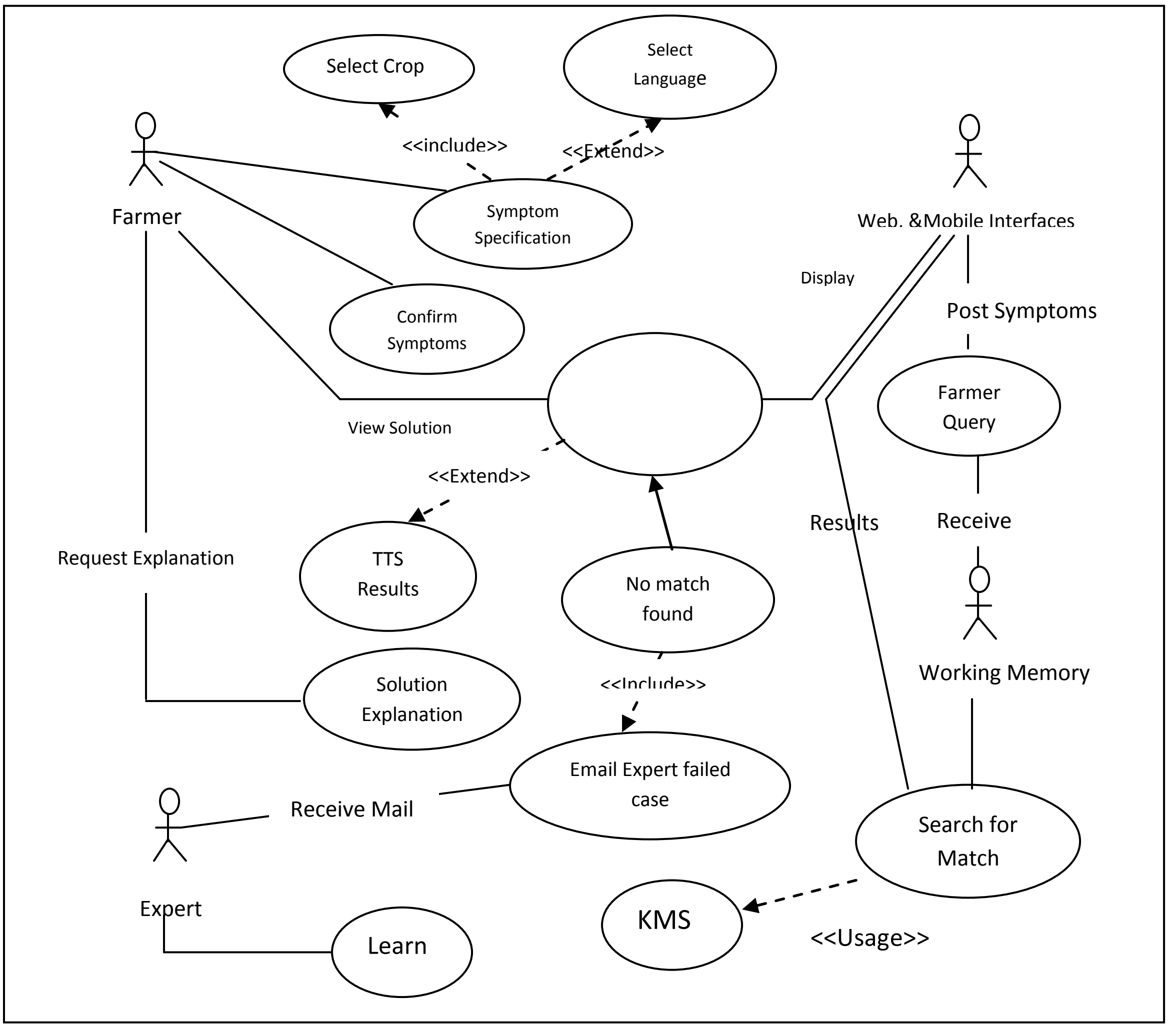


Figure 7.1: User case diagram

7.5.2 Sequence Diagram

Unified Modeling Language (UML) sequence diagrams model the flow of logic within the system in a visual manner, enabling you to document and validate the logic. UML is commonly used for both analysis and design purposes.

Sequence diagrams are typically used to model:

A usage scenario which is a description of a potential way the system will be used. The logic of usage scenario may be part of a use case or perhaps an alternate course.

The logic of methods Sequence diagrams can be used to explore the logic of a complex operation, function, or procedure. One way to think of sequence diagrams, particularly highly detailed diagrams, is as visual object code.

The logic of services A service is an effectively high-level method, often one that can be invoked by a wide variety of clients.

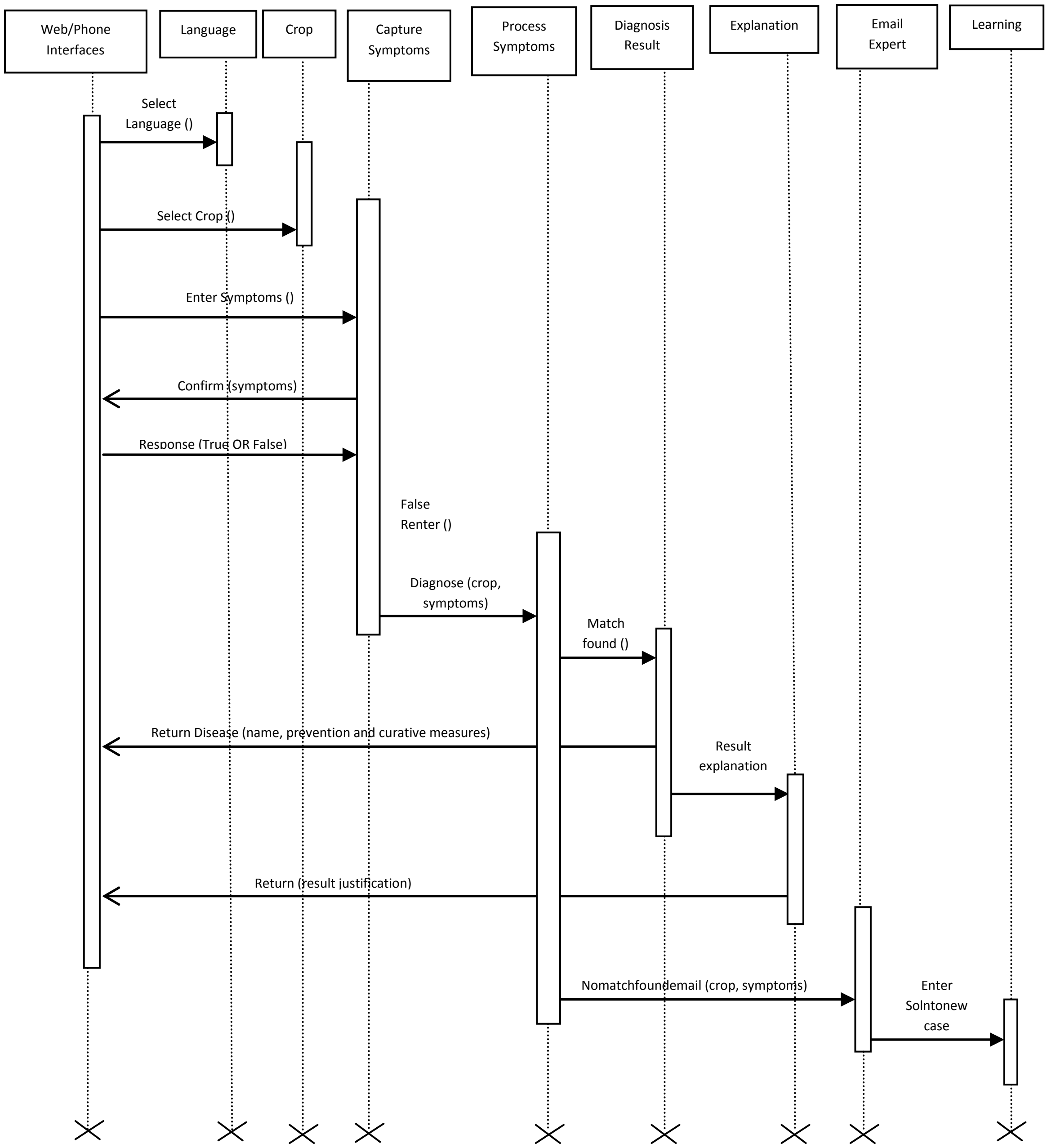


Figure 7.2: Sequence diagram

7.5.3 Component Diagram

The various components in the systems and their various dependencies are shown in the component diagram below. In this study, a component refers to a physical module of a code.

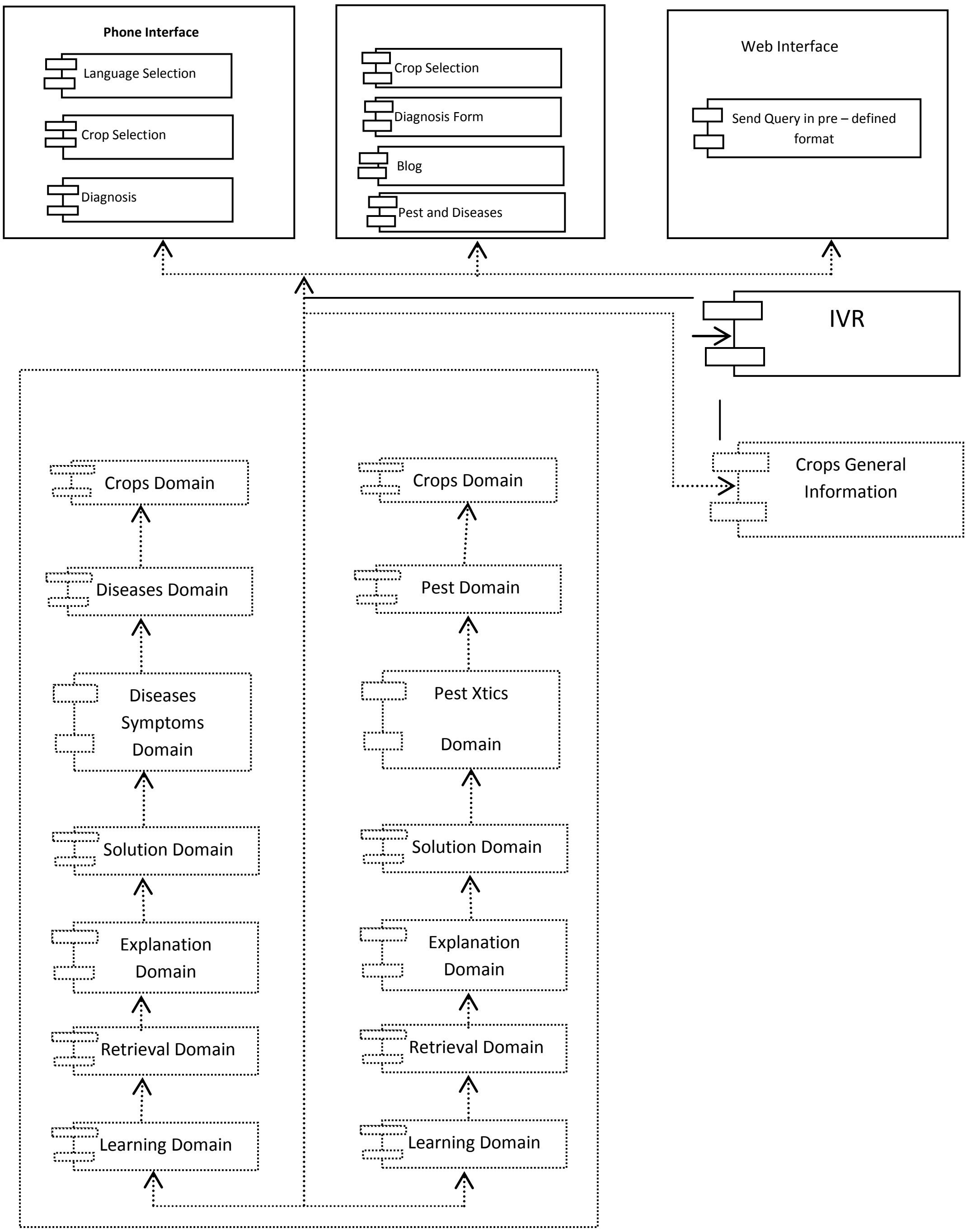


Figure 7.3: Component diagram

7.5.4 Activity Diagram

The description of the sequence of activities with support for both parallel and conditional behavior is provided by the activity diagram below. It shows the state diagram in which most, if not all the states are activity states.

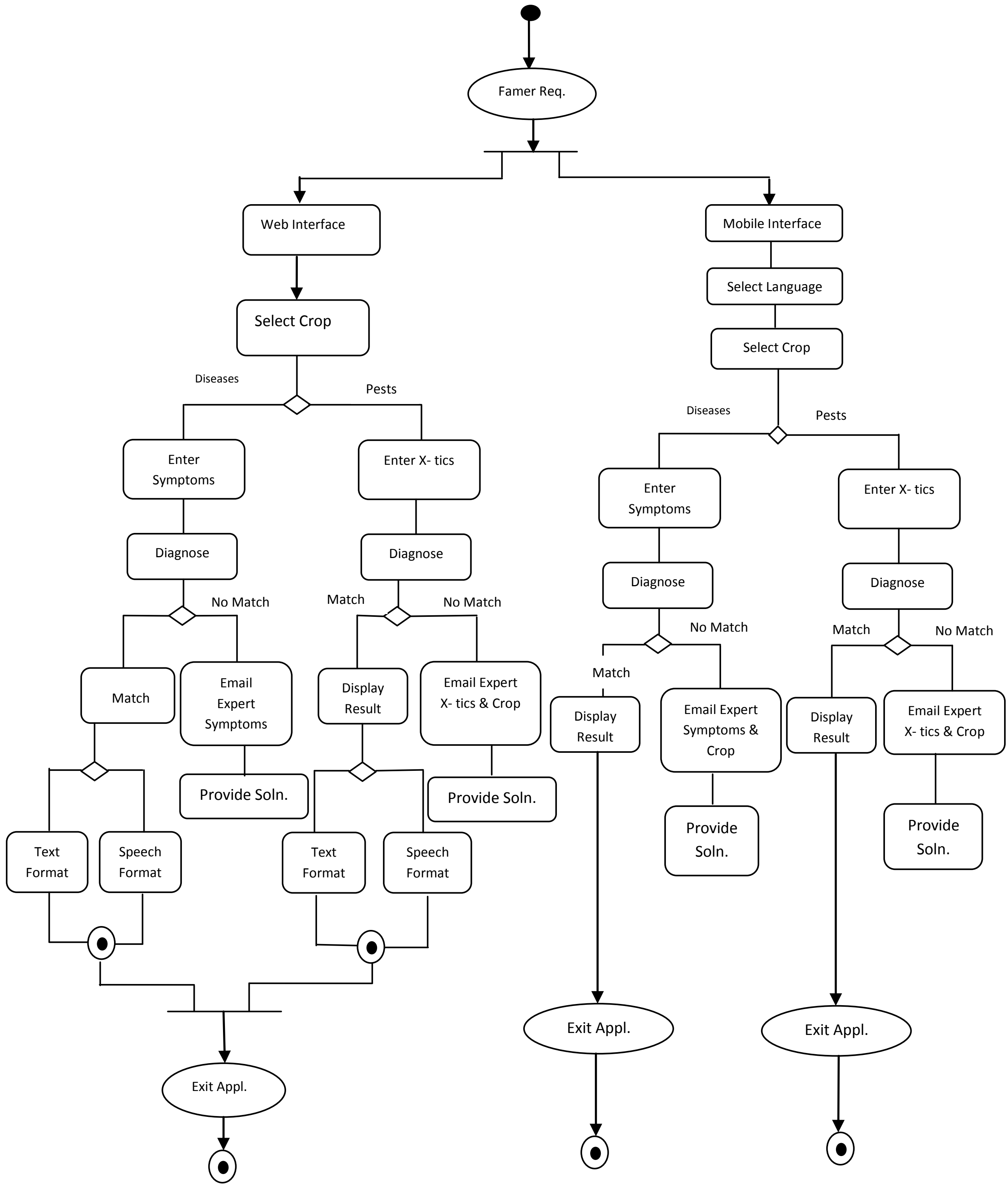


Figure 7.4: Activity diagram

7.5.5 Database Design

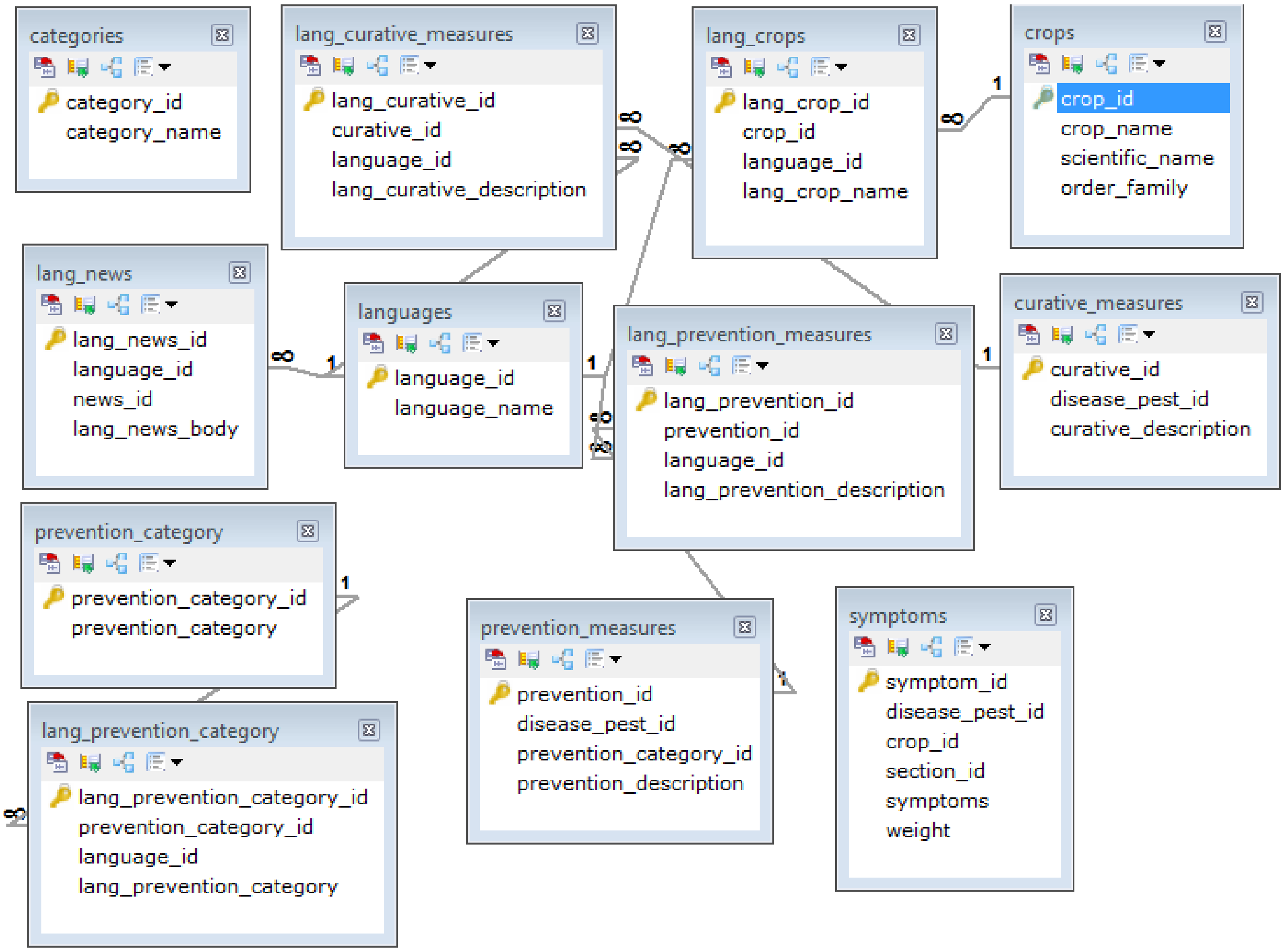


Figure 7.5: Database schema

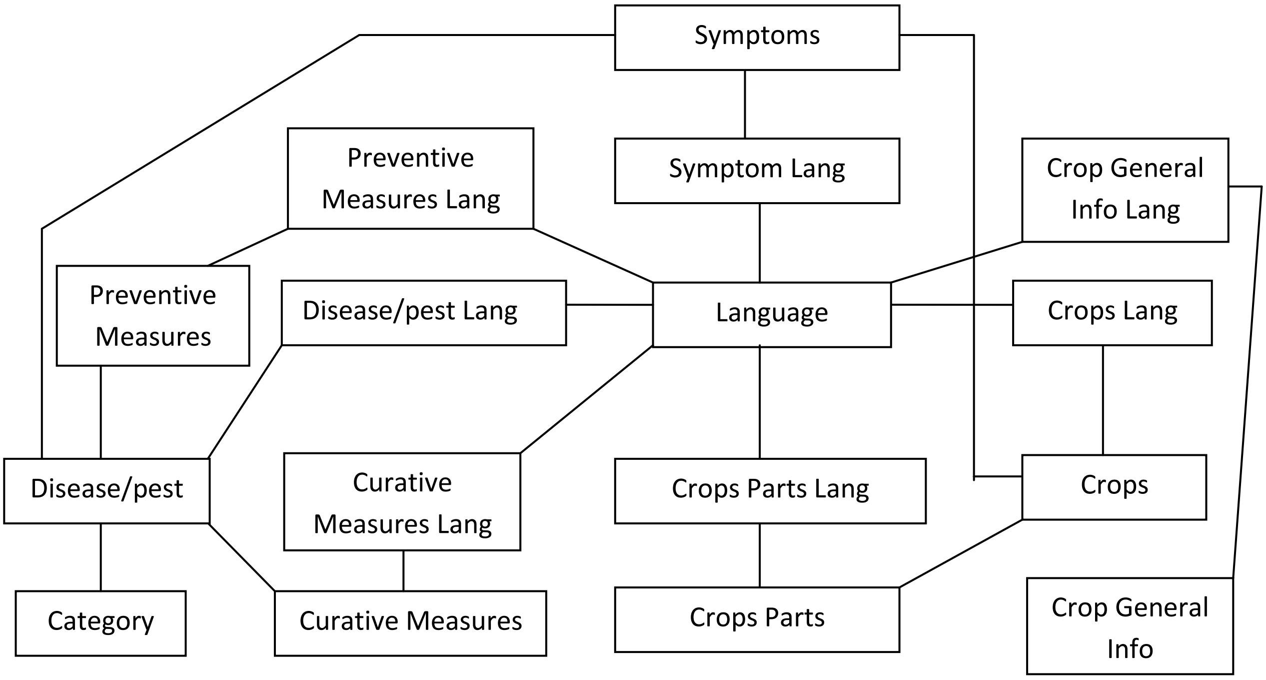


Figure 7.6: Database design diagram

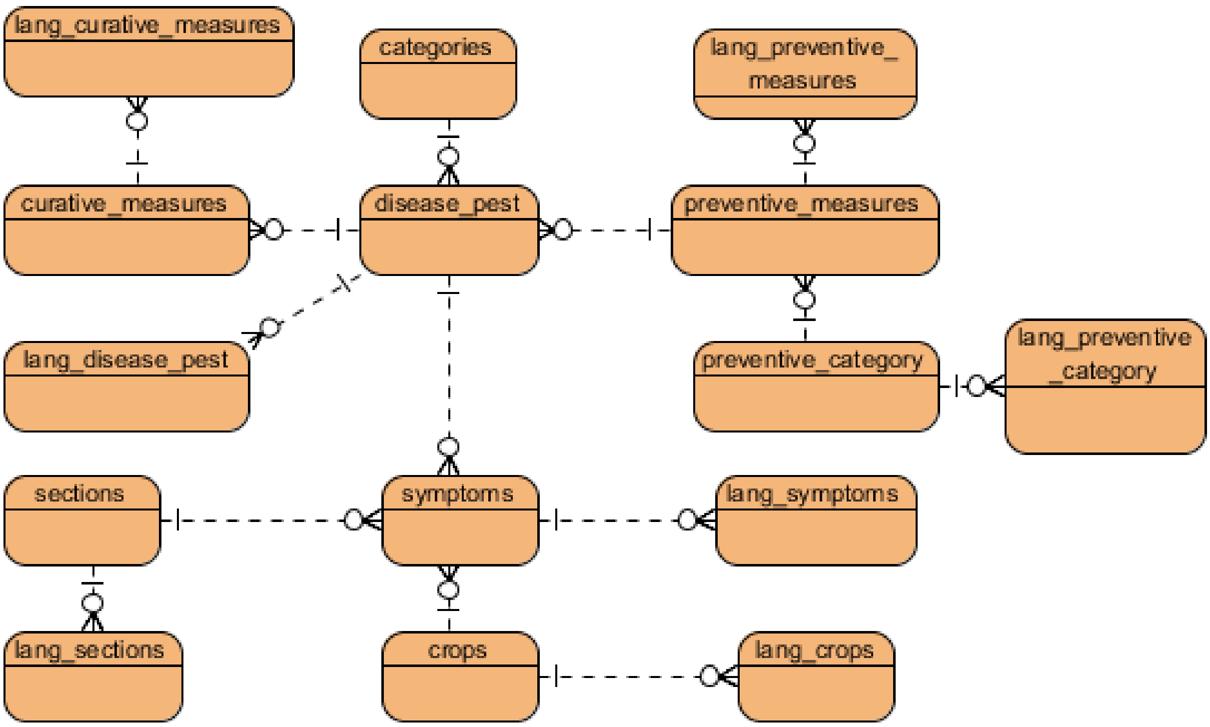


Figure 7.7: Entity Relationship Diagram

7.6 Assumptions and dependencies

It is assumed that:

- The users of this system understand at least one of the languages supported in the system.

- The users have the necessary technology which enables them to access and use the system.
- They have access to the internet that is reliable, that is it is available all the time they want it.

7.7 Implementation and Results

A mobile and web based artificial intelligent Diagnostic System: case for maize farmers was developed. This application receives the visual symptoms as input, applies a reasoning mechanism on the input to provide a correct and acceptable diagnosis of the problem along with any control and curative measures to be taken by the farmer. This section gives a summary of the implementation, testing performed on the system and sample output.

7.7.1 Implementation Tools requirements

A listing and description of hardware platforms and software requirements for the web and mobile components of the application is provided below.

Hardware Platform

The hardware specifications below were chosen for the successful completion of the project since they were sufficient to meet the functional and non-functional requirements of the system, especially with regard to processing and response times. A WAP enabled phone was used as a minimum requirement since GPRS enabled phone could be used alternatively.

- ✓ Pentium V Dual Core 3.0 GHz Processor
- ✓ 80Gb hard disk
- ✓ 512 MB RAM
- ✓ 100 Kbps LAN
- ✓ Nokia N95 Series

Software Development Platform:

- ✓ Wamp 5_1.6.1 (Windows)
- ✓ Windows Vista environment
- ✓ Macromedia Dreamweaver 8
- ✓ Internet Explorer version 6.0
- ✓ Mozilla Firefox Version 5.0
- ✓ Nokia Series 40 5th Edition SDK
- ✓ Nokia Series 40 5th Edition Feature Pack SDK
- ✓ Openwave SDK version 6.2.2
- ✓ Visual Studio.

Database:

- ✓ mySQL database

Programming languages:

- ✓ XHTML
- ✓ HTML
- ✓ AJAX
- ✓ Javascript
- ✓ PHP
- ✓ SQL
- ✓ ASP
- ✓ C#

Communication:

- ✓ TCP/IP, GPRS wireless connectivity

7.7.2 Testing

To ensure a reasoning veracity and completeness of the artificial intelligent system, a number of tests were conducted. Testing was iterative and incremental in nature. Of concern in this testing were both the functional and non-functional requirements which had been identified during the analysis stage. The tests were performed on an emulator for the mobile client before deploying the application on the mobile phone.

For the web client, it was done on a local server before hosting in a public domain.

One approach was applied to test the system:

Explore the capabilities of the system adding and removing symptoms. At each stage, check the results given along with the calculated probabilities of the diseases to see whether they match the analysis of which diseases are most likely to be implicated in causing these symptoms. If at any point inaccurate information is presented, corrections were made.

A set of possible observed symptoms were defined. The signs were used as input specification and the results compared with the mental picture of sensible diagnosis. A set of scenarios were evaluated.

Test on Functional Requirements

A sample test data shown below in table 7.1 was prepared to test the functional requirements of the system. It shows the expected behavior before the test and the actual behavior after the implementation of the system

Table 7.1: Sample Tests for Functional Requirement

Test No.	Description	Expected Behavior	Actual Behavior
1.	Veracious diagnostic results	The application should generate diagnosis results that are complete and genuine	The diagnostic results match the intuitive opinion of the individual doing the tests.
2.	Exhibit some learning with a variance in weights.	The application should vary the confidence rating of the results with addition of new symptoms	With addition of symptoms, the confidence rating varied and the number of possible problems fell until a solution was found
3.	Add or subtract input specification	It should be possible for a user to add or remove symptoms or input specifications as they wish.	The users could provide additional symptoms or remove and submit for a diagnosis.

Module Testing

Each module was tested on its own. This was done to ensure that every unit/module works properly on its own. Some of the tests carried out included entering wrong data or submitting blank fields for required fields in order to test the outcome e.g. submitting an empty form when the administrator is entering crop name the following error message is displayed.

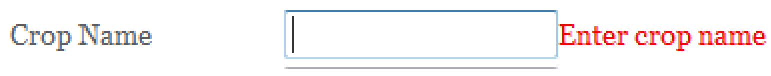


Figure 7.8: Page with an error message

Regression Testing

In the process of cording, new changes were sometimes made and incorporated into a module. The new changes and the entire module were tested again to ensure that the changes did not affect the functioning of previously verified codes.

System Testing

The module was integrated after the sub modules were completed, tested and found to function as per the expectation. The entire system was then tested to ensure that the system performed according to specification.

Sample Output Main Site for system manager(backend)

The following are sample output of the backend of the artificial intelligent system for diagnostics and management of maize diseases:

Login Page

The access to the backend of the system is restricted to the system manager. Below figure shows the login form for the authorized manager.

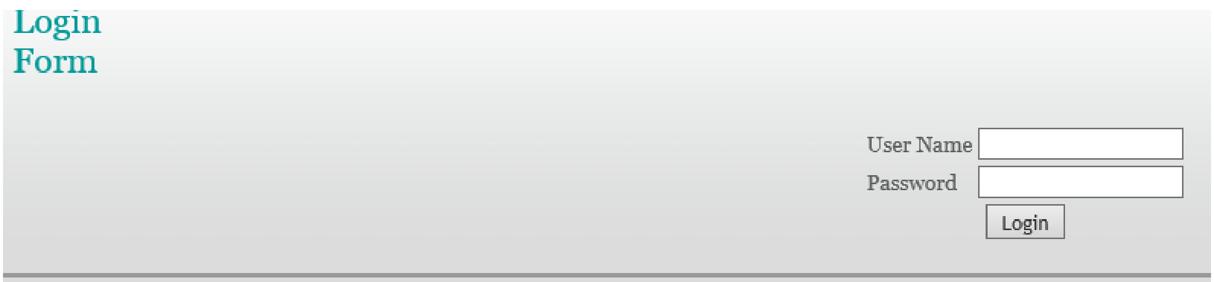


Figure 7.9: login form

Pending Cases page

Upon login by the system manager, a page showing pending cases which the system did not provide full diagnostic information to the end user appears. From here, the manager will complete the pending cases using the expert advice.

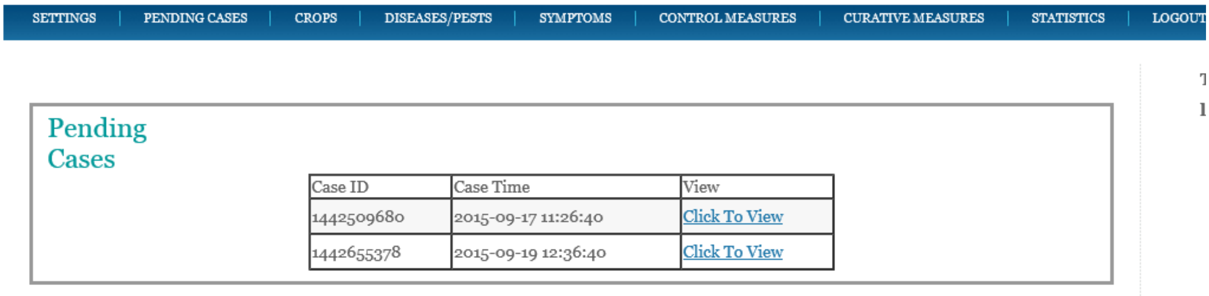


Figure 7.10: Pending cases page

Crops Disease form Page

One of the major functions of system manager was to: search for new diseases, their symptoms and management options, collect and input into the systems. However, this system can also be used for other crops other than maize. Because of this, the system manager must first capture the crop. This page is used for capturing the crop name to be supported by the system.

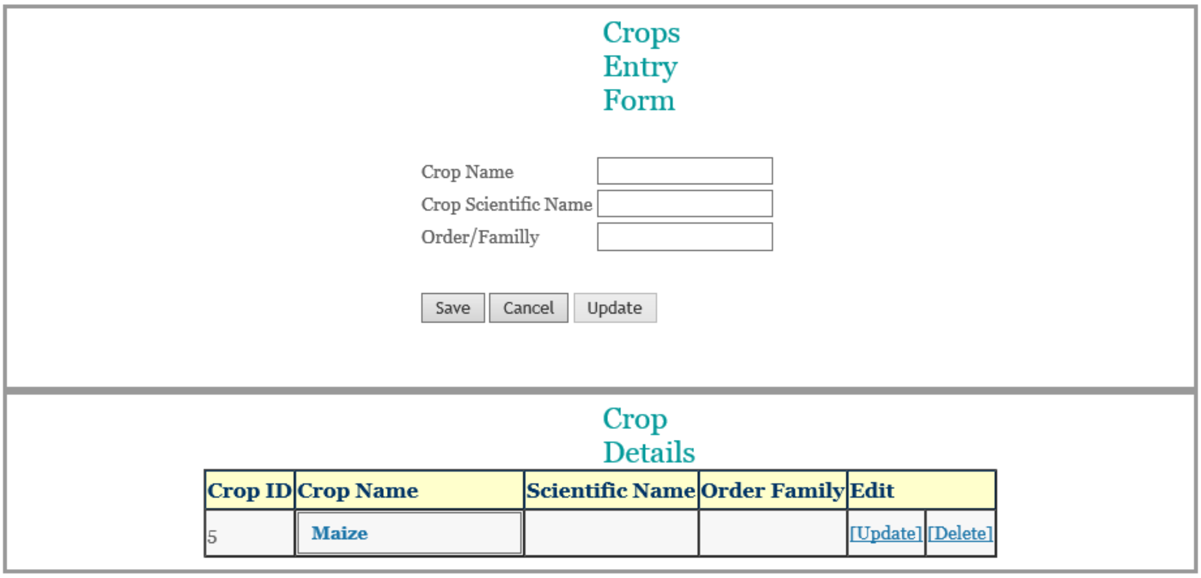
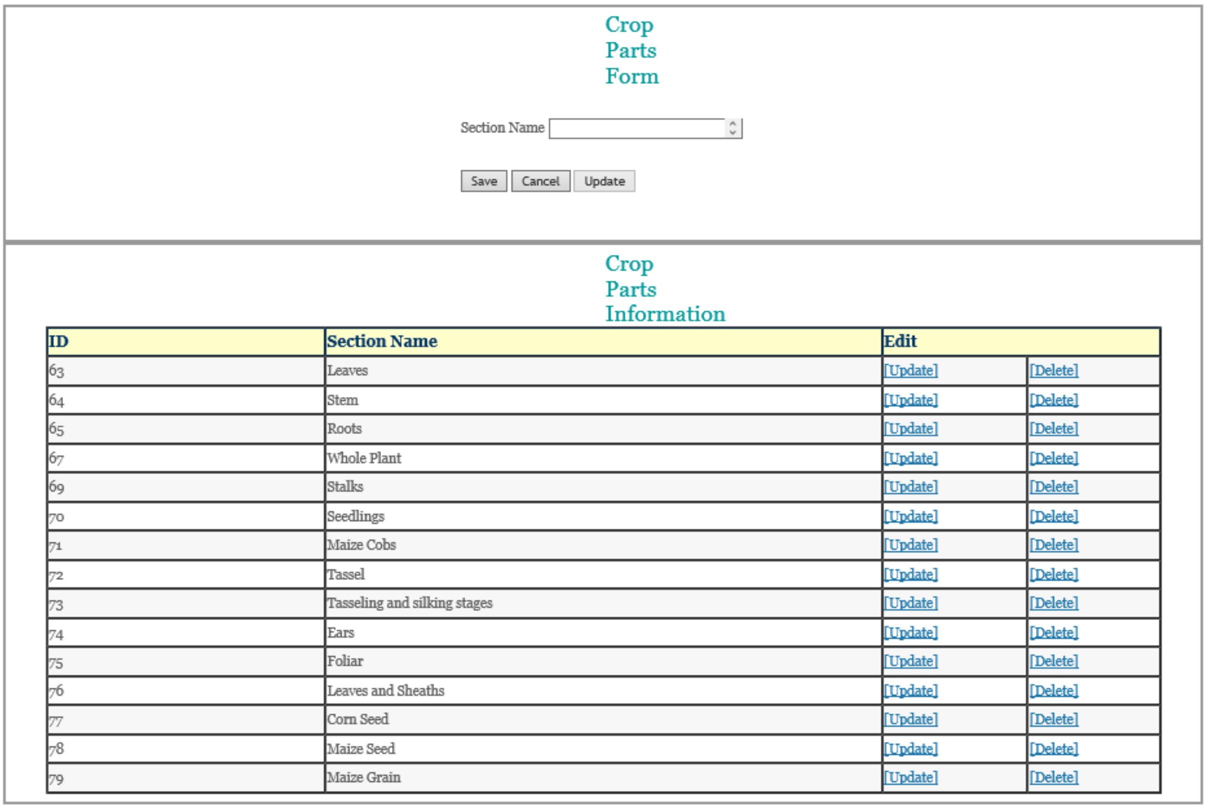


Figure 7.11: Crop Registry page

Crop Parts Form

One of the major functions of system manager was to: search for information on new diseases, their symptoms and management options, collect and input into the systems. During the collection and inputting the information in the system, the system manager must specify the part of the crop where the symptom appeared. Below form provided the system manager with an input point for the various crop parts where the symptoms appears.

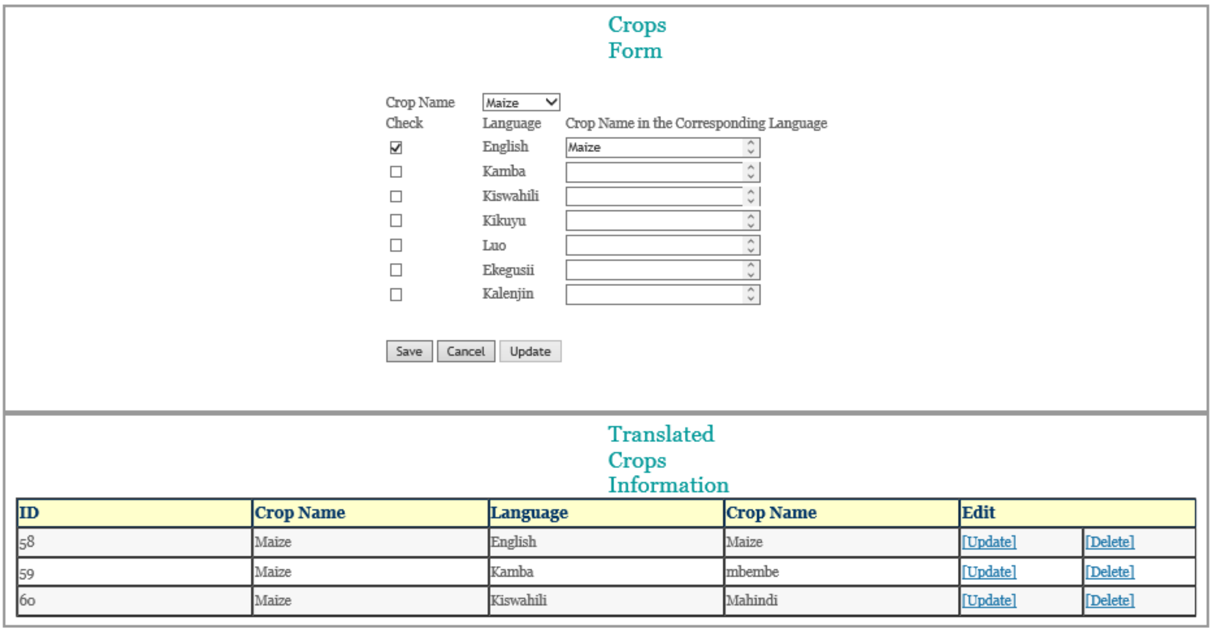


ID	Section Name	Edit	
63	Leaves	[Update]	[Delete]
64	Stem	[Update]	[Delete]
65	Roots	[Update]	[Delete]
67	Whole Plant	[Update]	[Delete]
69	Stalks	[Update]	[Delete]
70	Seedlings	[Update]	[Delete]
71	Maize Cobs	[Update]	[Delete]
72	Tassel	[Update]	[Delete]
73	Tasseling and silking stages	[Update]	[Delete]
74	Ears	[Update]	[Delete]
75	Foliar	[Update]	[Delete]
76	Leaves and Sheaths	[Update]	[Delete]
77	Corn Seed	[Update]	[Delete]
78	Maize Seed	[Update]	[Delete]
79	Maize Grain	[Update]	[Delete]

Figure 7.12: Crop Parts registry page

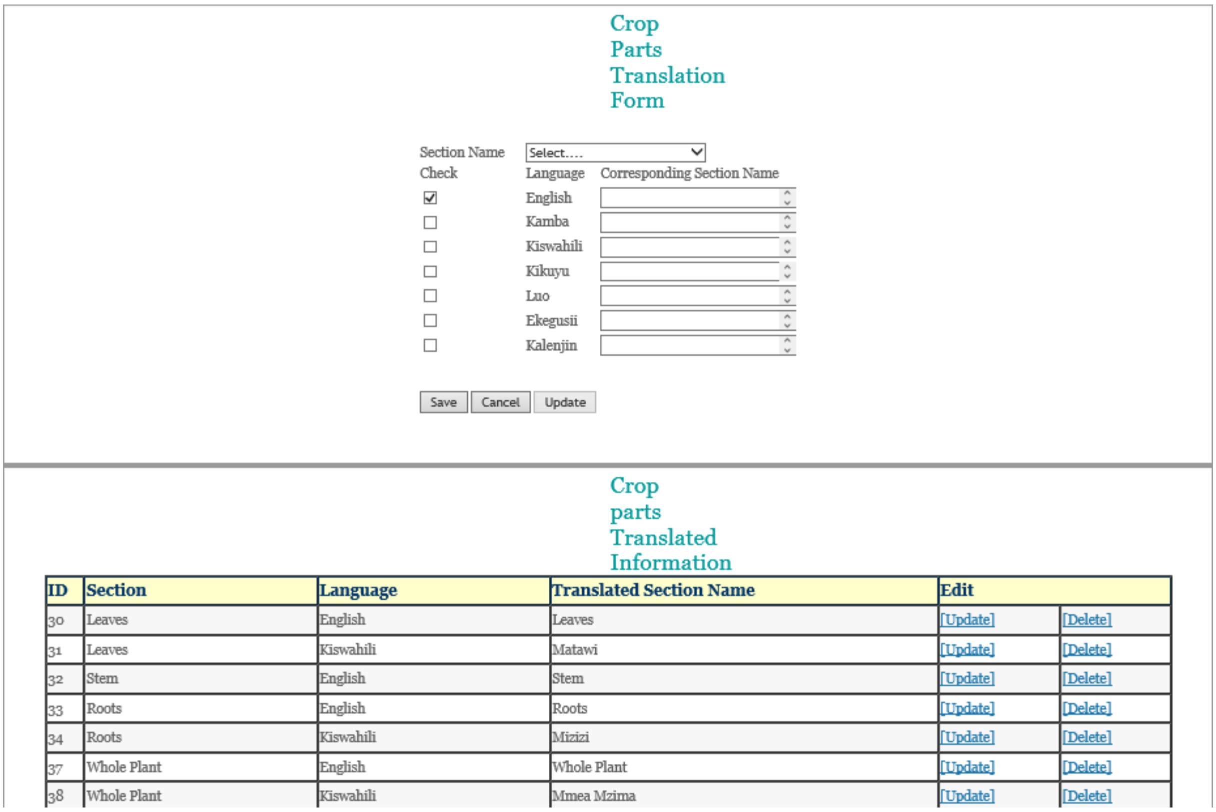
Crops name and parts translation pages

The system was designed to support multiple languages. The figures below show the translation page for the crop name and parts translation page.



ID	Crop Name	Language	Crop Name	Edit	
58	Maize	English	Maize	[Update]	[Delete]
59	Maize	Kamba	mbembe	[Update]	[Delete]
60	Maize	Kiswahili	Mahindi	[Update]	[Delete]

Figure 7.13: Crop translation page

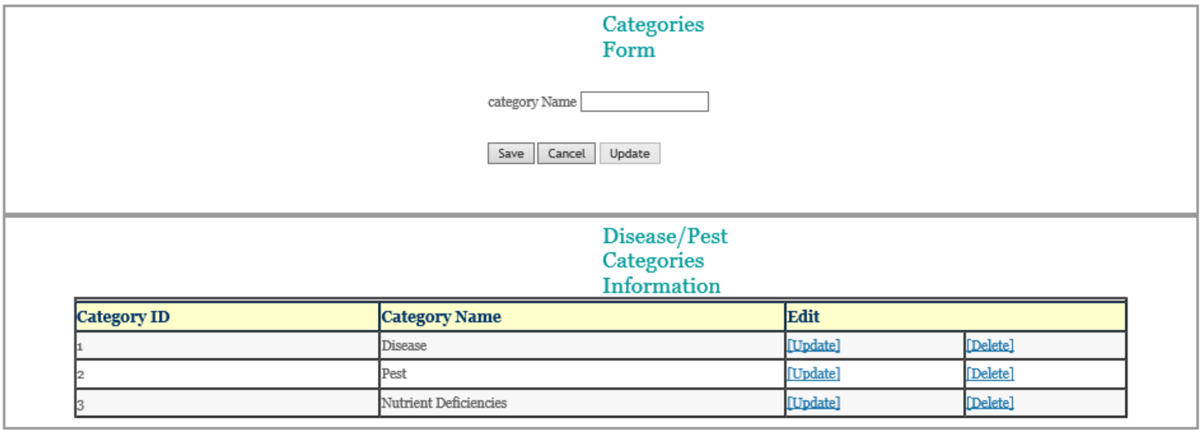


ID	Section	Language	Translated Section Name	Edit	
30	Leaves	English	Leaves	[Update]	[Delete]
31	Leaves	Kiswahili	Matawi	[Update]	[Delete]
32	Stem	English	Stem	[Update]	[Delete]
33	Roots	English	Roots	[Update]	[Delete]
34	Roots	Kiswahili	Mizizi	[Update]	[Delete]
37	Whole Plant	English	Whole Plant	[Update]	[Delete]
38	Whole Plant	Kiswahili	Mmea Mzima	[Update]	[Delete]

Figure 7.14: Crop Parts translation page

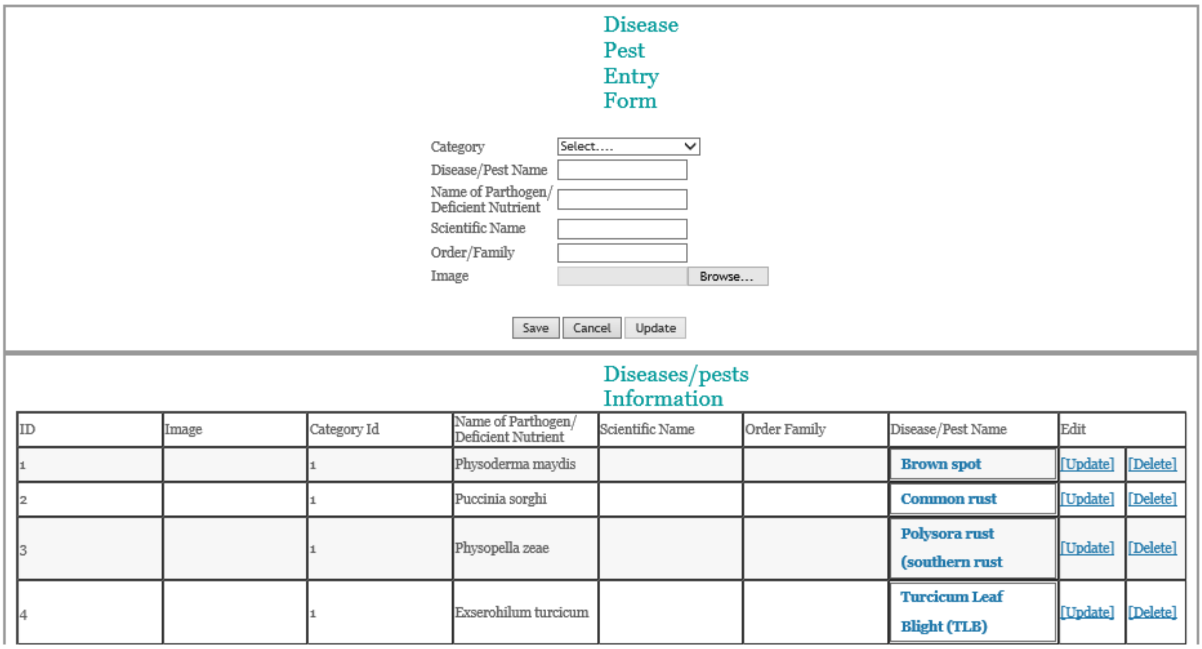
Disease, Symptoms and control measures Input Forms pages

The system's manager is also tasked with inputting the diseases, symptoms, control measures/ curative measures and the point of purchase. The system provided these features as described by the figures below



Category ID	Category Name	Edit	
1	Disease	[Update]	[Delete]
2	Pest	[Update]	[Delete]
3	Nutrient Deficiencies	[Update]	[Delete]

Figure 7.15: Disease categorization input page



Disease
Pest
Entry
Form

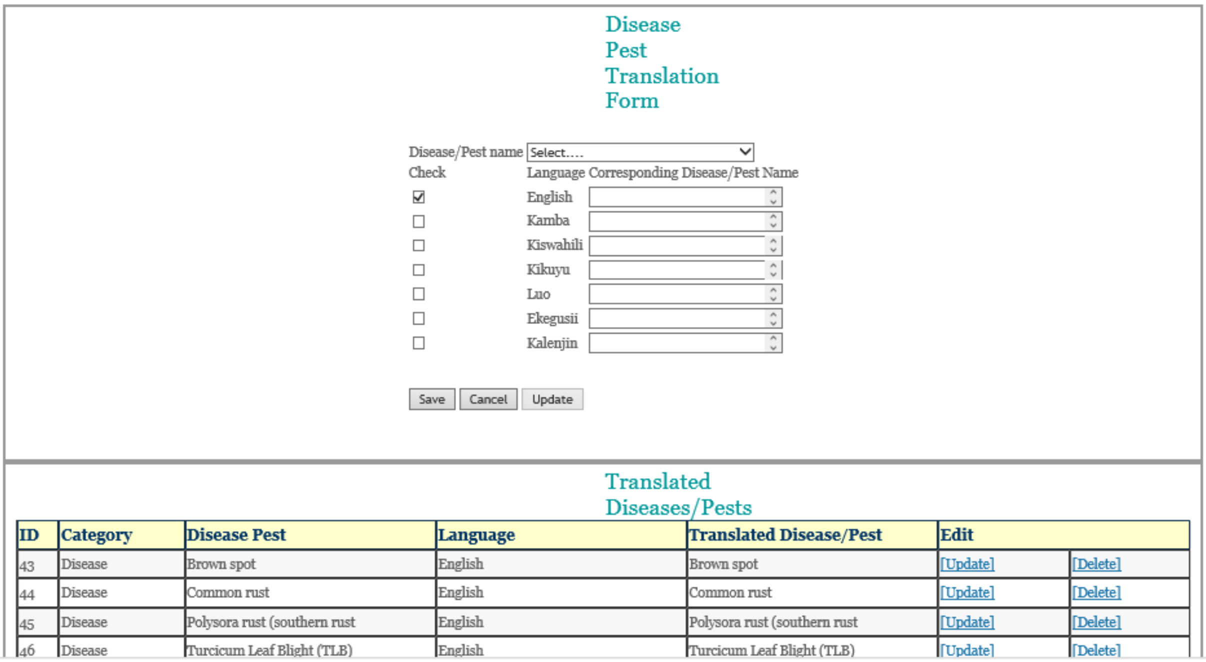
Category Select....
Disease/Pest Name
Name of Parthogen/ Deficient Nutrient
Scientific Name
Order/Family
Image Browse...

Save Cancel Update

Diseases/pests
Information

ID	Image	Category Id	Name of Parthogen/ Deficient Nutrient	Scientific Name	Order Family	Disease/Pest Name	Edit	
1		1	Physoderma maydis			Brown spot	[Update]	[Delete]
2		1	Puccinia sorghi			Common rust	[Update]	[Delete]
3		1	Physopella zeae			Polysora rust (southern rust	[Update]	[Delete]
4		1	Exserohilum turcicum			Turcicum Leaf Blight (TLB)	[Update]	[Delete]

Figure 7.16: Disease/Pest input page



Disease
Pest
Translation
Form

Disease/Pest name Select....

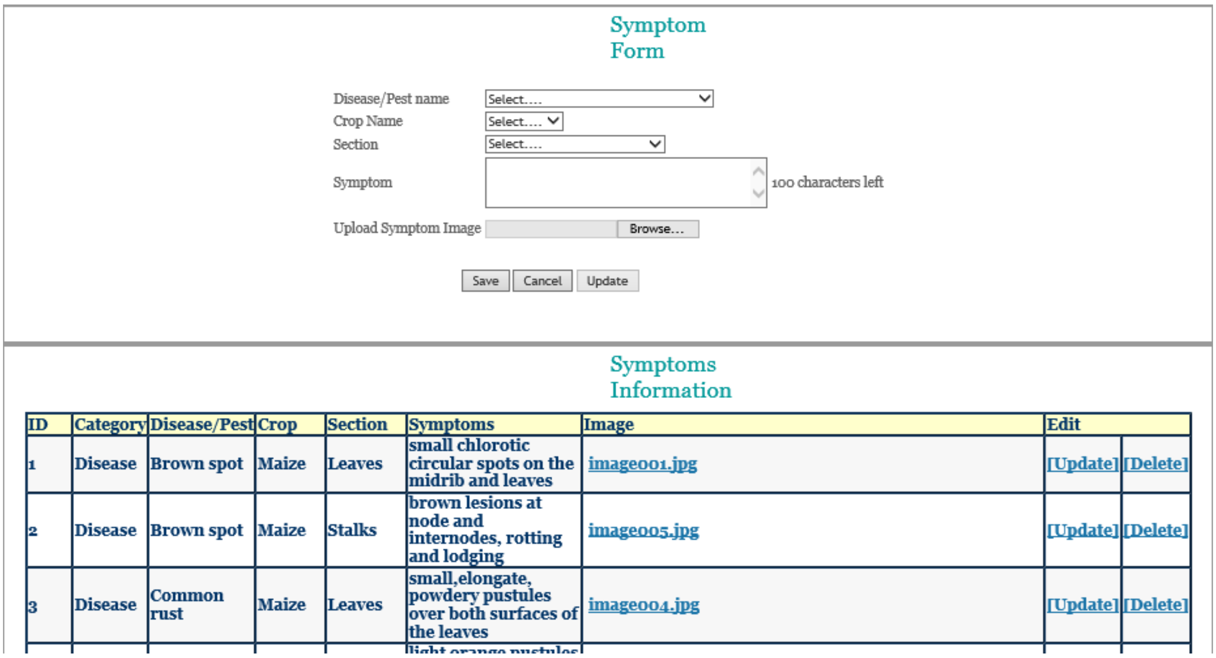
Check	Language	Corresponding Disease/Pest Name
☑	English	
☐	Kamba	
☐	Kiswahili	
☐	Kikuyu	
☐	Luo	
☐	Ekegusii	
☐	Kalenjin	

Save Cancel Update

Translated
Diseases/Pests

ID	Category	Disease Pest	Language	Translated Disease/Pest	Edit	
43	Disease	Brown spot	English	Brown spot	[Update]	[Delete]
44	Disease	Common rust	English	Common rust	[Update]	[Delete]
45	Disease	Polysora rust (southern rust	English	Polysora rust (southern rust	[Update]	[Delete]
46	Disease	Turcicum Leaf Blight (TLB)	English	Turcicum Leaf Blight (TLB)	[Update]	[Delete]

Figure 7.17: Disease/Pest translation page



ID	Category	Disease/Pest	Crop	Section	Symptoms	Image	Edit	
1	Disease	Brown spot	Maize	Leaves	small chlorotic circular spots on the midrib and leaves	image001.jpg	[Update]	[Delete]
2	Disease	Brown spot	Maize	Stalks	brown lesions at node and internodes, rotting and lodging	image005.jpg	[Update]	[Delete]
3	Disease	Common rust	Maize	Leaves	small,elongate, powdery pustules over both surfaces of the leaves	image004.jpg	[Update]	[Delete]

Figure 7.18: Symptoms form page

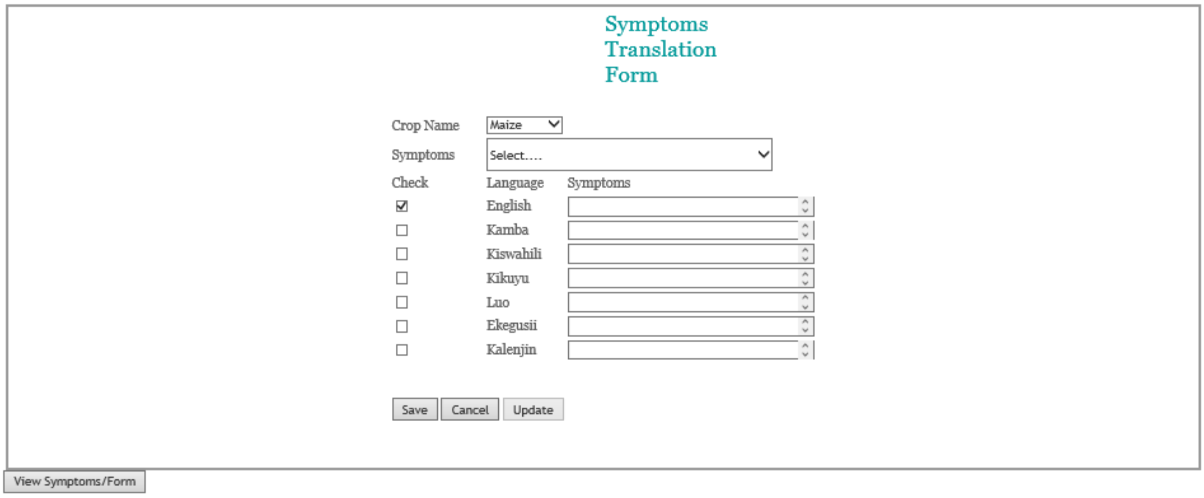
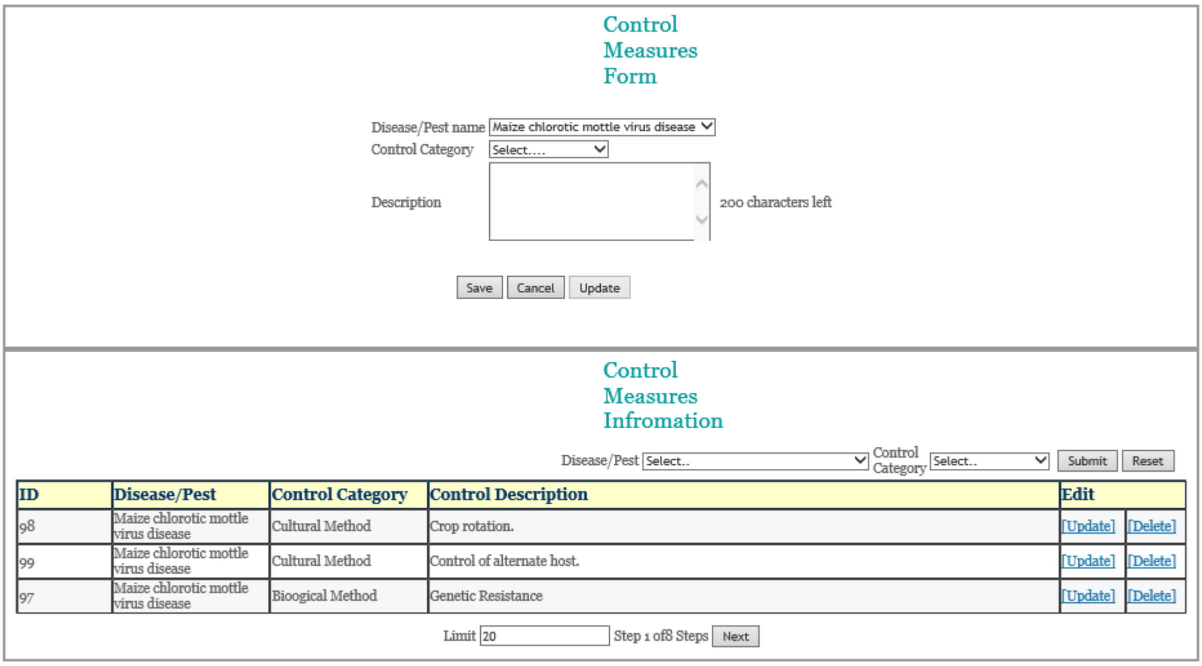


Figure 7.19: Symptom translation page



Control Measures Form

Disease/Pest name: Maize chlorotic mottle virus disease
Control Category: Select....
Description: 200 characters left

Save | Cancel | Update

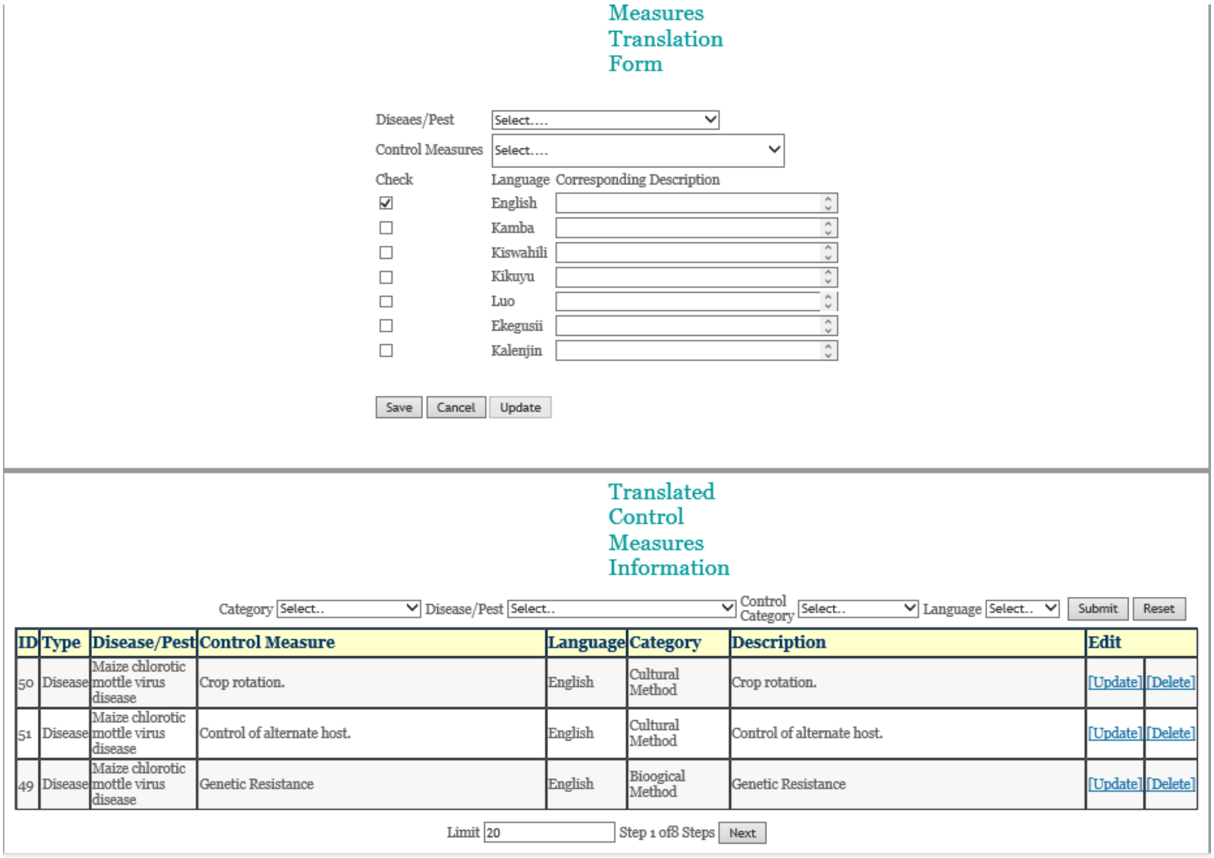
Control Measures Infromation

Disease/Pest: Select.. Control Category: Select.. Submit | Reset

ID	Disease/Pest	Control Category	Control Description	Edit	
98	Maize chlorotic mottle virus disease	Cultural Method	Crop rotation.	[Update]	[Delete]
99	Maize chlorotic mottle virus disease	Cultural Method	Control of alternate host.	[Update]	[Delete]
97	Maize chlorotic mottle virus disease	Bioogical Method	Genetic Resistance	[Update]	[Delete]

Limit 20 Step 1 of8 Steps Next

Figure 7.20: Disease/Pest control measures form page



Measures Translation Form

Diseaes/Pest: Select....
Control Measures: Select....

Check	Language	Corresponding Description
☑	English	
☐	Kamba	
☐	Kiswahili	
☐	Kikuyu	
☐	Luo	
☐	Ekegusii	
☐	Kalenjin	

Save | Cancel | Update

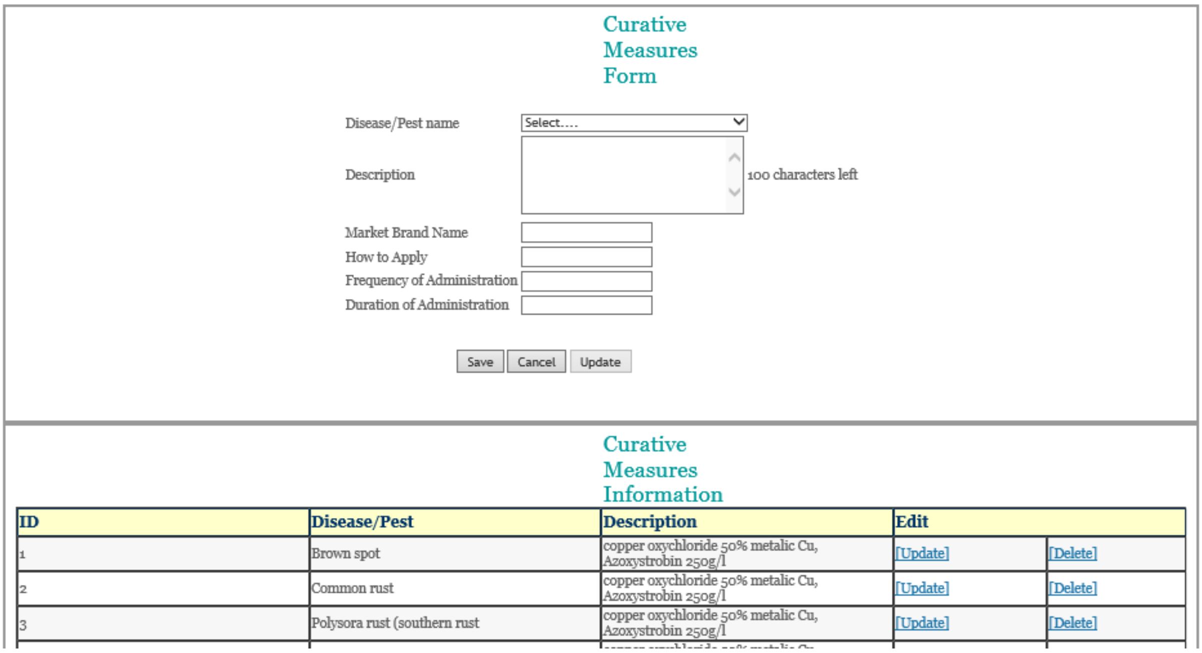
Translated Control Measures Information

Category: Select.. Disease/Pest: Select.. Control Category: Select.. Language: Select.. Submit | Reset

ID	Type	Disease/Pest	Control Measure	Language	Category	Description	Edit	
50	Disease	Maize chlorotic mottle virus disease	Crop rotation.	English	Cultural Method	Crop rotation.	[Update]	[Delete]
51	Disease	Maize chlorotic mottle virus disease	Control of alternate host.	English	Cultural Method	Control of alternate host.	[Update]	[Delete]
49	Disease	Maize chlorotic mottle virus disease	Genetic Resistance	English	Bioogical Method	Genetic Resistance	[Update]	[Delete]

Limit 20 Step 1 of8 Steps Next

Figure 7.21: Disease/Pest control measures translation form page



Curative Measures Form

Disease/Pest name: Select....

Description: 100 characters left

Market Brand Name

How to Apply

Frequency of Administration

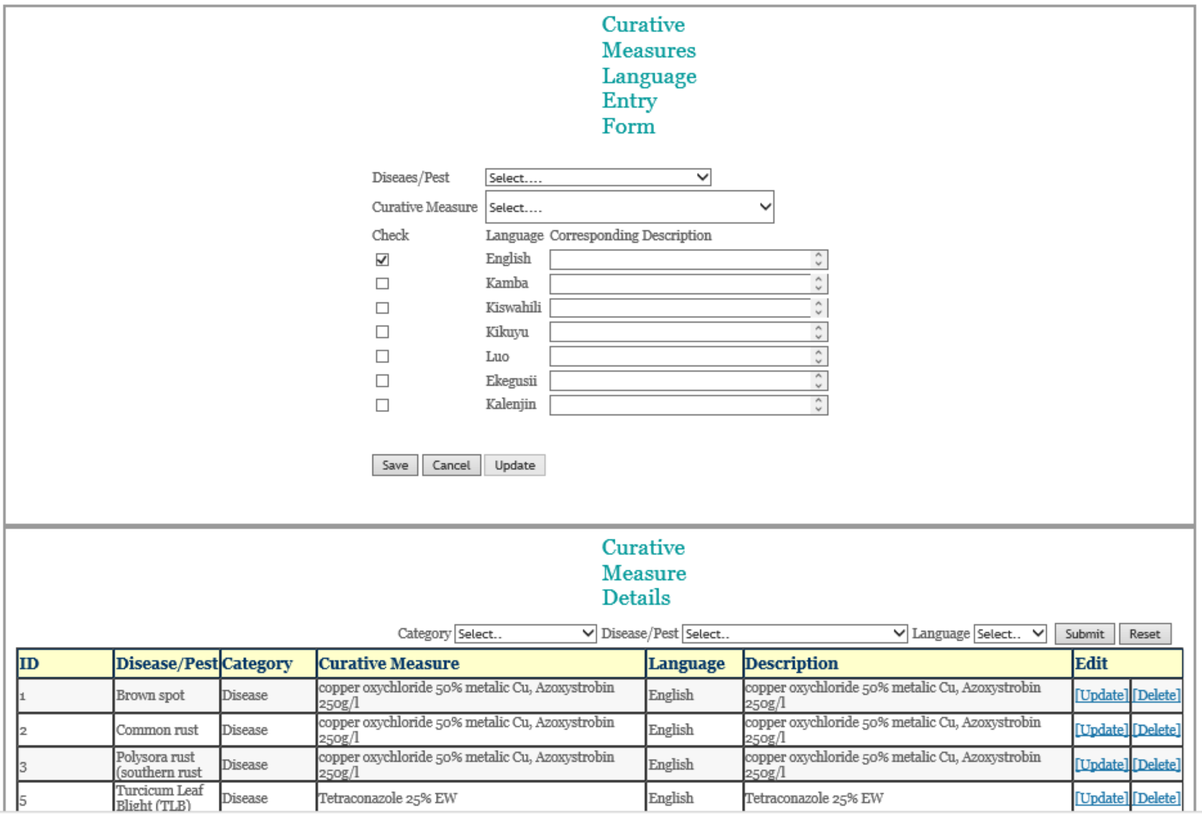
Duration of Administration

Save | Cancel | Update

Curative Measures Information

ID	Disease/Pest	Description	Edit	
1	Brown spot	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	[Update]	[Delete]
2	Common rust	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	[Update]	[Delete]
3	Polysora rust (southern rust	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	[Update]	[Delete]

Figure 7.22: Disease/Pest curative measures form page



Curative Measures Language Entry Form

Diseaes/Pest: Select....

Curative Measure: Select....

Check	Language	Corresponding Description
☑	English	
☐	Kamba	
☐	Kiswahili	
☐	Kikuyu	
☐	Luo	
☐	Ekegusii	
☐	Kalenjin	

Save | Cancel | Update

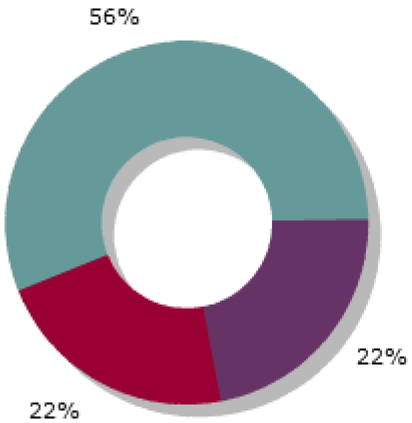
Curative Measure Details

Category: Select.. Disease/Pest: Select.. Language: Select.. Submit | Reset

ID	Disease/Pest	Category	Curative Measure	Language	Description	Edit	
1	Brown spot	Disease	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	English	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	[Update]	[Delete]
2	Common rust	Disease	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	English	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	[Update]	[Delete]
3	Polysora rust (southern rust	Disease	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	English	copper oxychloride 50% metalic Cu, Azoxystrobin 250g/l	[Update]	[Delete]
5	Turcicum Leaf Blight (TLB)	Disease	Tetraconazole 25% EW	English	Tetraconazole 25% EW	[Update]	[Delete]

Figure 7.23: Disease/Pest curative measures translation form page

The Most Dignosed Diseases in the last two weeks (Statistics)



Key Table	
	Seed Corn Maggot
	Bacterial stalk rot
	Fusarium root rot

Figure 7.24: Statistics of Disease/Pest diagnosis

Sample Output Main Site for Farmers and extension officers(Front end/User Interface)

Home page

This is the page where users input their cases for diagnosis and also receive their results. The users are required to select the guided symptoms description or match the image of the symptom to that they can see on their maize crop. Users are guided by the various parts of the plants. All possible symptoms which can affect the parts are presented to the user for selection. Below figures presents the query pages and final output for the case of Maize Brown spot (*Physoderma maydis*):

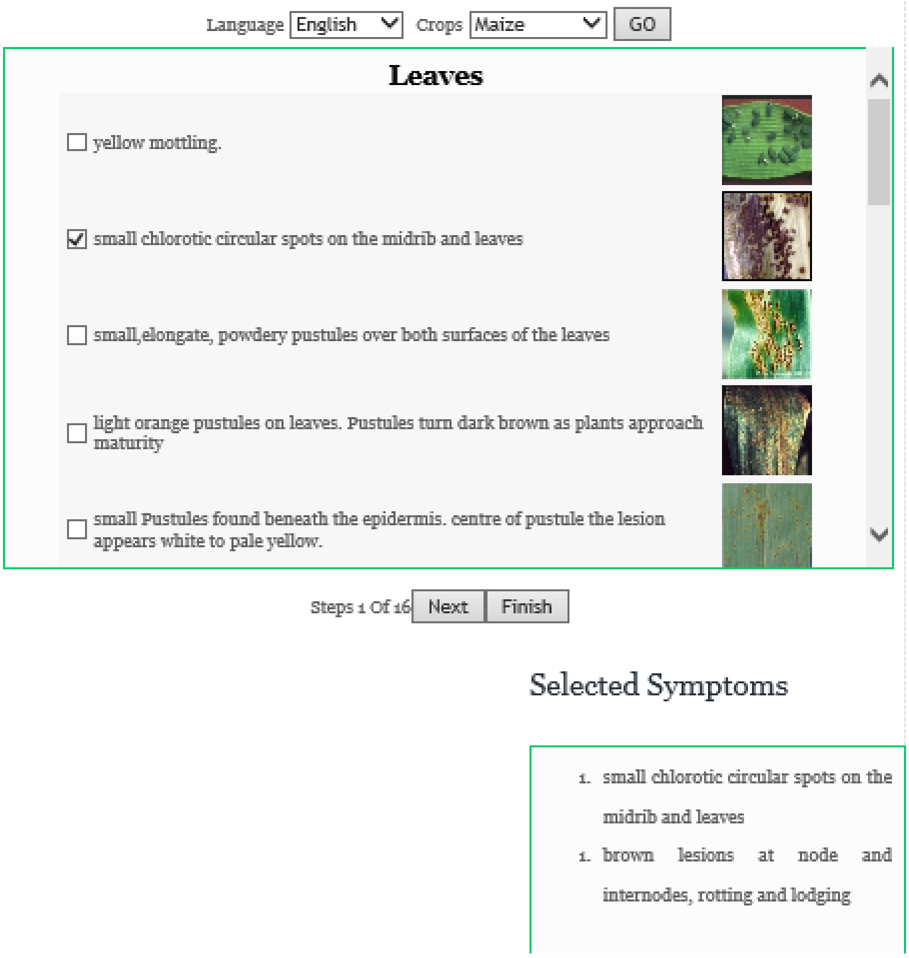


Figure 7.25: Symptoms selection on the leaves page

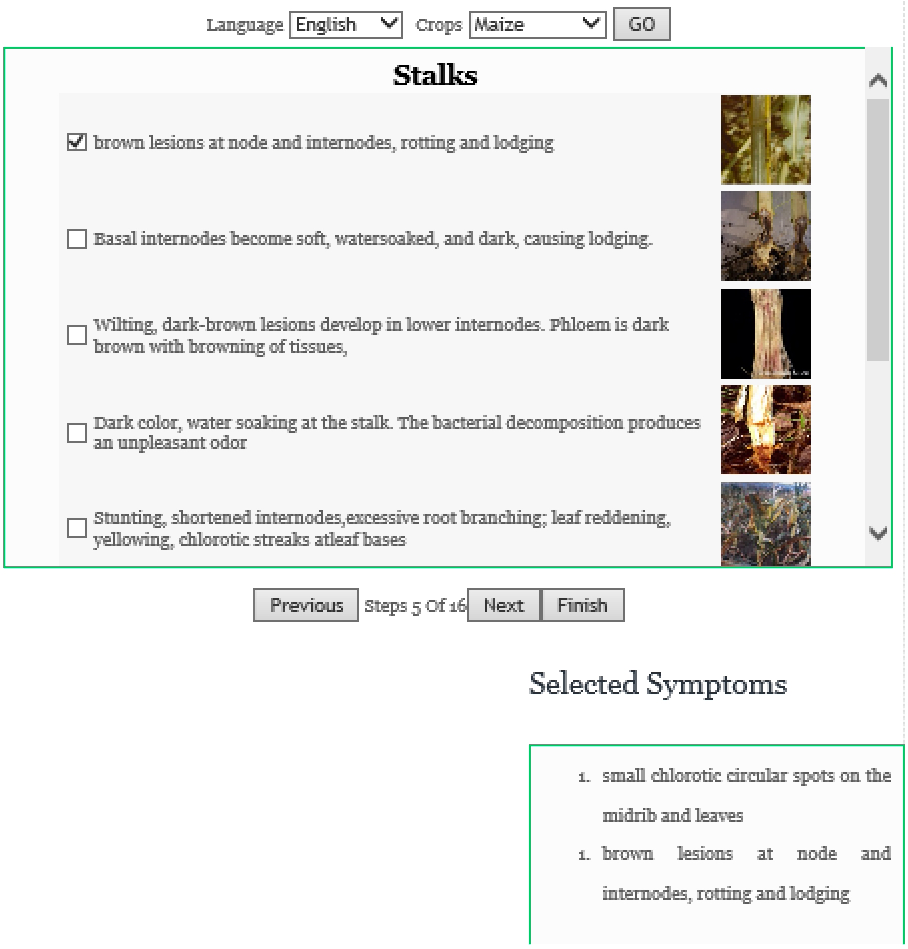


Figure 7.26: Symptoms selection on the stalk page

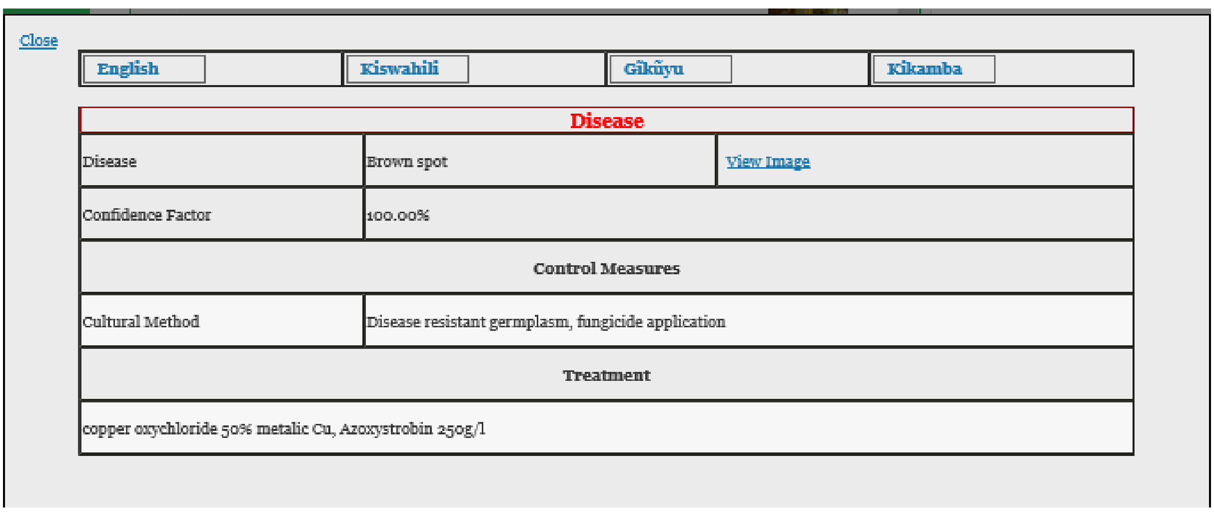


Figure 7.27: Output/ results of diagnosis

1.3 Sample Output Mobile Site

The system provides a mobile phone interface. this can be accessed by all basic feature phones with WAP. It provides both front end and back end. Front end can be accessed at http://cbr.uonbi.ac.ke/web and the backend can be accessed at http://cbr.uonbi.ac.ke/web /admin. to access the content of the back end, a user name and password is required. The system manager can input new information from the backend using the mobile phones. On the other hand farmers can access diagnostic services using mobile phones. This creates the cost effectiveness, timeliness and convenience in provision of diagnostic services to farmers.

The following are the sample output for the mobile:

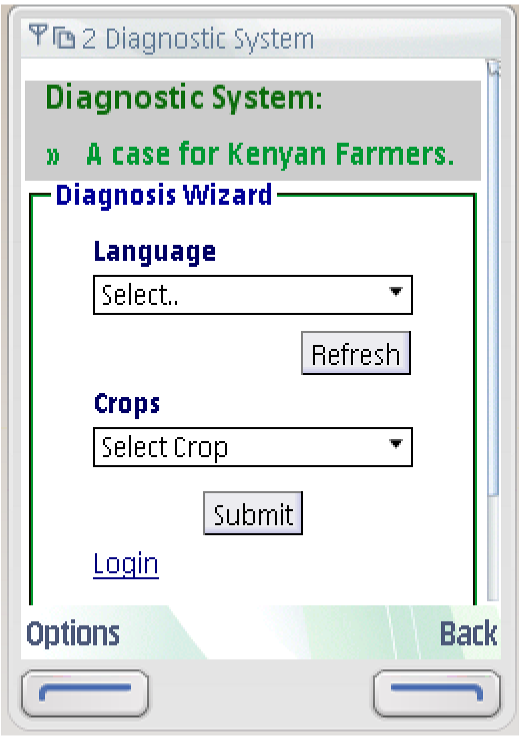


Figure 7.28: Output/ results of diagnosis

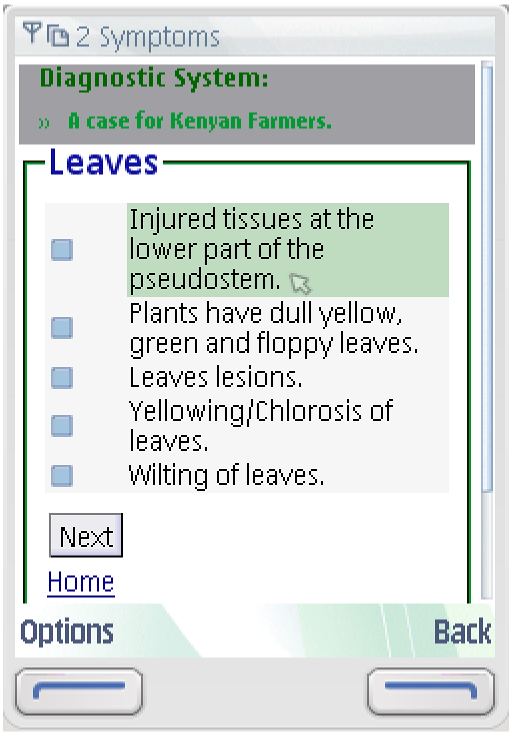


Figure 7.29: Symptoms selection page

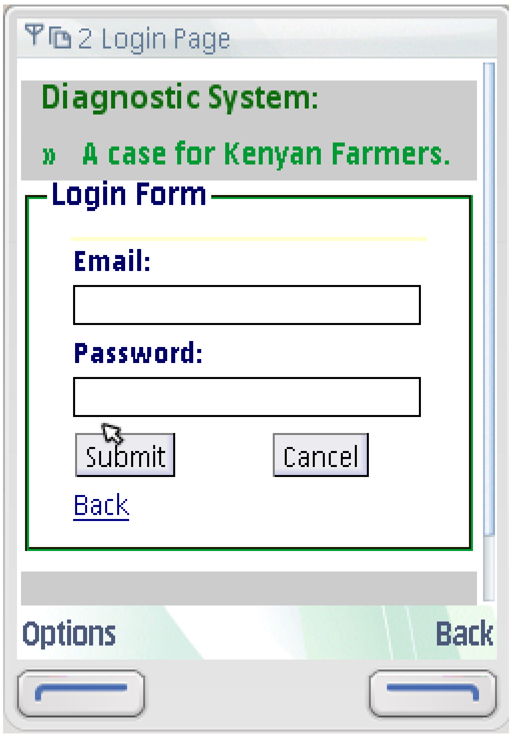


Figure 7.30: Login page for the administrator

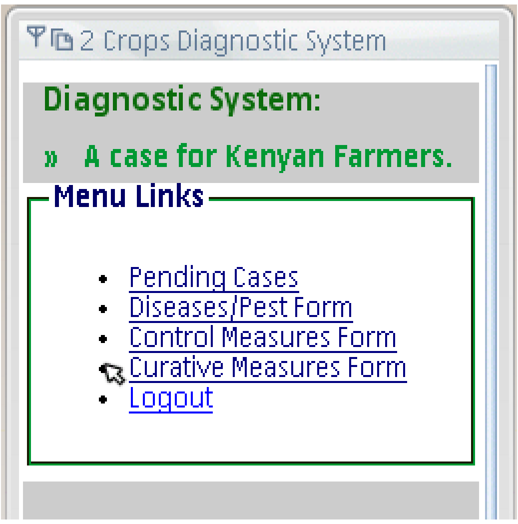


Figure 7.31: Mobile home page for administrator

7.8 Achievements

1. The developed a crops diagnostic case based reasoning artificial intelligent system that can be accessed by farmers in their remote locations. This was achieved through the deployment of the system on WAP enabled mobile devices which interact with the central server that host the knowledgebase via the GPRS connectivity. The system is sufficiently scalable to support several pests and diseases of crops and animal species.

2. Developed a learning module which enables the system to learn hence, becoming more intelligent with time through the intervention of expert.

3. Developed a language module that enables translation of text into several languages making the system more accessible and acceptable to farmers.

4. Developed a system back end to enable an expert to perform administrative tasks such as capturing new cases, editing and analysis.

7.9 Constraints

Despite successful development of the system, the challenges and constraints encountered were:

a) Obtaining reference material on mobile artificial intelligent systems was difficult. Besides, those that were sought in the internet were web-based developed using a shell.

b) Obtaining an appropriate shell proved futile. There were no open source shells available for use. This prompted for a different course of action. A lot of theories on implementation of self-learning in artificial intelligent systems were available but efforts to find previous implementation proved futile as well.

c) Several new technologies had to be learned and implementing them was challenging.

CHAPTER EIGHT

8.0 GENERAL DISCUSSIONS

The study started by collecting and analyzing the user requirement. The users considered in this study were the maize farmers and extension officers in Uasin Gishu County, Kenya. The study then proceeded to collect data on maize diseases and management option. The information content collected was guided by the user requirement. The researcher went ahead to design an electronics database for the maize diseases and management. Based on the user requirement, the study proceeded to formulate a model to drive an artificial intelligent system. A prototype to implement the model was developed and tested. This chapter provided a discussion of the results of all the processes undertaken during this study and also provides similarities and contrast to other previously conducted studies.

8.1 Users Requirement

8.1.1 Characteristics of extension officers

Analysis of data presented in Table 3.1 revealed that 50percent of extension workers were female and 50percent male. 33.3percent of extension officers are between 41 to 45 years of age. Thirty three percent (33.3percent) of extension officers are of the age between 46 to 50 years. Extension officers between the age of 36-40 years and those between 51 years and above were both 16.7percent.

In terms of education levels, 27.8percent of extension officers were holders of a master degree, 22.2percent diploma, 16.7percent Post graduate diploma, 16.7percent college certificates and 11.1percent were bachelor degree holders. Five point six percent (5.6percent) (1/18) of extension workers did not disclose their level of education.

The fact that majority of extension officers are of the age between 41years and 50 years can be attributed to reduced recruitment of extension officers over the last two decades. This fact can further be attributed to reduced budgetary allocations. The findings were similar to the facts presented by the Government of Kenya in its report in 2010 as one of the challenges affecting agriculture (GoK 2010). For the more, the farmer population has been in the increase as population grows while the recruitment of extension officer has come to a halt. This results support the finding presented on Africa science news which indicated extension officer to farmer ration of 1:1500 in Kenya.

In Table 4.1, the study findings revealed that 65.6percent (59/90) of farmers were male, while 34.4 percent (31/90) were females. Majority of farmers were of the ages between 36-40 years (31.1percent) Sixty percent (60percent) of the respondents were 40years and below.

On the other hand, 45.6percent of farmers had primary school education while 23.3percent had secondary school education. Sixty eight point eight percent (68.8percent) of famers' had secondary and primary school education. In addition, 33.3percent of the farmers had between 21-30 acres of land and the annual average farmer income from maize were at Kenya Shillings 350,766.67

These finding were similar to Trivedi et al, (2015) who also did a study to find out the cause of usage of mobile telephones by farmers for accessing agricultural information. Their study found out that, "30.0percent of male respondents and 19.2percent of female respondents were 45 and above years of age, whereas 19.2percent of male and 9.2percent of female respondents were 35 to 45 years of age. Twelve point five percent (12.5percent) of male and 5.0percent of female respondents were 25 to 35 years of age. Only 5.0percent of male respondents were 18 to 25 years of age. Distribution of respondents among gender and age group of combined respondents had a maximum cumulative value of 49.2percent of respondents were 45year and above of age, whereas 28.3percent of respondents were 35 to 45 years of age group followed by 17.5percent of respondents who were 25 to 35 years of age. Only 5.0percent of respondents were 18 to 25 years of age". (Trivedi et al, 2015).

Given the results, there is a significant growth in education levels among farmers as compared to two decades ago where; over 70percent of farmers had primary school levels of education. Rogers in his technology adoption model explains that the innovators and early adopters are young and educated. In the context of this study, the results show that the number of young farmers and the education levels are on the increase. This is an indicator to the fact that adoption of new technology in agriculture would be much easier than it was two decades ago. Therefore ICT based diagnostic information would be easily adopted.

8.1.2 Sources of diagnostic information

The results in table 3.2 revealed that, extension officers get information from seminars (100percent), own knowledge (77.8percent), agro-vet (55.6percent), journals(50percent), and other sources of information (27.8percent) (Agricultural officer 11.1percent, extension officer 11.1percent, and institutes officer 5.6percent). Internet, radio and mobile applications were all being used by 11.1percent of the respondents.

The results also revealed that there was no significant correlation between extension officers and their sources of information as shown in Table 3.3. This might be due to the fact that extension officers are employed by the Government and are taken through various similar trainings on accessing diagnostic information the employer despite their social-economic, environmental and other human factors.

The results revealed that seminars are the major source for diagnostic information. The information content used for training during seminars is drawn from published research work hence journal are the source of information used in seminars. The results also revealed that extension officers relied on their own knowledge for diagnostics. Investigating deeper, extension officer own knowledge is gained from the explicit knowledge learnt in training and implicit knowledge learnt in practice. Further more explicit knowledge is based on published research work where journal are part of.

Information is reliable and valuable only when it is credible a credible source. This study conclude that published research work and tacit knowledge by the extension officers are the most credible and reliable sources of agricultural diagnostic information.

In the context of artificial intelligent system requirement, the results indicate that the system which was to be developed requires having a system manager whose work would be to search from the journals, collect and input information on maize diseases and management into the system.

The results from table 4.2 revealed that, 56.7percent of the farmers get agricultural diagnostics information from extension officers, 55.6 percent from Radio and 47.8percent from Agro vets shops. The use of mobile phones short messages and mobile application is seen to be making gains at 10percent and 1.1percent respectively

Kituyi-Kwake, A. and Adigun, M.O. (2008) in their study found out that, The majority of the farmers (130; 65percent) use the radio for their information needs, while 71 (36percent) use the TV. While 17 (9percent) respondents use films for their information needs, there are more respondents who use the cell-phone (14; 7percent), compared to those who use the telephone (8; 4percent). The video is used by 10 (5percent) respondents for agricultural information needs. Only 5 (3percent) respondents use mobile-cinemas. Notably, there are no respondents who use the computer/Internet and CD-ROM. These finding were similar to those of this study in regards to radio and television usage. However, their findings differed with that of this study on the use of mobile phones and computer. This difference can be attributed to the time factor. There have been a lot of changes in the farmer population from 2008 when they did their study and 2015 when this study was undertaken. The difference which is the increase from 7percent to 98percent mobile phone usage, are mainly due to the access and knowledge increase on the usage of mobile phones and computers in comparison to 2008. On the other hand, there is a light increase in the usage of radio and television for access of information. This can also be attributed to advancement in electricity infrastructure and the falling prices of these ICT tools hence many farmers can own them. The increase is from 65percent to 88percent for radio.

From table 4.3, farmers who access agricultural diagnostic information from extension officers, internet and agro vet are negatively correlated. This implies that as the number of respondents who access agricultural diagnostics information from extension officer increases, the number of farmers who get the same information from the internet and agro vets within the same sample decreases and the vise verse is true.

There was a positive correlation between Internet, radio and television similar to Agro vet, radio, television and SMS are positively correlated. Radio TV and SMS are positively correlated. This implies that, it is possible and easy to move farmers who rely on television, radio and agro vet to a mobile phone based information source. Farmers who depend on extension officers do not embrace any other source of information. It is also better to develop information systems that incorporates all the positively correlated sources to ensure farmer reach ability. This group could change to any other source of information through training by the extension officers. With an artificial intelligent system which is fully supported by extension officers as shown in the previous chapter, moving these farmers to another technology will be easy. Moving farmers who rely on extension officers for information to internet based or mobile phone based information source will require more efforts such as training and the use of the extension officers as trainers of trainers.

The above findings were similar to a study done by ICT in agriculture which found out that farmers majorly get their agricultural information from extension officers and farmer organization. Their study proceeds to recommend that farmer organizations as sources of agricultural information can work better if the use of ICT is incorporated to improve information access and sharing. (http://www.ictinagriculture.org/sites/ictinagriculture.org/files/final_Module8.pdf)

8.1.3 Diagnostic information content requirements

The results in table 3.4, the study found out that the extension officers require full information related to the pests and diseases. The results indicated 100percent need, for entire diagnostic information content by the extension officers. This implies that the artificial intelligent system for diagnostic and management of maize diseases should provide information to extension officer and the content must include: the name of the disease, scientific name, all the symptoms, management options, and therapeutic products, how to apply the therapeutic product and where to purchase. Furthermore, the implication would influence the database design. The database must be designed such that it would accommodate the entire information requirement. It can therefore be concluded that the information content required by the extension officers in regard to disease diagnostics should include all aspects of disease symptoms, management option and the prescription.

Table 4.4 represents the various aspects of diagnostic information and percentages of the farmers who needed the information. From the results all the content presented to farmers received a significant level of need, considering the fact that the lowest, being scientific names of the disease and pest, was 18.9percent level of preference.

The results of Table 4.5 show that, there was a strong positive correlation between the name of the diseases and pests and the scientific name of the diseases and pests. This meant that, as the number of farmers who needed to know the name of the disease increased, in the same population, the number of farmers who needed to know the scientific name of the disease and the pest also increased. The results also showed that there was a positive and significant correlation between the name of the diseases and pests and their symptoms. This implied that as the number of the farmers who wanted to know the name of the pest and diseases affecting their crop increased, within the same population, the number of the farmers who needed to know more symptoms of the disease and/or pest also increased. There was a strong and significant positive correlation between the name of the pest and/or disease and the management option. This implied that as the number of farmers who wanted to know the name of the diseases and/or pest increases, the number of farmers within the same respondent population, who wanted to know the management options also increased. The trend continued to include the name of the chemical to be applied and how to apply it. The two factors were positively and significantly correlated to the name of the disease. Therefore it was deduced that, the farmer who wished to know the name of the disease and/or pest, also wished to know the symptoms, management options, name of the chemical to apply and the dosage, and how to apply the prescribed treatment option (product).

The data in Table 4.3 indicated a positive correlation between the scientific name of the diseases and/or pest, how to apply the dosage and where to purchase the drugs/chemicals. This implied that as the number of the respondents who wished to know the scientific name of the disease and/or pest increased, the number of the farmers within the same population who wished to know how to apply the chemicals and/or dosage and where to purchases the chemical/drug also increased. Therefore it can be deduced that those who wished to know the scientific name of the disease and/or pest also wished to know where to purchase the drugs/chemicals and how to apply it.

The results in Table 4.3 revealed that symptoms were positively and significantly related to management options, name of the chemical to be applied and how to apply it. This showed that as the number of the respondents who wished to know more symptoms increased, the number of respondents within the same population who wished to know the management options, name of the chemicals to be used and how to apply the chemical also increased. Therefore it can be deduced that farmers who wished to know more symptoms of the disease and/or pests affecting their maize, would also wish to know the various management options, name of the chemical/drugs to apply and how to apply the prescribed chemical/drug.

Based on the study findings of table 3.4, 4.4, and 4.5 it can be concluded that famers and extension officers consider agricultural diagnostic information adequate only when the content includes: the name of the disease and/or, the scientific name of the disease and/pest, more symptoms of the disease and/or pest, the management options available to control, prevent and cure the disease and/or pest, the name of the chemical/drug to apply/administer, how to administer/apply the prescribed drug/chemical and where to purchase the chemical/drugs from.

The findings were found to be unique. There was no previous study which had sort to understand the farmer and extension officer's view on satisfactory diagnostic information content. The finding therefore contributes new knowledge to this field.

8.1.4 Information format preference of extension officers for receiving diagnostics information

In Table 3.5, half of the extension officers preferred receiving information in print form and printable format. Print form in this case included written and visual picture. 5.6percent preferred receiving the information through email which also includes written and visual forms, 38.9percent preferred receiving the information through a printable mobile and computer web based interfaces. 22.2percent preferred receiving information through a mobile SIM based applications.

Therefore, the three significant information receiving form and format are print (written and audio visual) which included, email format and WebPages. Please note that USSD coded information and SIM based application are both mobile interactive technologies and they form a third form. USSD and SIM application are also written but are not printable. This information will guide the development of the user query interface and the results delivery form by the system to the extension officers and farmers.

It was therefore concluded that the extension officer would prefer to receive written and visual information. It was also revealed that the extension officers would prefer the information in a format which is printable. It may be concluded that the final information content given to the extension officer by the system must be in a printable format. The preference for written/printed information was attributed to the need for reference and records by extension officer

Analysis of data presented in Table 3.6 revealed no significant correlation between the various information formats which the extension officers would prefer to receive their information on agricultural diagnostics. This shows that no individual characteristic influences the respondents' choices on the various query interfaces they chose.

There was however no other study similar to this which had been done previously hence the lack of literature to compare and contrast with the findings.

8.1.5 Preferred information form and format for delivering information to Farmers by extension officers

Table 3.7, findings revealed that 66.7percent of extension officers preferred to deliver agricultural diagnostic information in printable and written formats. Other forms of delivery included Verbal phone call and verbal face to face formats with a preference rating at 11.1percent for each case. However, only 5.6percent of the respondents preferred the webpage as a mode of delivery. WebPages can be also used as a user (delivery) interfaces to farmers for the printable written and visual formats. It is therefore important to use web based interface to deliver agricultural diagnostics information to farmers. This is because the preferred form and format is printable, written and visual. The web based user interface would be a convenient and appropriate mode for delivery of agricultural diagnostics information in a remote manner/format/location.

Table 3.8 shows a strong positive and significant relationship between web-based information format, printable format and email format. This is a clear indication that farmers who prefer web based information form and format also prefer email and printable format of information

8.1.6 ICT tools

ICT tools considered during this study are all common with the extension officers except computers. In table 3.9, 27.8percent of the extension officers owned a computer. On the other hand, all extension officers own mobile phones even though not all of them own smart phones, 38.9percent of them own smart phones.

The study findings revealed that all extension officers owned mobile phones, radios and TVs. However, not all of the respondents owned smart phones, this indicates that application based diagnostics system would not be appropriate to the entire extension officer apart from the 38.9percent who owns the smart phone. It is important to note that the mobile phones referred to, during the study, was basic feature mobile phones with internet features (Wireless application Protocol).

The results presented in Table 3.10 revealed a significant positive correlation between extension officers who owned smart phones and those who owned computers

The results in table 4.6 revealed that 97.8percent (88/90) of the farmers own mobile phones. Fifty percent (50percent (45/90) of the farmers have smart phones which means that the 47.8percent (97.8percent-50percent=88-45) have feature phone. The feature phone presented were those that have internet/WAP. Radio also emerged as a frequently used ICT tool with 80percent (72/90) farmers using the tool. It can be deduced that transfer of agricultural diagnostics information through mobile phones will be the most preferred mode of communication. However, the above finding would not be conclusive enough and therefore it was important to understand the correlation between the ICT tools for better conclusion

Okello et, al, (2010) in his study found out that 99 percent of farmers had seen and/or heard of mobile phones and that the high level of awareness was the same for both male and female which was similar to the finding of this study was. However, he found out that only 36.3percent owned mobile phones. This could due to the duration which has elapsed since he conducted his study in 2010 and in 2015 when this study was done. The high level of awareness which he found out could not translate to ownership. However, the situation has now changed with the introduction of cheap mobile phones, advancement in technology, improvement in farmer disposable income hence ability to buy mobile phones, increased number of young population joining agriculture among other factors.

The results presented on Table 4.7 revealed that, computers ownership have positive but weak correlation with mobile phones and smart phones. There was a weak negative correlation with radio and television. This implies that ownership of computers was not influenced by ownership of other ICT tools. However, from Table 4.6, 21.1percent of the farmers have computers, hence forming a significant portion of the population. It is therefore important to consider using of computers in exchange of agricultural diagnostic information between farmers and extension officers.

Conversely there was a positive and statistically significant correlation between ownership of mobile phones with ownership of smart phones and radio. This implies that as the number of the respondents who own mobile phones increases, among them, the number of those who also own smart phones and radios also increase. It was also observed that majority of farmers who owned mobile phones also had radios because the mobile phones have radio as a feature within them. This means that mobile phones are an important ICT tool used by farmers. There was therefore a strong and significant positive correlation between use of radio and mobile phones. There was also a positive but not significant correlation between use of mobile phone and television. Radios had a positive and significant correlation with television.

These findings imply that conveying agricultural diagnostics information through mobile phones might be easily adopted by people who own mobile phones, smart phones radios and television sets. Mobile phones owned by respondents had internet/web application. It is therefore proposed that web based user interface would be appropriate even for the 21.1percent of respondents who owned computers.

8.1.7 Computer Use

Although the study findings in table 3.9 revealed that 27.8percent of the extension officers owned a computer, respondents were asked to respond to what features they use in their computers. The finding in table 3.11 shows that, 27.8percent use their computers for document preparations (Microsoft office) such as word documents; excel file and PowerPoint presentations among others and for accessing internet (internet explorer and other web engines). 22.2percent also use their computers for sending and receiving emails. It can be deduced from the data that the respondents who use computer are 27.8percent and 22.2percent of them use it for internet access and sending and receiving emails respectively. 22.2percent is a significant portion of the population hence their requirements must be considered in the system development. Accessing email and browsing the internet are features which fully depend on the internet. Browsing the internet involves the access of WebPages. Some emails are also accessed through web pages. The user interface must therefore be web-based for computer users since the computer owner's use their computer to access internet and to prepare documents. The web-based user interface will also be applicable to mobile phone users since all respondents had mobile phones which could be used to access internet.

The results in table 3.12 revealed three main finding: strong positive and significant correlation between accessing internet and document preparation, significant strong correlation between sending and receiving email and accessing internet, significant strong correlation between document preparation and sending and receiving email. It is shown that computer users are currently using their computers for three major purposes. These are accessing the internet (web-pages), sending and receiving email (Internet based) and document preparation (print and visual files). It is worth noting the overlap which exists on the users which shows that it is the same user who actually uses their computers for the three reasons. It can be deduce that the extension officers, who already have computers, would require a diagnostic system which is web-based. The content of the web based system should be in print and visual forms and should also be in a printable format as earlier revealed in the study.

Despite the fact that only 21.1percentof the farmers owned computers as shown in table 4.6, farmers were asked if they interact with computers from elsewhere and what they actually do with the computers. The farmers were presented with the various functions of a computer. The aim of the study was to establish the self efficacy with the various functions of computers in order to identify the best mode of delivery of agricultural diagnostics information using computers. Table 4.8 shows the various computer uses and the results in percentages using computers per the respondents

Analysis of data presented in Table 4.8 revealed that, 3.3percent of the respondents use computers to listen to music and access social media websites. A significant 20percent of the respondents also use computers to access internet. This implies that information which is conveyed through computers should be web based for ease of adoption as the respondents self efficacy with web sites is high, given the experience gained by accessing social media and internet

Analysis of data presented in Table 4.9 revealed that preparation of documents was positively and significantly correlated with access of internet, receiving and sending emails and developing of computer programs. Preparation of documents was also positively but not significantly correlated with transaction management. This implies that as the number of respondents who use computers to prepare documents increases, the number, in the same population of respondents, who use computers for accessing internet, sending and receiving email and developing applications also increases. Further, as the number of the respondents who use computers to execute transactions increases, the number of the respondents accessing internet and developing programs also increases but not significantly.

The data also showed a positive and significant correlation between accessing internet, developing programs, sending and receiving email. The overlap of factors shows that those who use computers for emails and developing programs also access the internet. This observation indicates that a web based agricultural diagnostics information system would facilitate access among farmers and extension officers

8.1.8 Mobile phone Usage

Extension officers were asked to choose the functions and features which they use their mobile for. Several choices were presented to the extension officers. The results in table 3.13 revealed that all the extension officers (100percent) use their mobile phones to make and receive calls, none of the extension officers was using their mobile phones for document preparation, 27.8percent use their mobile phones for making transactions such as M-Pesa, 55.6percent use their mobile phones for accessing the internet, 44.4percent use their phones for accessing applications, 94.4percent were utilizing the SMS facilities, 11.1percent were utilizing the social media access and communication applications(face book up) , 33.3percent were accessing and sending the emails and 22.2percent were accessing social media websites(face book website). These findings were similar to those of Crandall Angela (2014) in her study titled Kenyan Farmers' Use of Cell Phones: Calling preferred over SMS. In her study, she found out that 100percent of the farmers use their mobile phones for calling as compared to sending and receiving SMS.

From Table 3.7, verbal phone call was not preferred as a means to communicate diagnostics information to both the extension officer and farmers. Hence even though making phone calls is the most utilized feature in mobile phones at 100percent, it cannot be put as a requirement for the system information delivery form and format. The use of mobile phones to access internet (web-pages) is preferred by 55.6percent of the respondent hence web based system interface is recommended for the system.

Analysis of data in Table 4.6 revealed that, 97.8percent of the respondents had mobile phones, 50percent of the respondents had smart phones and 47.8percent had feature phones. It was therefore important to understand the various functions of the mobile phones with which the respondent had high self efficacy. Table 4.10 represents the various functions of the mobile phones which were presented to the respondents.

From Table 4.10, making calls is the mostly used function of a mobile phone among farmers at 97.8percent. Sending and receiving short messages is also a well used function by the farmers at 92.2percent. Accessing the internet is equally a known function of the mobile phone with 48.9percent of the farmers using it. The use of application and social media through mobile phone is also embraced by 33.3percent of the farmers interviewed in this study.
The aim of this is to identify the functions with high self efficacy among farmers and with the ability to be accessed remotely by several farmers at the same time

Analysis of data in Table 4.11, revealed a positive and significant correlation between the use of mobile phone for calling and accessing internet. There was also a positive and significant correlation between the use of mobile phone for sending and receiving SMS and accessing internet. This implies that as the number of those who use the mobile phone for calling and sending short messages increases, within the same respondents the number of people using the mobile phone for accessing the internet also increases. Based on the results in Table 4.10

showing calling and SMS functions as the most used, it can be deduced that access to internet is also on the increase. Inputs on technology transfer such as training would improve adoption of access to internet. An internet based agricultural diagnostics information system would therefore offer high farmers self efficacy, provide access remotely, and can be accessed by several people at the same time as opposed to calling and sending short messages who have limitations in terms of the number of people which can access at the same time and the volume of the content of information to be delivered

8.1.9 Use of Input commands

In table 3.15, the study findings revealed that the Web based interactive input method was preferred at 55.6percent. Mobile application was also preferred at 33.3percent. USSD coded input method was not preferred. This implies that web based input/query forms will be appropriate of the agricultural diagnostic intelligence system.

The study findings revealed (0.791) a very strong negative but significant correlation between web based and mobile applications input/querying technologies. This implies that, those with smart phones and can install application would not prefer a web-based query system, while those with basic phones who are the majority at 60.2percent prefer web-based application. It therefore means that web-based interface is still the preferred choice since those with smart phones have the ability to access web-based interface in addition to the ability to install applications.

From Table 4.12, web based interface is preferred at 60percent. USSD code interface, SMS based interface and mobile application are also significant at 26.7percent, 23.3percent and 28.9percent respectively. Based on the results, web based user interface will have a higher and quick adoption rate as the self efficacy of farmers with the interface technology is already high

8.1.10 Access to ICT channels

The study findings in table 3.17 revealed that Internet and GSM are available to all extension officers, while FM and TV waves are also available but not to all the extension officers. GSM channel has the ability to be used for phone calls and SMS. The GSM also provide the internet channel (Safaricom internet services) this therefore means that GSM and internet channels would provide larger geographical coverage than the frequency modulated waves and the television waves. Hence, the channel to be used for the system must be both GSM and internet channel.

Table 3.18 presents the result of the correlation between individual characteristics and the access to various ICT channels. The results revealed a very strong positive and significant relationship between GSM and internet channels among the extension officers. There is also a very strong positive and significant correlation between TV waves and Radio waves. There is however very weak correlations between the channels and education. GSM and internet channels are having a wider reach and those with GSM also have internet. The system to be developed must therefore operate on an internet channel.

In table 4.13, GSM channel had the widest coverage among farmers at 93.3 percent. Internet on the other hand had the lowest coverage at 48.9 percent. The study findings revealed that GSM channel had the ability to carry the internet channels through the mobile telephones. The two channels therefore go hand in hand. On the other hand, FM wave was the second largest channel at 92.2 percent. It is important to once again highlight that GSM has the ability to carry FM waves as well through mobile phones.

Based on the study findings, it can be concluded that GSM channels would be the most preferred communication channels as it provides a suitable platform for internet and radio channels.

Analysis of data in Table 4.14 revealed a strong positive and significant correlation between GSM, radio waves and TV waves. As GSM channels also provide a platform for internet channels, internet is a subset of GSM. GSM also provides a platform for radio waves and sometimes TV waves. Mobile phones have been produced with internet, Radio and TV enabled feature. Based on the study findings it is concluded that GSM channels provide the best channels for connecting the agricultural diagnostic system to the farmers and extension officers.

8.2 Electronic Database

The result in table 3.4, 4.4 and 4.5 showed the information content considered satisfactory by the extension officers and the farmers. The results indicated that farmers and the extension officers considered diagnostic information satisfactory only when the content includes the name of the disease/pest, the scientific name of the diseases/pest, the symptoms, the management options, the chemicals to be applied, how to apply the curative measures, and where to buy the drugs/chemicals. This information served as the database content. The results in table 3.2, 3.3, 4.2, and 4.3 showed the various sources of diagnostic information currently used by the extension officers and farmers. The extension officers informed the study that, some of their reliable information sources were the journals, seminars, and their own knowledge among others. Farmers on the other hand informed the study that their sources of diagnostics information included extension officers, radio, agro vets and mobile phone among others. 100percent of extension officers receive some of the diagnostics information from seminars organized by the Government. The training in seminars is based on published research work. 50percent of the extension officers also get the diagnostic information from Journals. 77.8percent support the diagnostic work from their knowledge which they learnt in colleges and universities as students. The learning at the universities and colleges are also informed by research publications. In addition, there is strong positive correlation between journals and seminars, seminars and own knowledge, and own knowledge and Journals. On the other hand 56.7percent of farmers get diagnostic information from extension officer, 55.6 percent from Radio and 47.8percent from Agro vets shops. The use of mobile phones short messages and mobile application is seen to be making gains at 10percent and 1.1percent respectively. There is huge reliance on extension officers who also get their information from published work. This information was used to guide the database design and content. The information considered satisfactory by the farmers and extension officers informed the data about diseases and pests to be collected, the data collected informed the database structural and the architectural designs. The various information sources which led to the conclusion of published research work and journals as the credible diagnostic information source, informed the reliable information source and the mandatory inclusion of system administrator whose work is to collect the new information on maize diseases and pest and their management options and continuously update in the database. The database schema and design diagram are represented in figure 9 and 10 respectively.

8.3 Formulation of the Artificial Intelligent Modules

The user centric approach used during this study revealed key information which informed the model used.

From the discussions earlier in this chapter, the results from table 3.5 revealed that extension officers preferred receiving diagnostics information in a written form and printable format through a webpage. Results from table 3.7 also revealed that extension officers prefer to share diagnostic information, in a written form and printable format through webpage, to farmers. Table 3.8 shows a strong positive and significant relationship between web-based information format, printable format and email format. This indicated that extension officers who prefer web based information form and format also prefer email and printable format of information

More findings in chapter three of this study revealed that extension officer owned computers and mobile phones and that the extension officer's preference was to receiving and sharing information on a web-based platform as the query interface. In addition extension officers had access to GSM channel than any other ICT channels.

Conversely, farmer requirement findings, in chapter four, also indicated that 97.8percent of farmers owned mobile phones with wireless application protocol and 21.1percent owned computers. The finding in table 4.6, 4.7 and 4.8 also indicated that farmers would prefer receiving diagnostic information through a web based application. In addition, farmers indicated that they had very high self efficacy with web-based query interface. 93percent of the farmer had access to GSM channel.

The above finding guided the modeling of the user interface. The user interface was modeled into two windows. The first window was the farmer and extension officer interface and the second window was the system administrator interface.

Analysis of data collected from existing related system models was used to model diagnostic system. The system was divided into two components namely the backend architecture and the frontend Architecture

The backend model was borrowed from Onsumo (2009). The model called Case Based Reasoning which is driven by the four sub-models namely retrieves, reuse, revise and retain. Figure 11 and figure 12 represent the model.

The frontend architecture provided two models through which the users could interact with the system. The two modules are WAP and the Website. These two modules were informed by the user requirement. WAP module which relied heavily on the mobile phone with Wireless application protocol through the GSM channel and through the internet to connect to the CBR system is represented in figure 14. The Website module was also informed by the user requirement and use of computers by the users. The website module is represented in figure 13. These finding were similar to those of Orwar et al (2009) and Onsumo, (2009)

CHAPTER NINE

9.0 GENERAL CONCLUSION AND RECOMMENDATION

Conclusions

- Extension officer obtain agricultural diagnostic information mainly from seminars conducted by the Government and from journals.
- Extension officers prefer access to full content of agricultural diagnostic information regarding the names of pests and diseases, symptoms, diagnostic features as well as treatment and prescription.
- Extension officer prefer to obtain agricultural diagnostic information in printable form through a web page and can be availed as hard copy.
- Extension officers preferred ICT tools given the form and format requirements are mobile phones and computers
- Extension officers have high self efficacy on the use of computers for document preparation(Microsoft office) and web browsing (internet access)
- Extension officer's posses high self efficacy on the use of mobile phones web browsing(internet access), short message services and calling services
- Extension officers have coverage and access of internet and GSM(WAP) ICT channels
- Farmers use extension officers, radio, TV, and their existing knowledge to access agricultural diagnostic information. They also use internet, mobile phone application and short message services. The use of mobile phone is gaining dominance. This trend should be considered in developing an artificial intelligence system
- The contents of agricultural diagnostic information required by farmers should include; The name of the disease and or pest, The scientific name of the disease and or pest, The symptoms of the disease and or pest, The available management option, The chemicals and or drugs to be administered, How the chemicals and or drugs should be administered, Where the chemical and or drugs can be purchased

- The mobile phones and computers are the most appropriate ICT tools for artificial intelligence system for exchange of agricultural diagnostics information.
- The internet and GSM (WAP) are the appropriate ICT channels for sharing diagnostics information to many farmers at the same time.
- Farmers have high self efficacy with browsing the internet and accessing websites using computers and mobile phones.
- Farmer have high self efficacy with web based user interfaces.

Develop an electronic database for existing knowledge and practices on Maize pests and their management

- An electronic database for existing knowledge and practises on Maize pests and their management can be developed and can provide easy storage, manipulation and retrieval.
- The study validated the feasibility of development of an electronic database for maize diseases and their management.
- The study demonstrated that the electronic database can be used as the knowledge base for the artificial intelligent systems for diagnosis and management of pests and diseases affecting maize in Kenya.
- A typical algorithm for calculating nearest neighbor and the case based reasoning module, where *w* is the importance weighting of a feature (or slot), *sim* is the similarity function, and fI and fR are the values for feature *i* in the input and retrieved cases respectively were suitable for the artificial intelligent system.
- Artificial intelligent systems can provide diagnostics services to the farming communities.

Recommendations

a) Based on the conclusions above it was recommended that:

- There for the Government and the county Governments to develop an artificial intelligent system for diagnosis and management of maize diseases in their respective areas.

- System manager is required to search, collect and input information on pests and diseases obtained from seminars and published literature into the system, during actual system development and to update the.
- Information accessed by extension officers in relation to disease diagnostics must be included.
- The electronic database designed must accommodate all requirements for agricultural diagnostics information.
- The final information content given to extension officer by the system must be in a printable format and must be accessed through Webpage and internet based applications
- Future artificial intelligent system for agricultural production must have mobile phone interface and web based interface.
- The contents of agricultural diagnostic information conveyed to the farmers should include;
- The name of the disease and or pest
- The scientific name of the disease and or pest
- The symptoms of the disease and or pest
- The available management option
- The chemicals and or drugs to be administered
- How the chemicals and or drugs should be administered
- Where the chemical and or drugs can be purchased
- Agricultural information system to be developed in the future must incorporate mobile phones and computers as an appropriate ICT tools.
- Future information system for agriculture must us internet and GSM (WAP) as ICT channels for sharing information.
- Because of the farmers high efficacy to accessing and sharing information through the internet, web based systems will be appropriate for future systems development.

- Studies meant to establish electronic database of all crops and livestock should be undertaken.
- A study to implement and evaluate the adoption of the artificial intelligent system should be undertaken.
- The Government of Kenya and the county Government in Kenya should adopt and implement the artificial intelligent systems for maize diseases diagnostics and management. This will ensure timely, efficient and cost effective delivery of diagnostic services.

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11.0 APPENDIX

Appendix I A: Extension officer interview Guide

A ARTIFICIALINTELLIGENT SYSTEM FOR DIAGNOSIS AND MANAGEMENT OF MAIZE DISEASES IN KENYA

Extension Officer Interview Guide

This interview guide is aimed at collecting information from the extension on their needs in an automated computer aided diagnostics system for maize. Any information collected from this interview guide shall not be used for any other purpose apart from the one started here. The study is being undertaken by Mr. Hillary Nyanganga Thadias who is a Phd student at the University of Nairobi, Faculty of Agriculture, and Department of Agricultural Economics. Provided that a sufficient level of response is received, this research intends to develop an expert system that will facilitate disease diagnostics in maize.

Name:……………………………………………………

County:………………………………………………….

Sub-county………………………………………………..

Contact………………………………………………….

1. Gender Male ◯ ale ◯
2. Age

   25years and below 26-◯yrs 31-◯rs 36◯yrs 41-◯rs ◯

   46-50yrs ◯1 and above ◯
3. Highest Level of Education

   Bachelor degree ◯ Post Graduate Diploma ◯

   College certificate ◯ Master ◯

Diploma ◯ PhD ◯

4. From where do you get your maize disease diagnostics and management information from? (can be more than one choice)

a) Journal ◯

b) Internet ◯

c) Self ◯

d) Agro vet shop ◯

e) Radio ◯

f) Television ◯

g) Mobile application ◯

h) Seminars and training ◯

i) Others Please ◯ntion …………………………………..

5. What specific information do you expect to receive from your diagnostics source for you to be satisfied?(can be more than one choice)

a) Name of the disease and pest ◯

b) Scientific name of the disease and pest ◯

c) More symptoms ◯

d) Management option ◯

e) Name of the chemical to apply and the dosages ◯

f) How do apply the prescription ◯

g) Where to purchase the chemical ◯

6. In what form would you like to receive this kind of information

a) Printed paper ◯

b) Verbal phone call ◯

c) Verbal face to face communication ◯

◯

d) Email

e) SMS

f) Webpage

g) USSD coded information

h) SIM Bases technology

7. In what form would you like to convey this information to the farmer?(use numbers 1,2,3 ,4, 5….. to show level of priority)

a) Printed paper

b) Verbal phone call

c) Verbal face to face communication

d) Email

e) SMS

f) Webpage

g) mobile phone application

h) SIM Bases application

8. Do you have below ICT tools(can be more than one option)

a) Computer

b) Mobile phone. If yes ch type?...Smartphone..........yes No

c) Radio

d) Television set

9. What do you use your computer for

a) Document preparation

b) Transaction management

c) Accessing internet

d) Sending and receiving emails

e) Developing programs and applications

f) Listening to music and accessing social media websites

10. What do you use your mobile phone for

a) Making and receiving calls

b) Document preparation

c) Transaction management

d) Accessing internet

e) Accessing applications

f) Sending and receiving SMS

g) Whatsapp and social media application access and communication

h) Sending and receiving emails

i) Listening to music and accessing social media websites

11. What form of input commands do you consider easy to use on your mobile phone

a) USSD code

b) Web based

c) Mobile application

d) SMS

12. Do you have access to the below ICT channels

a) Internet

b) GSM (Global system for mobile communication)

c) Frequency modulated waves(radio waves)

d) Analogue or digital Television broadcasting waves

End

Appendix I B: Farmers Interview Guide

A ARTIFICIALINTELLIGENT SYSTEM FOR DIAGNOSIS AND MANAGEMENT OF MAIZE DISEASES IN KENYA

Farmers Interview Guide

This interview guide is aimed at collecting information from the farmer, extension offices and researches on their needs in an automated computer aided diagnostics system for maize. Any information collected from this interview guide shall not be used for any other purpose apart from the one started here. The study is being undertaken by Mr. Hillary Nyanganga Thadias who is a Phd student at the University of Nairobi, Faculty of Agriculture, Department of Agricultural Economics. Provided that a sufficient level of response is received, this research intends to develop an expert system that will facilitate disease diagnostics in maize.

Name:……………………………………………………

County:………………………………………………….

Sub-county…………………………………………………..

Contact………………………………………………….

13. Are you a maize farmer? Yes…………No………….
14. Gender Male ◯ le ◯
15. Age

25years and below 26- ◯ yrs 31- ◯ rs 36- ◯ yrs 41- ◯ rs ◯

46-50yrs ◯ 1 and above ◯

16. Highest Level of Education

Primary School	◯	Bachelor degree	◯
Secondary School	◯	Post Graduate Diploma	◯
College certificate	◯	Master	◯
Diploma	◯	PhD	◯

17. Farm size (farmers only)(can only be one choice, sum of the total land under maize)

10 acres and below ◯

11-20 acres ◯

21-30 acres ◯

31-40acres ◯

41 and above ◯

18. From where do you get your maize disease diagnostics and management services from? (can be more than one choice)

j) Extension office ◯

k) Internet ◯

l) Self ◯

m) Agro vet shop ◯

n) Radio ◯

o) Television ◯

p) SMS ◯

q) Mobile application ◯

r) Others Please ◯ntion …………………………………..

19. What specific information do you expect to receive from your diagnostics source for you to be satisfied?(can be more than one choice)

c) Name of the disease and pest ◯

d) Scientific name of the disease and pest

c) More symptoms

d) Management option

e) Name of the chemical to apply and the dosages

f) How do apply the prescription

g) Where to purchase the chemical

20. In what mode would you wish to receive this information?(use numbers 1,2,3 ,4, 5….. to show level of priority)

i) Printed paper

j) Verbal phone call

k) Verbal face to face communication

l) Email

m) SMS

n) Webpage

o) USSD coded information

p) SIM Bases technology

21. Do you have below ICT tools(can be more than one option)

e) Computer

f) Mobile phone. If yes ch type?...Smartphone..........yes No

g) Radio

h) Television set

22. What do you use your computer for

g) Document preparation

h) Transaction management

i) Accessing internet

j) Sending and receiving emails

k) Developing programs and applications

l) Listening to music and accessing social media websites

23. What do you use your mobile phone for

j) Making and receiving calls

k) Document preparation

l) Transaction management

m) Accessing internet

n) Accessing applications

o) Sending and receiving SMS

p) Whatsapp and social media application access and communication

q) Sending and receiving emails

r) Listening to music and accessing social media websites

24. What form of input commands do you consider easy to use on your mobile phone

e) USSD code

f) Web based

g) Mobile application

h) SMS

25. Do you have access to the below ICT channels

e) Internet

f) GSM (Global system for mobile communication)

g) Frequency modulated waves(radio waves)

h) Analogue or digital Television broadcasting waves

End

Appendix II

Secondary data collection tools which will be used to capture maize diseases and pests, their symptoms and management option

Pathogenic Diseases

Disease	symptom	Part affected	Picture	Name of pathogen	Modern management options	Specific drug/ Chemical to be applied	Frequency And quantity to be applied

Nutritional Related diseases

Deficient Nutrient	Symptoms	Part affected	Picture	Traditional Management option	Modern management options	Specific drug/ Chemical to be applied	Frequency And quantity to be applied

Pest related diseases

Pest name	Symptoms	Part affected	Picture	Traditional Management option	Modern management options	Specific drug/ Chemical to be applied	Frequency And quantity to be applied

Appendix III

Secondary data collection tool for system modeling

Name of the system	Input	output	Accuracy level	Speed	Cost	Expert rule	Bayesian	Statistical	Decision tree