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Web Based Decision Support System for Management of *Grevillea Robusta* Tree Species in Kenya

BY

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ABSTRACT

Forestry research and development decision making critically depends upon availability of integrated information and knowledge organized and presented to forest stakeholders in timely and easily understood manner. Decision Support Systems (DSS) have emerged to meet this need. This project describes the design of a web based DSS for *Grevillea robusta*. The Internet has created great opportunities to develop new approaches to solve technology transfer problems. DSS have been used in forestry to identify insect and damage they cause to trees, advising on herbicides, making silviculture decisions, supporting land use in agroforestry, providing useful and scientific information, tree and shrub selection etc. however, very little has been done to compile a comprehensive knowledge for development and management of *G. robusta* tree in Kenya. In this project, the author has managed to build a web based DSS system for *Grevillea robusta* tree. The system has three components, the data manager, the model and the expert system components. The database manager is used to manage scientific data while the model is used to calculate and predict tree growth and yield. The expert module employs a rule-based method for representation of knowledge. The user interface prepares the input data and parameters, executes the program and integrates the DSS software into a seamless system.

DEDICATION

This project is dedicated to my family.

DECLARATION

This project is my original work and has not been presented in any University or college in any country.

Signed by.. 21/April/2011...............

Samuel N. Gatiti.

This project has been presented for examination with approval of the Supervisor at the **University of Nairobi**.

Signed by..

21/4/2011 Mr. Elisha Opiyo

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ABBREVIATIONS AND ACRONYMS

ADO - Active Data Object

AES - Agroforestry Expert System

AI - Artificial Intelligent

AJAX – Asynchronous JavaScript and XML

ASP – Active Server Pages

CBIS - Computer-Based Information Systems

CD – Compact Disk

CM – Centimeter

CPU – Central Processing Unit

CSS - Cascading Style Sheets

DBH - Diameter at Breadth Height

DFD - Data Flow Diagram

DSN – Data Source Name

DSS – Decision Support System

DST - Decision Support Tool

ERD – Entity Relationship Diagram

ES - Expert System

FMDSS - Forest Management Decision Support System

GB – Gigabyte

GDSS - Group Decision Support System

GFAR - Global Forum on Agricultural Research

GIS - Geographic Information System

GOK – Government of Kenya

HIPO - Hierarchical Input Processes

HTML - Hypertext Markup Language

IP – Internet Protocol

ICRAF – International Centre for Research in Agroforestry

ICT – Information Communication Technology

IIS - Internet Information Server

IT - Information Technology

KBES - Knowledge Based Expert System

KBS - Knowledge Based System

KEFRI – Kenya Forestry Research Institute

KRRC - Karura Regional Research Center

LAN – Local Area Network

M – Meters

MA – Moderately Agree

MBMS – Model Base Management System

NRM – Natural Resource Management

MWD - Meriam Webster's Dictionary

PC – Personal Computer

PNW - Present Net Worth

RDBMS – Relational Database Management System

R&D - Research and Development

SA - Strongly Agree

SD – Strongly Disagree

SQL – Sequential Query Language

SSADM - Structured Systems Analysis and Design Method

UK – United Kingdom

UNUAES - United Nations University Agroforestry Expert System

US – United State

USA - United State of America

USDA – United State Department of Agriculture

XML - Extensible Markup Language

CHAPTER ONE

INTRODUCTION

Information is prerequisite for wise forest management decision, but is inadequate in many situations, especially in the context of small-scale farm forest growers in central and eastern highlands of Kenya. According to Kenya Forestry Research Institute (KEFRI 2007), the critical drawback in the management of forests is dissemination of research findings. Forestry science community has not yet found the solution to the problem of getting continuously changing science efficiently and effectively into the hands of those who need it in their daily work, the forest practitioners. Linkages between researchers, tree growers and collaborators are also weak, and most cases information is not available for decision-making. *Grevillea robusta* tree growers are faced with a number of problems; lack of awareness about its importance as source of timber, low adoption among the tree farmers, low production, poor management leading to low yield, problems of pests and diseases, lack of guidelines on how to assess the value of trees.

The Information and Communication Technology (ICT) plays an important role in forestry technology and knowledge dissemination. The use of ICT to transfer information in forestry domain will be investigated in this study. In this work, a research will be conducted in the area of transferring the knowledge and expertise accumulated in forestry research to extension workers and tree growers, using ICT in general and decision support system in particular.

The purpose of this study is to develop a decision support system (DSS) for management of *Grevillea robusta* tree in central highlands of Kenya. The system will consist of an expert system for the species and appropriate decision tool for capturing and dissemination of information and knowledge about research in *G. robusta*, scientists working on the species and publications issued by the researchers. The system is to facilitate exchange and access to scientific and technological information in forestry and rural development topics by end users, as well as the flow of knowledge and information among stakeholders of forestry research and development. The capacity to access information, and to convert it into useful knowledge, is of paramount importance for the development objectives: poverty eradication, wealth creation, sustainable development and increased productivity and competitiveness. Knowledge based systems, an emerging technology in information processing and decision support, may become very useful tools for accessing information and assisting in decision-making processes.

Decision support systems (DSS) are a subset of computer-based information systems (CBIS), which consist of a constellation of variety of information systems. It is an umbrella term used to describe any computer application that enhances the user's ability to make decisions. More specifically, the term is usually used to describe a computer-based system designed to help decision-makers use data, information, and knowledge and communications technology to identify problems and make decisions to solve those problems. A DSS composed of specialized system components may be used to optimize decision-making processes.

DSS linked with specialized systems such as expert systems, databases and model can be used to encapsulate technical information in a suitable form that enable their users (extension workers, tree growers, and researchers) to get customized advice according to their environment. Database consisting of data and documents management repositories can be used to store and retrieve needed information. Computer models using data and parameters can aid the decision maker to predict and evaluate situations. Computer network can be used to disseminate this information to the country and to get global information through the Internet connectivity. Web technology can be used to develop front pages through which information can be accessed.

DSS are recognized as an appropriate technology because they address the problem of transferring knowledge and expertise from highly qualified specialists to less knowledgeable personnel (Rafea & Shaan 1996). In forestry research this transfer is always taking place from research to extension, from extension to farmers, and even from farmer to farmer. DSS can help avail vital knowledge that increases the effectiveness of less experienced personnel. Another application is the estimation of the yield given a simulation model linked with the DSS. The prediction of models can serve the decision makers in deciding the trees product volumes with the most income and advice on management of tree stands or on the financial possibilities of establishing new stands.

1.1 Motivation

- Training received at school has provided adequate knowledge in developing decision support based systems.
- Readily available expertise from KEFRI's research scientists and forest technologists.
- Curiosity and personal interest in application of (ICT) in forestry research and development.

1.2 Problem Statement

Forestry information sources are highly disjointed. Users have to make decision on grounds of uncertainties due to limited capacity to interpret factors affecting their environment. Technology generated from research is not consolidated and information is not readily available to researchers, tree growers, forest extension personnel or extreme are beyond the users' control. The purpose of this study is to develop a decision support system to disseminate forestry based knowledge and information. The system is expected to collect, store, organize, integrate and disseminate information so as to make it useful to end-users.

1.3 Objectives

The study has the following objectives:-

- To determine if the DSS can perform on par with recognized experts, i.e. scientist or forester with extensive experience of rising and management of *G. robusta* tree species.
- To develop tools to aid in building decision support systems in forestry

- To design and develop decision support system based on farm forestry to assist users when making decisions.
- To model the characteristics of *Grevillea robusta* tree species based on growth and yield.
- To consult with forestry practitioners the suitability of the system in technology transfers.

1.4 Research Questions

The project aims at finding answers to the following research questions.

1) How do we model tree growth and yields using known and yet to be identified factors?
2) What are the diseases that affect *G. Robusta*? How do we model and simulate the role of an expert in the diagnosis of tree pests and diseases?
3) How do tree growers, foresters and researchers make decisions? Is it possible to model decision support tool to help them make decisions more efficiently?

1.5 Justifications

The design and development of the decision support tool is useful as a guideline to forest practitioners to apply the system for the purpose needed. It is important in the state of the world today that demand better decision-making by end users. There are believes that decision of improved quality can still be obtained by improving the process of decision-making. DSS is a tool to enhance the performance of decision makers as they helped them to gain more knowledge, experience and consequently enhance as well as improving the quality of the decision-making. The system is to create knowledge repository that will contain problem-solving experiences in a farm forestry domain that is required to improve the effectiveness of extensions workers and also assist scientists when making decisions.

1.6 Scope

The study is limited to the development of decision support system for management of *G. robusta* tree species with the hope that the results could be generalized to other trees and shrubs in Kenya.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the important components of this research that are the decision support systems in forestry research study. The discussion will elaborate on theory of the components with the explanantion based on the literature review.

2.2 Decision Support Systems

The concept of a decision support system is extremely broad and its definition vary depending on the author's point of view (Druzdel & Flynn 1999). It can take many different forms and can be used in different ways (Alter 1980). Different definitions of DSS are provided by (Turban & Aronson 2004). The author stresses that the central purpose of DSS is to support and improve decision making. According to 'Wikipedia' (2010) DSS is 'a specific class of computerized information systems that supports business and organizational decision-making activities'. A properly-designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions.

2.2.1 Decision Making and Support Systems

Decision making is a process that involves a variety of activities, most of them dealing with the handling of information (Watson, Houdeshel & Rainer 1997). By understanding the dynamics of the process, the decision makers can make decision more effectively and efficiently (Jones 2006). It is considered to consist a set of steps or phases which are carried out in the course of making decision. The process can be conceptualized as consisting of intelligence, design and choice phases (Simon 1960).

Intelligence involves the identification of a problem that requires a decision, and the collection of information relevant to the decision. Design involves the creation and evaluation of alternatives course of action. The decision makers may speculate the possible outcomes based on each of the alternatives. The possible outcomes are reviewed in terms of the organization's purpose (Holsapple & Whinston 2001).

To decide mean to make a choice among alternatives or selection of the course of action. Several of the alternatives may return similar outcome or there may be instances when none of the alternatives seem to satisfy the selection of the decision maker. At this point, the decision maker can either make choice based on what is presented or choose to return to one of ealier stages to reformulate new alternatives or additional information.

According to (Jones 2006), there is a fourth phase that is implementation. Once the alternative has been chosen, the next step is to implement or put the choice into action. This may include alarting affected individuals of what is to be done next or simply reporting which alternative has been selected. The decision making process actually culminates with implementation.

The decision making process involved in forestry research, development and application is composed of several components: the person or group making the decision, the problem, the approach or method to solve the problem, and the decision. DSS are variety of techonologies that can be used to integrate diverse set of information. DSS do not replace the decision making by the land owner or forester, but they facilitate the decision making process by making planning process informed and more objective.

2.2.2 Knowledge Management

Turban and Aronson (2004) define knowledge as 'information that is contextual, relevant, and actionable', while Davenport and Prusak (1998) define knowledge 'as fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information'. The implication is that knowledge has strong experiential and reflective elements that distinguish it from information in a given context. Having knowledge implies that it can be exercised to solve a problem. An ability to act is an integral part of being knowledgeable. Knowledge also includes level of understanding that human attributes to information. Davenport and Prusak (1998) claim that knowledge is derived from information as information is derived from data. According to them, information is converted to knowledge through the process of comparison, connection, understanding relations, conversion, uncovering what others think about information, and consequences how information affect decisions.

Knowledge management can now be defined as process of elicitation, transformation, and diffusion of knowledge throughout an enterprise so that it can be shared and thus reused. Knowledge management helps organizations find, select, organize, disseminate, and transfer important information and expertise necessary for activities such as problem solving, dynamic learning, strategic planning, and decision making (Gupta, Iyer & Aranson 1999). Knowledge management transforms data and/or information into actionable knowledge in a form that when it is made available can be utilized effectively and efficiently throughout the organization (Angus, Patel & Harty 1998).

2.2.3 Types of Decision Support Systems

There are a number of decision support systems. These can be categorized into five types.

2.2.3.1 Communication – Driven DSS

The breed of DSS is often called group decision support (GDSS). They are a special type of hybrid DSS that emphasizes the use of communication and decision models intended to facilitate the solution of problems by decision makers working together as a group. GDSS supports electroninc communication, scheduling, document sharing and other group productivity and decision enhancing activities and involves technologies such as two-way interaction video, bulletin boards, email, etc.

Most communication-driven DSS are targeted at internal teams, including partners. Its purpose are to help to conduct a meeting, or for users to collaborate. The most common technology used to deploy the DSS is a web or client server. For example chats and intant messaging software, online collaboration and net meeting systems. Communication - Driven DSS will exhibit at least one of the follwing characteristics:

a) Support coordination and collaboration between two or more people;
b) Facilitate information sharing
c) Enable communication between groups of people;
d) Support group decisions.

2.2.3.2 Data Driven – DSS

Data - driven DSS are a form of support system that focuses on the provision of internal (and sometime external) data to aid decision making. Most often this will come in the form of data wharehouse that is a database designed to store data in such a way to allow for its querying and anlysis by users.

An example of a data driven DSS would be a Geographic Information System (GIS), which can be used to visually represent geographyically dependent data using maps. These DSS has file drawer system, data analysis systems, data warehousing and emphasizes access to and manipulation of large databases of structured data.

Most data – driven DSS are targed at managers, staff and also product/service suppliers. It is used to query a database or data warehouse to seek specific answers for specific purposes. It is deployed via a main frame system, client/server link, or via the web.

2.2.3.3 Document – Driven DSS

Document – driven DSS are support systems designed to convert documents into valuable business data. While data - driven DSS rely on data that is already in a standardized format that lends itself to database storage and analysis, document –driven DSS makes use of data that cannot easily be standardized and stored.

Document – driven DSS is the newest field of study in Decision Systems. Examples of document – driven tools can be found in the Internet search engines, designed to sift through vast volumes of unsorted data through the use of keyword searches. The three primary forms of data in document driven DSS are:

a) Oral (i.e. transcribed conversion)
b) Written (i.e. reports, publications, memos, email and other correspondence):
c) Video (i.e. TV commercials and news reports).

These systems help users retrieve and manage unstructured documents and web pages by integrating a variety or storage and processing technologies to provide complete document retrieval and analysis. It also access documents such as company policies and procedures, product, specification, catalogs, corporate historical documents, minutes of meetings, important correspondence, corporate records, etc. and are usually driven by task-specific search engine.

Document – driven DSS are more common, targeted at a broad base of user groups. The purpose of such a DSS is to search web pages and find documents on a specific set of key words or search terms. The usual technology used to set up such DSS is via the web or a client/server system.

2.2.3.4 Knowledge - Driven DSS

Knowledge – driven DSS are systems designed to recommend actions to users. Typically, knowledge – driven systems are designed to sift through large volumes of data, identify hidden partterns in that data and present recommendation based on those patterns.

These systems provide recommendation and/or suggestion schemes which aid user in selecting an appropriate alternative to a problem at hand. Knowledge driven DSS are often referred to as managent expert systems or intelligent decision support systems. They focus on knowledge and recommends actions to users based on an analyis of certain knowledge base. Moreover, it has special problem solving expertise and are closely related to data mining i.e. sifting through large amount of data to produce content relationship.

2.2.3.5 Model – Driven DSS

Model – driven DSS support systems incorporate the ability to manipulate data to generate statistical and financial reports, as well as simulation models, to aid decision makers. Model – based decision support systems can be extremely useful in forecasting the effect of changes in business processes, as they can use past data to answer complex 'what – if' question for decision makers.

Model - driven DSS are complex systems that help to anlyze decisions or choosing between different options. These are used by managers and staff members of business, or people who interact with the organization, for a number of purposes depending on how the model is set up. These DSS can be deployed via software/hardware in stand-alone client/server systems, or the web.

The underlying model that drives the DSS can come from various discipline or areas of speciality and might include accounting models, financial models, representation models, optimization models, and others. It uses data and parameters to aid decision makers in analysing a situation. These systems usually are not data intensive and consequently are not linked to very large databases.

2.2.4 The Structure of DSS

According to (Turban & Aronson 2004) a DSS application is composed of the following subsystem, data management, model management, knowledge-based management and user interface.

2.2.4.1 Data Management Subsystem

The data management subsystem includes a database, which contains relevant data for situation and is managed by software called the database management system (DBMS). The data management subsystem can be interconnected with the corporate data warehouse, a repository for corporate relevant decision-making data.

2.2.4.2 Model Management Subsystem

This is a software package that includes financial, statistical, management science, or other quantities that provide the system analytical capabilities and appropriate software management. Modeling language for building custom models are also included. This software is often called a model base management system (MBMS). This component can be connected to corporate or external storage of models.

2.2.4.3 Knowledge-based Management Subsystem

This subsystem can support any of the other subsystem or act as an independent component. It provides intelligence to augment the decision maker's own. It can be connected with the organization's knowledge repository, which is called the organization knowledge.

2.2.4.4 User Interface

The user communicates with and commands the DSS through this subsystem. The user is considered part of the system. Researchers assert that some of the unique contributions of DSS are derived from the intensive interaction between the computer and the decision maker.

The figure below shows the components that form the DSS application, which can be connected to the corporate intranet, to an extranet, or to the Internet. The components provide a basic understanding of the general structure of a DSS.

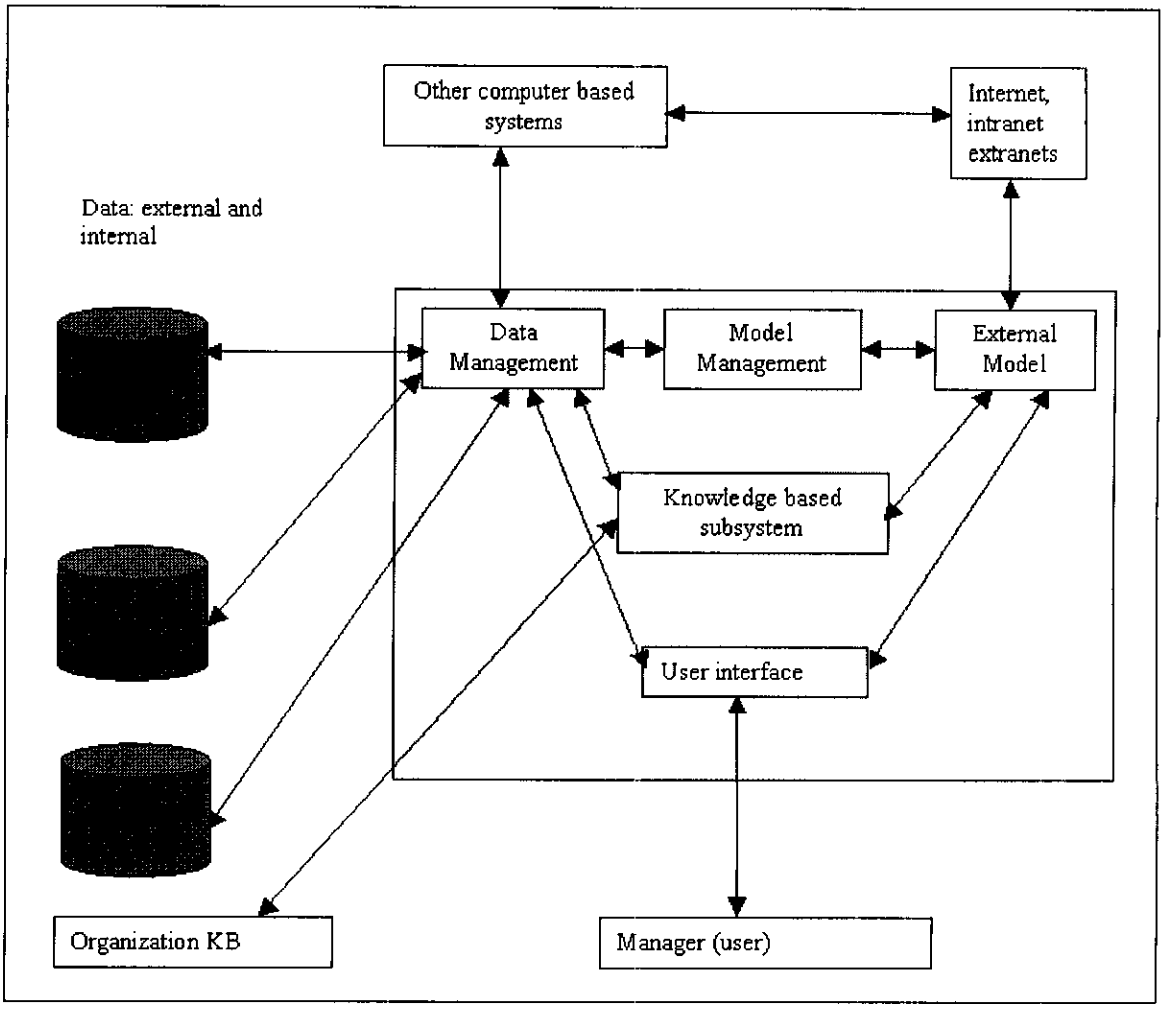

Figure 2: A schematic view of DSS (Turban & Aronson 2004).

2.2.5 Artificial Intelligence and Knowledge Based Systems

The discussion of expert systems, as a sub-category of knowledge-based systems, should be started with the definition of Artificial Intelligence (AI), which is a very broad and often incorrectly understood concept. In popular perception AI is sometimes associated with human like robots or with supercomputers, which sometime tend to take over the world. Despite that this also is part of AI domain let us try to formulate more precise definitions. "AI is the study of how to make computers do things which, people are better at the moment" or that ".... AI is the branch of computer science dealing with symbolic, non-algorthmic methods of problem solving". The more general definition given by Akerkar (2005, p. 2). says that "AI is part of computer science concerned with designing intelligent computer systems that exhibit the characteristics used to associate with intelligence in human behavior".

2.2.6 Expert Systems

Similarly as there is no one definition of AI, there is no one general definition of Expert System (ES). Turban state that ES is a system that uses human knowledge captured in a computer to solve problems that ordinarily requires human expertise. Well-designed systems imitate the reasoning process experts use to solve specific problems. Such systems can be used by experts as knowledge assistant. ES are used to propagate scarce knowledge resources for improved, consistent result. Ultimately, such systems could function better than any single human expert in making judgment in a specific, usually narrow, area of expertise. This possibility may have a significant impact on advisory professionals i.e. financial analyst, researchers, foresters, tax advisors, lawyers and so on (Turban & Aronson 2004). All expert systems have certain common characteristics, which may be formulated as follows (Waterman 2004):

- they exhibit expert performance
- they have high level of skill
- they reason heuristically, using what experts consider to be effective rules of the thumb
- they interact with human in appropriate ways, including via natural language
- they can function with data, which contain errors using via natural language
- they use complex rules
- they represent knowledge symbolically
- they handle difficult problem domain
- they can explain why they are asking questions
- they can justify their conclusion

Knowledge Based System (KBS) and ES are the sub-categories of AI computer software, which go beyond the traditional procedural, algorithmic, numeric, and mathematical representations or models. They are fashioned along the lines of how an expert would go about solving a problem, and they are designed to provide expert advice. They use a knowledge base of human expertise to aid in solving problems. The degree of problem solving is based on the quality of data and rules obtained from human expert. Expert systems are designed to perform at a human expert level. In practice, they will perform both answers by running the knowledge base through an inference engine, a software program that interacts with the user, and process the results from the rules and data in the knowledge base.

2.3 Applications of Expert Systems In Agriculture

In recent years the expert systems and knowledge-based systems have found practical application in many fields of agriculture and natural resources management. The known examples include forestry, agroforestry, horticulture, crop cultivation, weather, soil and dairy herd management. In the area of agriculture, Knowledge-based expert system technology has been applied to a variety of problems since the early eighties. Agriculture domain can further be classified into sub domain namely: plant production, animal production and management of natural resources related to agriculture operations such as soil and water. This study will concentrate here on plant production part as most expert systems in agriculture have been developed in this sub domain. Example areas of expert systems applications related to agriculture are listed by (Rafea 2009). Another way of classifying agricultural expert systems is the domain specific task that this system performs such as: irrigation, fertilization, pest management, diagnosis of plant diseases, and others.

Agriculture expert system developed so far covers most of the knowledge areas for crop management including strategic decision such as variety selection, land preparation, planting, irrigation, fertilization, and harvesting, and tactic decision such as disorder diagnosis, control, and treatment (Rafea 2009). A typical agriculture expert system will ask the user about his/her plantation data for soil, water, weather, and any other abnormal observation and/or requirements, and produce a specific recommendation.

In 1983, Michalski et al developed one of the earliest expert system in the area of plant diseases diagnosis. The PLANT/ds was developed at the University of Illinois as an experimental expert system. The application was used to provide consultation on the diagnosis of Soybean diseases. The system is a component of a general system, PLANT, designed to advise users about the diagnosis and decision-making regarding both crop diseases and insect damage (Michalski et al. 1983).

In 1985, Roach et al. developed a computer-based consultation system for apple orchard management using Prolog at the Department of Computer Science and Applications, Department of Plant Pathology, Physiology and Weed Science Virginia Polytechnic Institute and State University, USA. The system is used for direct dissemination of expert knowledge to agricultural producers through computer programs that increase product quality as well as the profit margin. The construction of an expert system, called POMME was developed to help farmers to manage apple orchards. The system provides advice regarding specific pest management, treatment of winter injuries, drought control and general pesticide selection. The system consists of a sample interaction and the knowledge structures used in the construction of the system. A model of the apple scab disease cycle is incorporated into POMME to give the system a more fundamental reasoning capability from typical rule-based system (Roach et al. 1985).

Another example of using expert system in plant production is COMAX – a system for Cotton Crop Management that was developed in 1986 by Lemmon, a Computer scientist for the United State Department of Agriculture (USDA), Agricultural Research Service. The system has a knowledge base consisting of a sophisticated cotton plant simulation computer program, a set of "if-then" rules, and a computer program called an inference engine. COMAX determines the best strategy for irrigating, applying fertilizer, and applying defoliants and cotton boll openers. Sensors in the cotton fields automatically report weather conditions to the system, and COMAX reevaluates its recommendations daily. COMAX was tested on a large farm and demonstrated excellent results in reducing the unit costs of production (Lemma 1986).

In the area of weed control, a very interesting is the study performed by Schulthess et al. In 1996, a picture-based expert system called NEPER-Weed was developed at Crop and Soil Sciences Department, Michigan State University. The system uses hierarchical classification tool. Text descriptions are replaced with pictures, to minimize the use of technical terms. Hypotheses are established or ruled out on the basis of the user's choices among options presented as pictures. This approach reduces the number of characters required for weed identification and the user does not need to know technical terms. In the system, the classification of grasses is based on the morphologies of the leaf base and leaf surface. Broadleaf weed classification is based on the shapes of the cotyledon and true leaf. The system contains 51 Egyptian weeds. The hierarchical classification tool allowed for a clear separation of the knowledge from the structure in which the knowledge is organized. The object-oriented nature of this approach simplifies adding or removing weeds. This approach can be readily applied to other domains, such as disease identification, fertilizer recommendation, or cultivar's selection (Schulthess et al. 1996).

2.4 Applications of DSS and ES Systems In Forestry

2.4.1 Decision Support Systems in Forestry

Design concept for and implementation of DSS have been evolving rapidly in recent years. Decision Support developed so far focuses on the forest stand or enterprise level with heavy emphasis on timber management support. The concept of forest sustainability has long tradition and current practice of forest management is confronted with an ongoing shift paradigm from sustainable yield and constant forest cover towards sustainability of an increasing diversity of values, goods and benefits. The decision support tools helps forest managers in this complex environment direct a stronger focus on a sustainable forest management. Researchers and Forest managers have had a longer tradition in the development of application of DSS. Decision support systems are maturing and expanding in capabilities and are being used more frequently in actual management practice. On the other hand, DSSs have not yet been widely adopted as standard tools of forest management in most of the world. We may be soon approaching a point in time when existing DSS have matured enough that decision makers in forest management will routinely turn to them for help in their complex decision making environment (Rauscher, Reynolds & Vacik 2005).

In 2005, Twery et al. designed a system called NED-2 from the earlier version to improve project-level planning and decision making by providing useful and scientifically sound information to natural resource managers. Resources addressed include visual quality, ecology, forest health, timber, water, and wildlife. The system was expanded from the previous version of NED applications by integrating treatment prescriptions, growth unit. The NED-2 system is adaptable for small private holdings, large public properties, or cooperative management across multiple ownerships. NED-2 implemented a goal-driven decision process that ensures that all relevant goals are considered; the character and the condition of forestland are known; alternatives to manage the land are designed and tested; the future forest under each alternative is simulated; and the alternative selected achieves the owner's goals. NED-2 is designed to link with the NedLite package for field data collection using a handheld Personal Digital Assistant (PDA), and is constructed to be easy to link to third-party applications. The NED process is being field tested to demonstrate its utility and identify weaknesses. Results of case studies are summarized for two owners, a private individual and the City of Baltimore, Maryland, and its reservoir lands (Twery et al. 2005)

In the same year, Crookston & Dixon developed a system called Forest Vegetation Simulator (FVS) in 2005. The system is a distance-independent, individual-tree forest growth model widely used in the United States to support management decision-making. Stands are the basic projection unit, but the spatial scope can be many thousands of stands. The temporal scope is several hundred years at a resolution of 5–10 years. Projections start with a summary of current conditions evident in the input inventory data. FVS contains a self-calibration feature that uses measured growth rates to modify predictions for local conditions. Component models predict the growth and mortality of individual trees, and extensions to the base model represent disturbance agents including insects, pathogens, and fire. The component models differ depending on the geographic region represented by regionally specific model variants. The differences are due to data availability and the applicability of existing models. The model supports specification of management rules in the input, such as thinning if density is too high. The rules can be extended to represent other factors. For example, the effect of climate change on stand development by entering rules that specify how growth and mortality will change in response to changing climate (Crookston & Dixon 2005).

In 2007, Lu developed an Integrated Forest Management Decision Support System (FMDSS) by integrating LANDIS 4.0 model with ESRI ArcGIS platform. The system was developed with Visual Basic, ESRI ArcObject libraries and Microsoft Access database. The system make simulation preparation of simulation parameters easy for forest managers with friendly graphic interfaces, it also makes available the powerful Geographical Information Systems (GIS) functions and spatial data processing capabilities of the ESRI ArchGIS plaform (Lu 2007).

2.4.2 Decision Support Systems in Agroforestry

In the area of agroforestry, decision support tools (DST) and expert systems help integrate information to facilitate the decision-making process that directs development, acceptance, adoption, and management aspects in agroforestry. Computer Based DSTs include databases, geographical information systems, models, and Knowledge base or expert systems and 'hybrid' decision support systems. These different DSTs and their applications in agroforestry research and development are listed by Ellis et al. Agro forestry lacks the large research foundation of its agriculture and forestry counterpart, the development and use of computer based tools in agro forestry have been substantial and are projected to increase as the recognition of the productive and protective service roles of the tree-based practices expand (Ellis, Bentrup & Schoeneberger 2004).

In 1990 Warkentin et al. presented an Agroforestry Expert System (AES) at the United Nations University (UNU) for planning and design of agroforestry systems. AES is a first attempt to apply this technique to agroforestry. UNU-AES is a prototype Knowledge-Based Expert System (KBES) designed to support land-use (agricultural, forestry, etc.) officials, research scientists, farmers, and individuals interested in maximizing benefits gained from applying agroforestry management techniques in developing countries. This prototype addresses the options for alley cropping, a promising agroforestry technology that has potential applicability when used under defined conditions in the tropics and subtropics. Alley cropping involves the planting of crops in alleys or interspaces between repeatedly pruned hedgerows of fast-growing, preferably leguminous, woody perennials. The primary benefits from this technique include nutrient enrichment, soil improvement, and erosion control. UNU-AES, which is the first known attempt at the application of expert system procedures in the field of agroforestry, uses a total of 235 decision rules to develop its recommendations. With the inclusion of more climatic and socio-economic data and improved advisory recommendations, UNU-AES can be expanded to provide advice on alley cropping in more diverse geographical and ecological conditions and eventually address other agroforestry techniques (Warkentin et al. 1990).

2.4.3 Application of Expert Systems In Forestry

Forestry applications of expert systems are still relatively new, and little information has been compiled on methods for developing and evaluating expert systems in forestry, or on their effectiveness as tools for solving forest problems. This paper addresses the need for such information, and describes various systems developed so far in this domain.

One of the earliest attempts to develop an expert system in forestry was in 1989 when *Rose et al.* designed and completed a prototype for an integrated forest-planning package for use on microcomputers. The microcomputer-based system facilitates the development of optimal operational and strategic forest plans. The system integrates two planning modules. The first, an automated stand prescription writer, utilizes a silvicultural expert system for Lake state species to automate the process of developing stand-level alternatives over a full planning horizon. Another program translates these silvicultural alternatives into economic cash flows. Reflecting the costs of carrying out model based on the Hoganson – Rose algorithms (Rose et al. 1989).

In the same year 1989 Schmoldt & Martin developed a system called PREDICT, an expert system for diagnosing pest damage of red pine stands in Wisconsin. The system runs on IBM or compatible microcomputers and is designed to be useful for field foresters with no advanced training in forest pathology or entomology. PREDICT recognizes 28 damaging agents including species of mammals, insect, and pathogens, as well as two types of a biotic damage. Two development tools were used (EXSYS and INSIGHT2+). Each employs a rule-based method for presenting knowledge, which was obtained from literature and from human experts in the field of forest pathology and entomology. The pest inference rule blocks, for each damaging agent, are based on the abduction model of diagnosis and rules for eliminating a pest from further consideration, diagnosing a pest as a certain, and compiling evidence in favor of a pest. Both development employs backward-chaining control strategy. Input to PREDICT is obtained from pest damage report containing specific information about stand/site conditions, tree symptoms, and signs. Diagnosis from PREDICT take the form of a list of one or more possible agent with corresponding confidence values. Actual and hypothetical test cases were used to refine the knowledge base, and then a separate set of 20 actual cases as a basis for testing and evaluating the completed system. Two version of PREDICT tools were, respectively evaluated and compared with three recognized experts and two field foresters. No significant difference were found between the performance of PREDICT and the experts; however, PREDICT performed significantly better than the two foresters (Schmoldt & Martin 1989).

An expert system called FOREX for integrated silviculture planning was presented by Leboux in 1997. The system makes silvicultural decisions that integrate potential growth and yield, logging technology, economics, wildlife, markets, log prices, and the time value of money. FOREX uses data from simulation model called MANAGE. The user can obtain information on present net worth (PNW), optimal timing of thinning entry, optimal economic stand rotation age, average diameter at breast height (dbh), volume by grade and value of the tree harvested, and depending on the cable yarder or ground based system used, average slope yarding or skid distance, truck class, log-bucking method, and number of thinning desired. FOREX also provide information on the effect of harvesting treatment on wildlife habitat. Users can obtain data on the management objective, and perform a sensitivity analysis simulation. FOREX is also used to predict growth and volume yields, yields of individual wood product, estimate stump-to-mill logging costs, predict cash flows and discounted PNW revenues, project the suitability of habitat wildlife, estimate optimal periods between thinning or other silvicultural treatments. From these data, users can gauge the impact of various silvicultural treatments on wildlife and evaluate management tradeoffs such as longer rotations for wildlife versus shorter ones for fiber production (Leboux 1997).

In 2003, Thomson & Willoughby developed a web-based expert system for advising on herbicides use in Great Britain at Forest Commission, Forest Research in the United Kingdom (UK). The system was used to advise on the relative efficacy of different herbicides for mixes of weed and crop species at different times of the year in a forestry setting. The system assumes that the weed identification and impact assessment or predictions have already been accomplished and that there are not cost-effective non-chemical alternatives. The expert system produces a relative suitability index for each herbicide, as well as an English language discussion of the case (Thomson & Willoughby 2003).

In 2005, an insect identification expert system for forest protection was developed by Kaloudis et al. at Department of Forestry, Technology Institute of Lamia, Greece. The system uses expert knowledge to identify forest insects and proposes relevant treatment. The system could identify more than forty distinct insects, either from some stage of their lifecycle or from damage they cause to trees or from the findings that that they leave in the forest. Once an insect identification is completed, the system can recommend an appropriate treatment, aiming at reducing spread of insects in the whole forest and at minimizing damage. The system is enhanced with photos and drawings that assist the user in the precise and quick identification of an insect. It can be used by unspecialized personnel or inexperienced user, such as forest owners. It can be used in education or training purposes, as a simple tutoring system (Kaloudis et al. 2005).

2.5 Research and Development

Research and development (R&D) is defined by (Rukunudin 2009) as part of the overall process of innovation where an idea is transformed into tangible output that has utility. Most of the developed and advanced countries in the world today owed much of their technological success and economic growth to their relentless efforts in R&D; it does not only generate new technology and product but also help to create wealth and knowledge and stroke the economy of a nation. The same is also true of the world's successful corporations that internalized R&D as part of the business it supports.

Kenya Forestry Research Institute (KEFRI), conduct research and development in forestry and natural resources. The research activities are guided by the Institute's Strategic Plan, which is in line with the Government's vision 2030. The research activities include development and demonstration of successful technologies: forestry plantation development; conservation and rehabilitation; natural forest conservation and participatory management; propagation, planting and utilization; harvesting and integration of trees on farms; processing and distribution of high quality tree seed; and development of wood and non-wood forest products.

2.5.1 Research Process

A forestry scientist will conduct a research in forestry, generate and develop improved technologies and practices. The research result obtained usually leads to advances in understanding the role of forest in the society, and improved technique for forest planning and management for sustainable development. The knowledge and information generated is usually contained in publications and human experts. However, the results must be put into practice, so they need to be communicated effectively to forest stakeholders. According to (Byron 1999) dissemination is vital element and emphasis the need to improve communication of research findings. Forestry scientists act as users and producers of information. However, the users of information will vary from top policy makers, dissemination and extension officers, farmers and researchers.

2.5.2 Dissemination of Research Results

Forestry extension is defined by (Agbogidi & Ofuoku 2009) as the dissemination of relevant information and advice to farmers and a mechanism for delivering information and advice as an input in modern farming. Extension provides the mechanism by which technologies and practices generated by researches are disseminated for adoption by farmers. Forestry extension programs are designed to meet the needs of small- scale farmers through agro-forestry technology, conservation of small-size log and wood processing technology, scientific information about biodiversity and new concepts in conservation. This can only be achieved with aggressive forestry extension. The current approaches and methods of information dissemination used in forestry include; field and open days, mass and print media, audio visual, demonstration plots, extension staff, farmer to farmer extension, publications and website.

2.5.3 Problems with the Current Website

The current system web environment is mainly designed based on a system approach. Less or little emphasis has been put on the farm tree users in such settings. Users are expected to be able to address the "what", "where" and "how" questions in their quest to seek information in order to make decisions. They are expected to be able to formulate good queries to represent their information needs, or to map their queries onto often-unknown knowledge structure such as subject directories. This is not an easy job. Although users information needs are often related to some form of their immediate task in one way or another, current digital system or information systems do not generally organize information according to the various user tasks. As a result, users usually employ the trial and error method to move from one Web page to another or from one information resource or system to another. Another common problem faced by users is that the required information resources are generally scattered all over the place with the quality, content and coverage differing at different locations. When this happens, users have to traverse from one server to another or from one information resource to another in order to find the desired information.

2.6 *Grevillea robusta* Tree

Grevillea robusta is a tree commonly known as Silky Oak or Silver Oak, has gained widespread popularity in warm temperate, subtropical and tropical highland regions of many countries, originally as a shade tree for tea and coffee and more recently as an agroforestry tree for small farms. It provides economically valuable products including timber, poles, firewood and leaf mulch; it is easy to propagate and establish and is relatively free of pests and diseases; its proteoid roots help it grow in low-fertility soils; it does not compete strongly with adjacent crops; and it tolerates heavy pruning of its roots and branches. With its fern-like pinnate leaves and prominent attractive orange flowering display, it is also popular as an ornamental (Harwood 1998).

G. robusta was introduced in Kenya in the late nineteenth century from India and Sri Lanka where the species had shown great potential as a shade tree in tea, coffee and cinchona plantation (Harwood 1989). By the mid-twentieth century the species had become dominant tree for shade tree in coffee and tea plantations. Since then, the use of *G. robusta* as a shade tree has been declining rapidly. Nowadays the species is intensively planted as multipurpose tree in agrisilvipastoral systems covering an estimated area of 750,000 ha in the central highlands around Mt. Kenya. *G. robusta* is so intensively planted in the region that it is the dominant of tree cover in some parts especially on eastern and southern slopes (Muchiri, Miina & Pukala 2002). Most farmers in the central highlands of Kenya grow *G. robusta* for timber, poles and firewood for sale rather than as a source of providing their families with tree products and services. The species has successfully been planted on farms because it generally grows rapidly, is easy to propagate and establish, has good stem form and provides economically viable products.

2.6.1 *Grevillea Robusta* Tree Models

Tree model is defined by (Vanclay 1994) as an abstraction, or a simplified representation, of some aspect of reality. Growth models assist forest researchers and managers in many ways. Some important uses include the ability to predict future yields and to explore silvicultural options. This project will refine existing information and develop models for the prediction of *G. robusta* tree growth and yield from those provided by KEFRI. Plant stand growth and yield models are essential decision support tools to professional foresters providing forest landowners with advice on managing existing stands or on the financial possibilities of establishing new stands. These fundamental models give the user expected current trees stand biomass and volume yields and estimate future stand growth. The models provide the decision support system that allows forest tree owners to take maximum advantage of competitive markets by making the stand management decisions that produce the product volumes with the most revenue.

2.6.2 Tree Measurement

The purpose of measuring trees is to estimate yields, production of wood. Diameter and height are the most important measurements. The parameters give an indication of volume. Basal area is a concept of forest and is the total cross-sectional area in square feet of the stems of a species based on diameter at 4.5 feet above the ground. (1.b.h) (Buysse et al. 2006).

2.6.3 Measuring the DBH

The international standard of measuring dbh is to measure the circumference of a tree stem or the diameter perpendicular to its longitudinal axis at 1.3 meters above ground level (dbh = diameter at breast height = $d_{1.3}$). According to international standard, dbh is measured at 1.3 m (4 feet 3 inch) above ground level, report using the metric system, expressed as diameter (cm) also when measuring circumference, degree of accuracy used and round numbers to the nearest even number, for instance 13.5 becomes 14 and 12.5 becomes 12.

2.6.4 Measuring the Basal Area

The diameter or circumference is mainly used to calculate the basal area or cross-section area and this basal area is further used to calculate the bole volume.

$$g = \pi r^2 = \pi/4d^2 = c^2/4\pi$$

Where g is basal area, r is the radius, d is the diameter and c is the circumference.
Buysse et al. 2006 defines basal area as the area of a circle with a circumference of the tree at 1.3 m above ground level. This means we should measure the circumference.

2.6.5 Measuring Tree Bole Volume

From the inception of cubic scaling the Smalian's formula, which calculates logs on the basis of a parabolic frustum, was adopted as cubic scale rule. The scale requires measurement of the two inside bark diameter and the length. Smalian's formula states that: the volume of a log can be closely estimated by multiplying the average of the area of the two log's length. The units used for the areas and the length must be the same, (e.g., square meters and meters in the Yukon Territory), in order to arrive at the volume in cubic meters.

Smalian's formula is commonly expressed as follows:

$$V = \left(\frac{A_1 + A_2}{2}\right) L$$

Where V = the volume of the log in cubic meters (m^3)
A_1 = the area of the small end in square meters (m^2)
A_2 = the area of the large end in square meters (m^2)
L = the length of the log in (m)

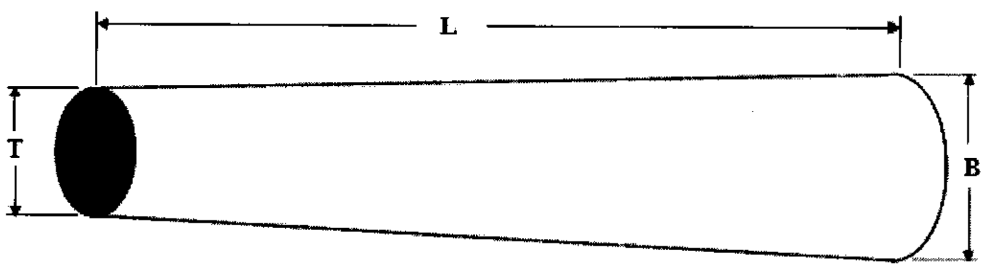

Figure 2.1 Parabolic frustum

The Smalian's simplified formula is expressed as follows:

$$V = (T^2 + B^2) \times L \times C$$

Where V = volume of the log in cubic meters,

T = the top radius in centimeters (or the diameter in rads)

B = the butt radius in centimeters (or the diameter in rads)

L = the length in meters, and

C = 0.0001570796 (constant)

(1 rad = 2cm)

2.7 The Architecture of the DSS

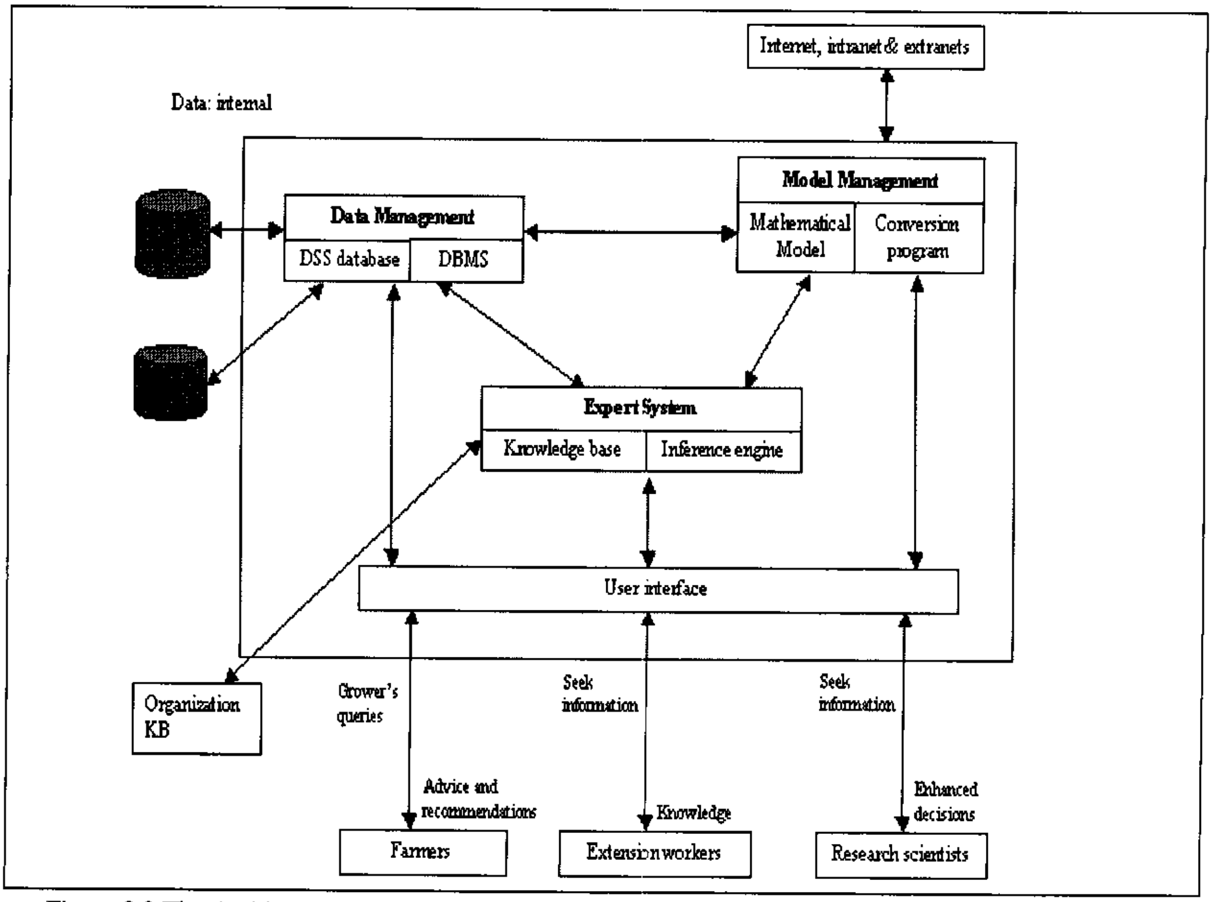

Figure 2.2 The Architecture of the DSS

CHAPTER THREE
METHODOLOGY

3.1 Introduction

In order to understand the underlying issues, the methodology for research involved system analysis and design and knowledge engineering to reveal the users information needs as stated in the objectives. The study meant finding suitable ways of processing available data for *Grevillea robusta* tree species and design a prototype that can be used to disseminate knowledge and information to forest stakeholders. The practical work of this development was divided into five (5) phases:

- System Analysis
- Knowledge Engineering
- Design
- Implementation, Testing and Evaluation
- Result and Findings

3.2 Fact Finding Methods

3.2.1 Interviews

This involved asking questions from appropriate people to give information. Such people include members of Kenya Forestry Research Institute, stakeholders and any other concerned with development and utilization of *G. robust* tree species. The interview questions were used for three categories of respondents' namely small-scale farmers, foresters, entomologists, extension officers and scientists. Face to face interviews were conducted to get the views of the stakeholders in Kibwezi, Embu, Meru and Nyeri.

3.2.2 Document Reviews

This involved inspecting the documents used in decision-making, monitoring and impact evaluation of the projects. These include guidelines, monitoring and evaluation reports, project listings etc.

3.2.3 Observation

This technique involved data collection from the field through observation, entry of collected data into the computer, report production, interpretation and analysis of reports. The Author also observed actual procedures of data collection, processing, storage and dissemination of *G. robusta* tree information to stakeholders and users. This facilitated acquisition of first hand information that could not be gathered through interviews and questionnaires.

3.2.4 Questionnaire

Structured questionnaire was developed and pre-tested on thirteen (13) respondents. The questionnaire was then modified prior to distribution. Twenty eight (28) respondents were identified at KEFRI Muguga and Karura Regional Research Center (KRRC). The respondents were scientists, farmers, extension personnel, foresters and the general public. The sample was convenient because it represented various stakeholders and users of the system. Each questionnaire returned was re-checked to ensure they were fully completed.

3.3 System Analysis

System analysis phase demonstrate the extent to which the software engineer/analyst has understood the problem domain presented to him, identifying the implication of the alternative solution collected during system preliminary analysis and documenting it in a manner that will aid in the design phase.

3.3.1 Requirements Analysis

Requirement analysis is one of the most important steps in system development life cycle. It aims not only at gaining the deepest understanding of the problem at hand but also getting into contact with the users one is developing the system for. It enables the systems analyst or software engineer to describe and document the essential operational requirements of the system under development. The table shows the system actors and information needed. The table also summarizes the users' requirements.

Who	**Information Needed**
Tree Farmer and Producer	o Tree species' name interpretation o Tree growth and yield information o Advice and recommendations o Tree problems resolution information o Flowering and seed collection time o Selection of mother tree for seed collection o Seedling selection for planting o Seed harvesting o Tree economic uses information o Tree volume calculation o Wood quality information o *G. robusta* seed information

Forest Extensions - Foresters - Dissemination officers - Extension officers	o Training tool and resources o *G. robusta* tree management information
Scientists - Researchers - Stakeholders - Students - Entomologists - Pathologists	o *G. robusta* library resources (reports and publications) o Cases of tree diseases and insect pests information o Important links o Information of researchers and their specialty o Completed and ongoing projects information
Decision makers	o *G. robusta* tree research and development monitoring information o Statistics, analysis and intelligent reports o Decision making

Table 3 Information needs for various DSS users.

3.3.2 Dataflow Diagram

Data Flow Diagram (DFD) is a process-oriented graphical presentation of data flow, data storage and functions, which users readily accept. In the words of (Hoffer, George & Valacich 1999) a DFD "is a picture of the movement of data between external entities and processes and data stored within a system." Data flow diagrams provide a view of the system that is understandable to the user: a user's view. The DFD explain what happens within the system and show the external entities with which the system communicates. This communication is achieved through data flowing either into or out the system. These entities can be other organizations, other systems, or other departments of the same company for which the system is being developed. The external entities therefore indicate the boundary of the system or the system scope.

Since the Structured Systems Analysis and Design Method (SSADM) methodology was adopted in the design of systems, the following symbols have been used to draw the data flow diagrams.

Symbols Used in Dataflow Diagrams

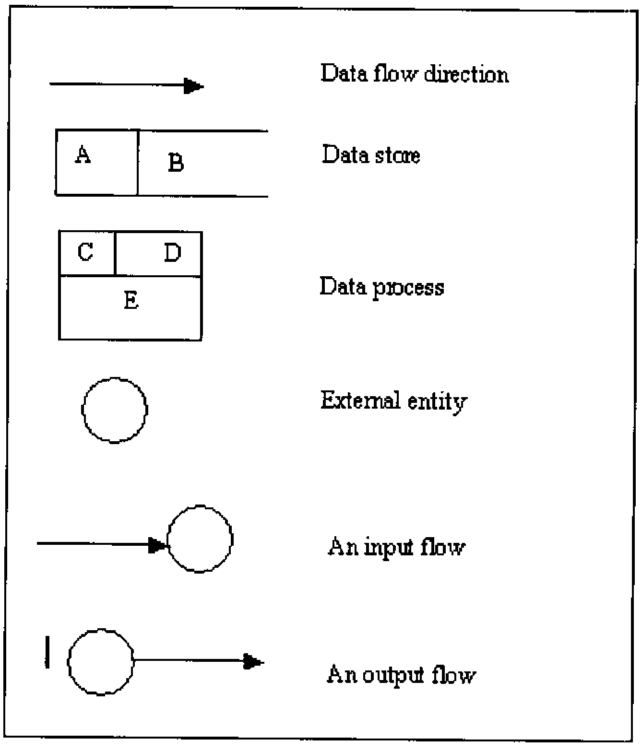

Figure 3: Data flow symbols

Key

A - Data store number

B - Data store name

C - Process number

D - Process name

E - Process activity

Context Dataflow Diagram

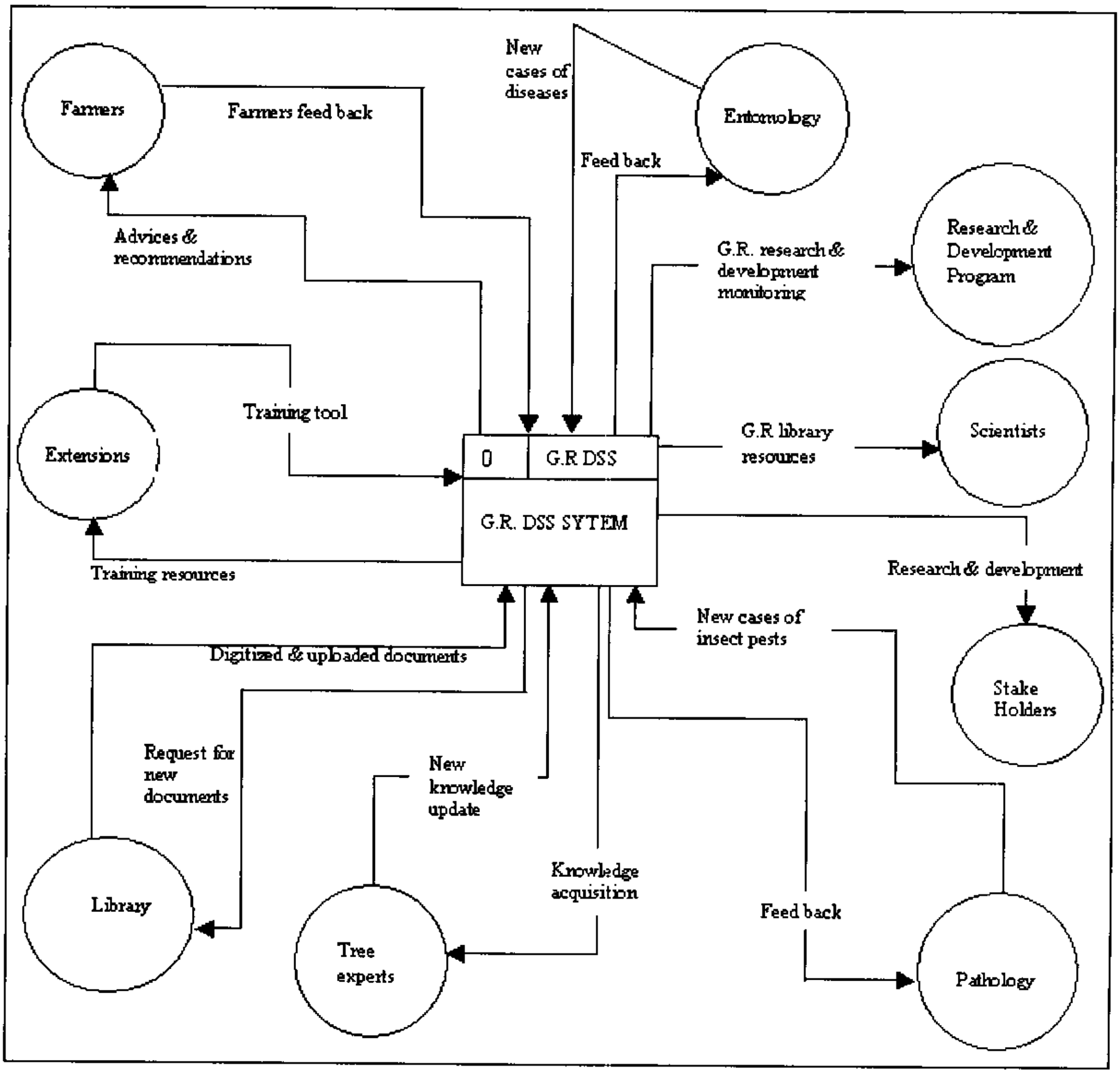

Figure 3.1: Context diagram

Top Level DFD Diagram

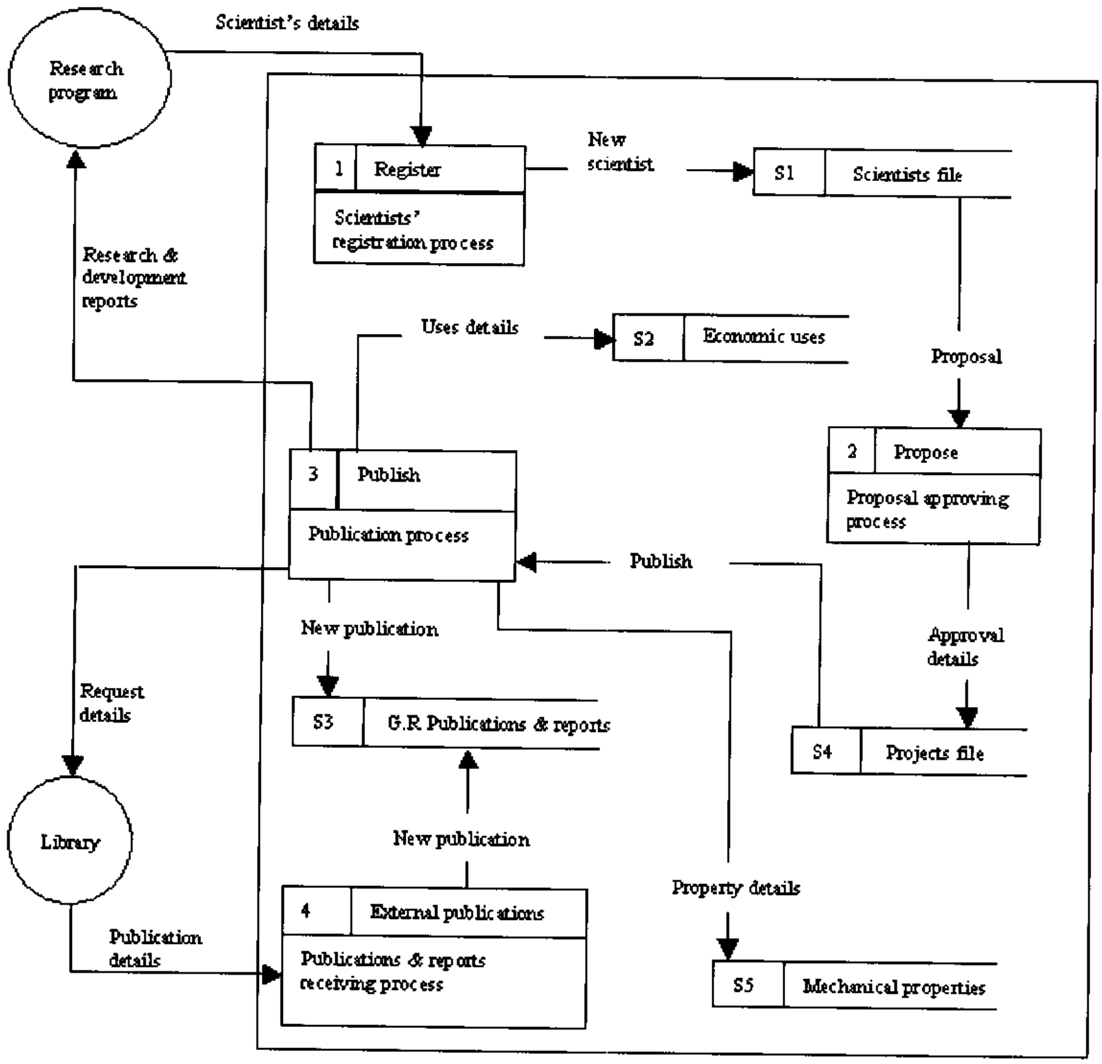

Figure 3.2: Top-level DFD diagrams.

Level 1: DFD Diagram

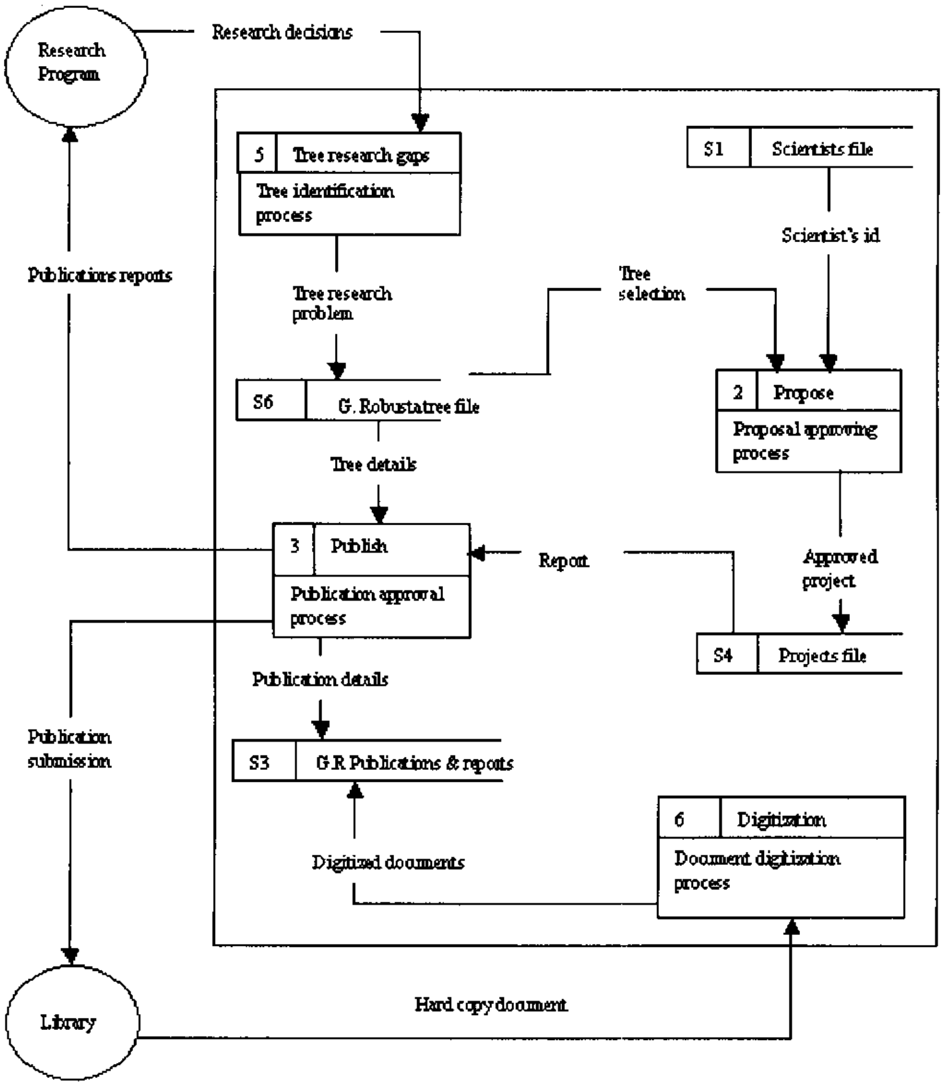

Figure 3.3: Level 1 DFD diagram

Level 2: DFD Diagram

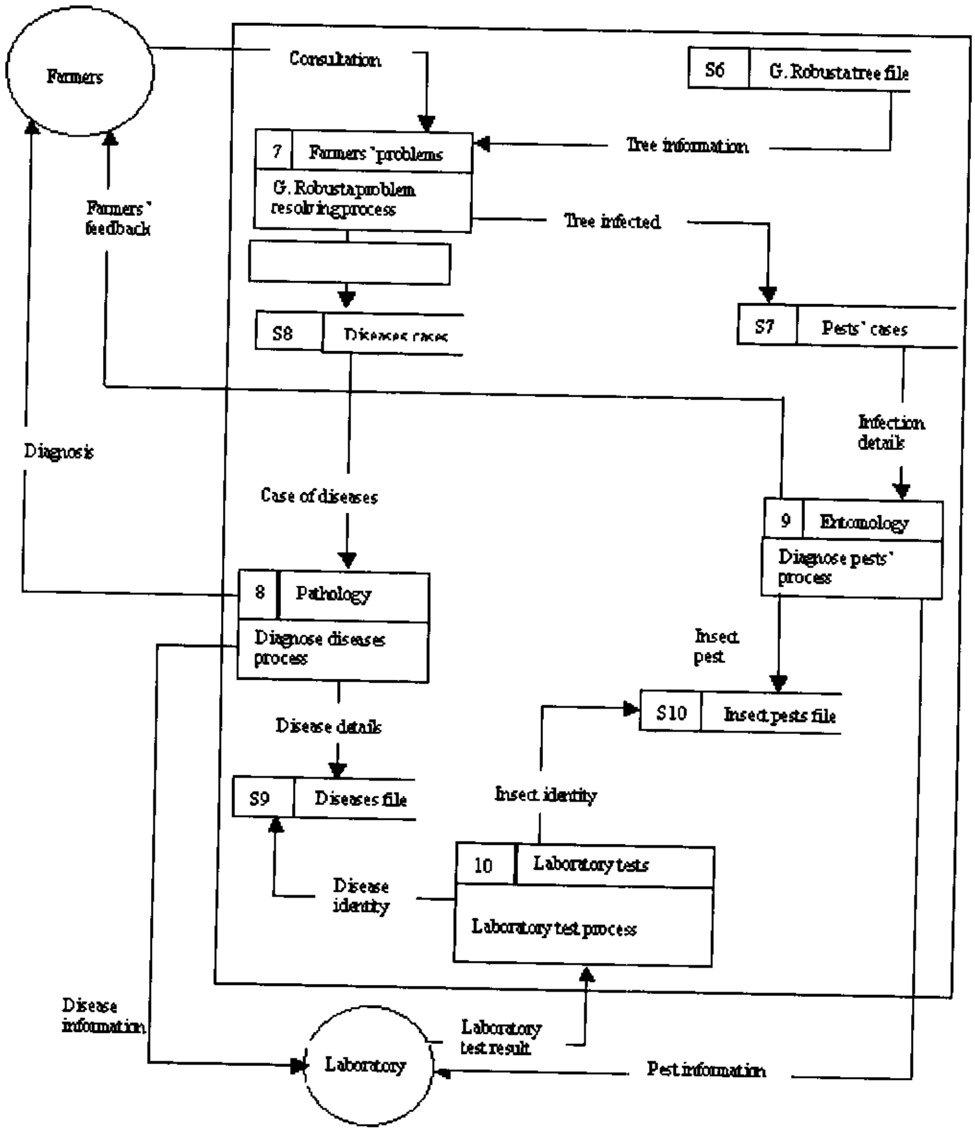

Figure 3.4: Level 2 DFD diagram

3.3.3 Logical Modeling

The purpose of this stage is to present the problem in a logical model using the results obtained in the above stages. A logical model is the act of exploring data-oriented structures, it also a representation of the data used by the system. Data model shows how data is logically grouped together. Data modeling process involves developing entities, their relations and their attributes.

3.3.3.1 Entities

An entity is identifiable object, concept or activity in a system. The following is a step-by-step process that was used to identify entities of the system.

i) Scientists
ii) Publications
iii) Projects
iv) Trees
v) Insect Pests
vi) Diseases
vii) Case diseases
viii) Case Insects
ix) Uses
x) Mechanical Properties
xi) Users

3.3.3.2 Entity Relationships

The following diagram illustrates the initial relationships of the above entities. The boxes represent the entities. The lines connecting the entities represent the relationships between the respective entities.

Entity Relationships

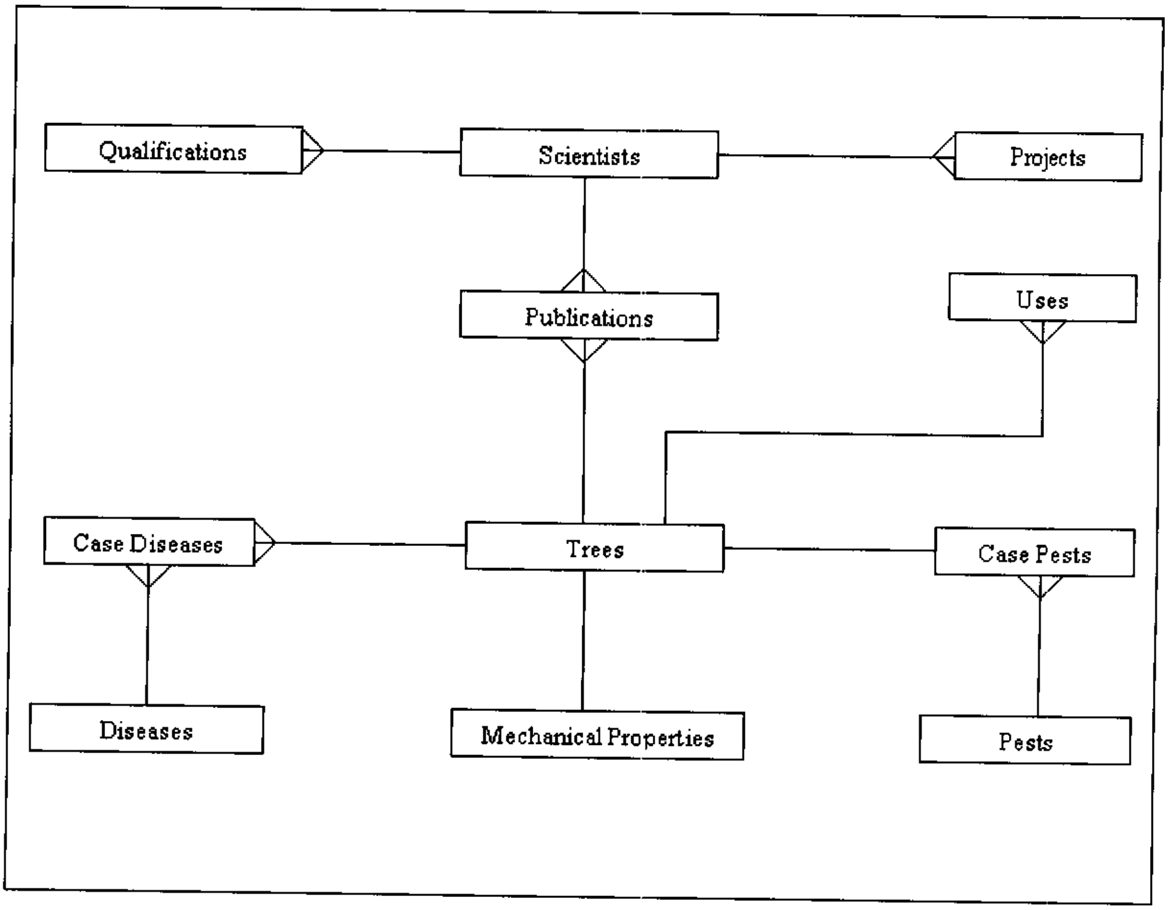

Figure 3.5: Initial relationship diagram

3.3.3.2.1 Attributes

An attribute is a characteristic of an entity. It distinguishes one entity occurrence from another. The following attributes were obtained for each entity.

a) Scientists

Scientist's number, employment number, scientist's names, designation, Institution, work telephone number, mobile number, address, email address, specialization and passport image

b) Publications

Publication number, title, type, year of publication, publisher, author co-authors, publication uniform resource locater, number of pages, theme and abstract.

c) Projects

Project number, project title, objective, investigator, co-investigator, project start date, project end date, sponsor project site and project status.

d) Trees

Tree identification number, species name, family common name, type and image.

e) Insect Pests

Case insect pest identity, insect, part affected, host name, stage of insect, remark image and resource locator

f) Diseases

Disease identification number, disease name, species, genus, family, order, subclass, phylum and kingdom.

g) Case diseases

Case disease identification number, part affected, host damage, remarks

h) Case Insect pests

Case insect pest identification number, part affected, host damage, stage of insect and remark.

i) Uses

Use identification, use category and description

j) Mechanical Properties

Mechanical property identification, property and quantity

k) Users

User identification number, first name, last name, email address, telephone number, nationality and password.

3.3.3.2.2 Normalization

The main purpose of normalization is to produce a well-designed database that provides a high degree of independence and produce meaningful tables called entities/relations. Relational database scheme was preferred for designing the data manager because of its simplicity and popularity. An entity is considered as relation (table) with attributes as the relation's attributes (columns). Thus, each entity was mapped into a relation.

Normalization is set of rules that are applied to the relations in order to simplify them. There are three steps in normalization:

- Normalizing relations to their *first normal form.* A relation is in its first normal form if it does not have repeating groups. Any repeating group is eliminated and used to form a new different relation
- A relation is in its second normal form if it's already in first normal form and every non-key attribute is fully depended on the key attributes. Any non-key attribute that does not fully depend on the key attributes is eliminated from the relation, and used to form a new relation with the depending key attribute as the new key attribute.
- A relation is in its third normal if it's already in the second normal form and every non-key attributes is independent from any other non-key attribute. Removing the non-key attributes that depend on other non-key attributes to form a new relation eliminates such dependencies that are not desirable.
- The advantage of normalization is that it avoids data redundancy and makes relations more understandable.

3.3.3.2.3 Normalization Terms

a. *Primary key* – This is unique identifier for any table or entity. Combinations with the property that at any given time, no two rows of the table contain the same value that column or columns combination. The primary key is a special case the candidate key.

b. *Candidate key* (composite key)- This key or combination of keys (a column or columns) that can be used alternatively uniquely identify a table instead of the primary key. A table has to have at least one candidate key. A table has to have at least one candidate key because, even if when there is no unique single key, a combination of all keys is always unique.

c. A *foreign key* – An attribute is said to be a foreign key if it appears as primary key in another table. This type is said to relate and especially used in database to show one - to – many relationships between tables.

After normalization, the following relations and their attributes were derived. The underlined attributes are the key attributes for the respective entities.

I) Scientists

Scientist's number, *<u>employment number</u>*, scientist's names, designation, Institution, work telephone number, mobile number, address, email address, specialization and passport image

m) Qualifications

Qualification identification number, qualification description, certificate name, Institution and year obtained

n) Publications

Publication identification number, title, type, year of publication, publisher, author co-authors, publication uniform resource locater, number of pages, theme and abstract.

o) Projects

Project identification number, project title, objective, investigator, co-investigator, project start date, project end date, sponsor project site and project status.

p) Trees

Tree identification number, species name, family common name, type and image.

q) Insect Pests

Case insect pest identification number, *insect, part affected, host name, stage of insect, remark image and resource locator*

r) Diseases

Disease identification number, disease name, species, genus, family, order, subclass, phylum and kingdom.

s) Case diseases

Case disease identification number, part affected, host damage, remarks

t) Case Insect pests

Case insect pest identification number, part affected, host damage, stage of insect and remark.

u) Uses

Use identification number, use category and description

v) Mechanical Properties

Mechanical property identification number, property and quantity

w) Users

User identification number, first name, last name, email address, telephone number, nationality and password.

3.3.3.2.4 Relationships

When the possible values of an attribute in an entity must be values in another attribute in another entity, then the two entities are related. There are various forms of relationships.

i. One to one denoted by 1:1. An instance of the related attribute in the first entity can occur only once in the second entity, and vice-versa.
ii. One to many denoted 1:M. An instance of the related attribute in the first entity can occur many times in the second entity while an instance of the related attribute in the second entity can occur only once in the first entity.
iii. Many to one denoted M:1. An instance of the related attribute in the first entity can occur only once in the second entity, while an instance of the related attribute in the second entity can occur many in the first entity.
iv. Many to many denoted by M:N. An instance if the related attribute in the first entity can occur many times in the second entity, and vice versa.

Participation of an entity in a relationship may be mandatory or optional. In a mandatory relationship, each instance of the entity *must* participate in the relationship. In an optional relationship, each instance of the entity *may* participate in the relationship. Letter "m" denotes a must relationship while letter "o" denotes optional relationship. Thus, the further forms of relationships are:

i. 1(m):1(m), 1(m):1(o), 1(o):1(o), 1(o):1(m)
ii. 1(m):M(m), 1(m):M(o), 1(o):M(o), 1(o):M(m)
iii. M(m):1(m), M(m):1(o), 1(o):1(o), M(o):1(m)
iv. M(m):M(m), M(m):M(o), M(o):1(o), M(o):M(m)

The words "must" or "is" and "may" have been used to show a mandatory and optional participations of entities in relationships.

No	Entity	Entity Relationship	Relation Type	Description
1	Scientists	Publications	1(o):M(m)	A Scientist may publish document A publication belong to an author
2	Publications	Trees	M(o):1(m)	The theme of publication may be about a certain tree. Information about a tree is contained in a publication document
3	Projects	Scientists	M(m):1(o)	A project is undertaken by a scientist A scientist may undertake a project
4	Trees	Case diseases	1(o):M(o)	A host may be affected by a disease A tree host is affected by a disease
5	Insect pests	Case insect pests	1(o): M(m)	Insect pest case may be reported Insect pest case is reported
6	Diseases	Cases diseases	1(o):M(m)	Diseases may be reported in some cases Case of disease is reported
7	Case diseases	Tree	M(o):1(m)	Case of disease may be of a tree A tree disease case is reported
8	Case Insects pests	Tree	M(o):1(m)	A case of insect pest may be from a tree A tree insect attack is reported
9	Uses	Tree	M(o):1(m)	Economic uses may be of a particular tree A tree is used for
10	Mechanical Properties	Tree	M(o):1(m)	Mechanical properties may belong to a tree A tree has mechanical properties

Table 3.1: Table relation type

3.3.3.2.5 Entity Relationship Diagram (ERD)

Entity relationships are diagrammatic representations of the relationship between entities. They are very useful since they make the relationships to be more understandable. The following symbols were used in drawing the ERD.

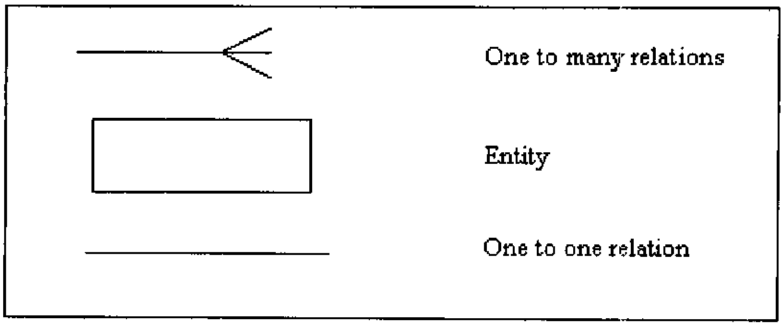

Figure: 3.6 ERD symbols

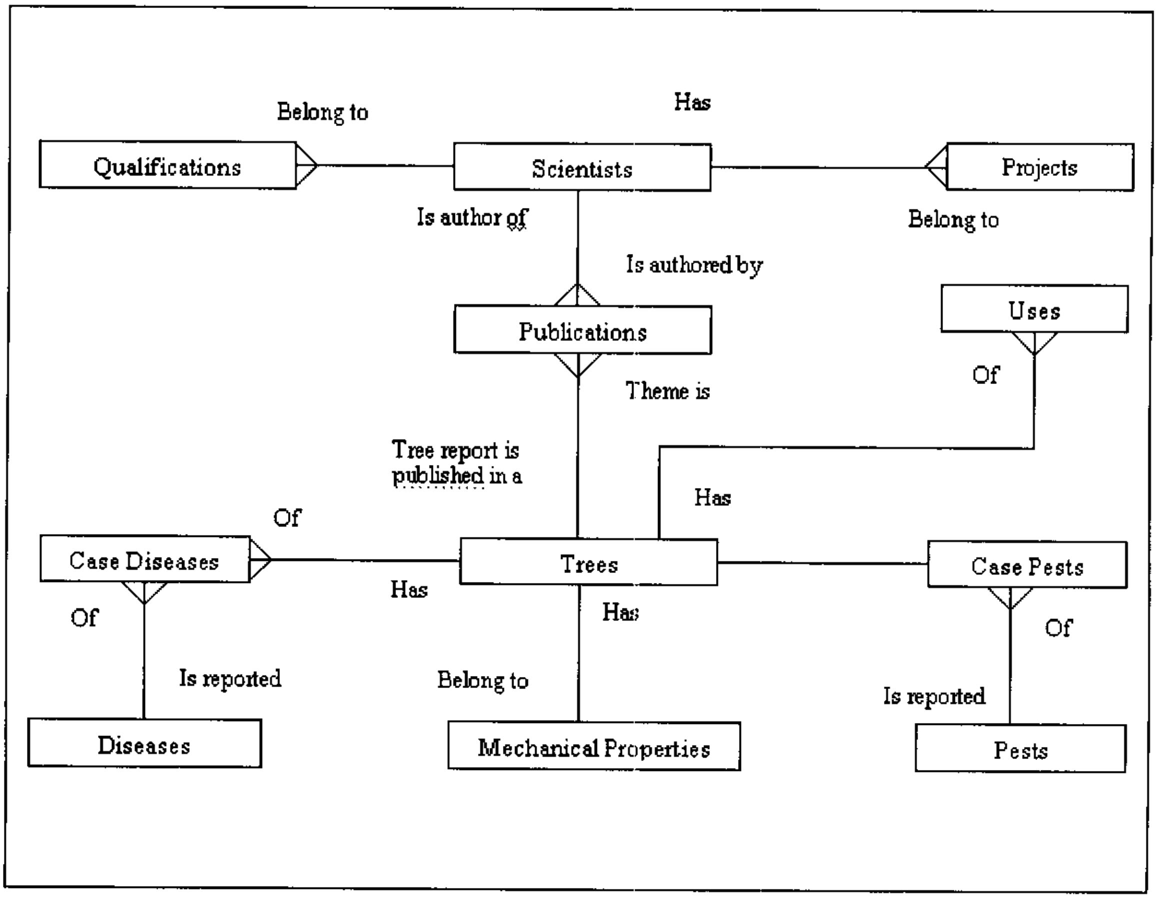

Figure 3.7: Final Entity Relationship Diagrams

3.3.3.2.6 Complete ERD

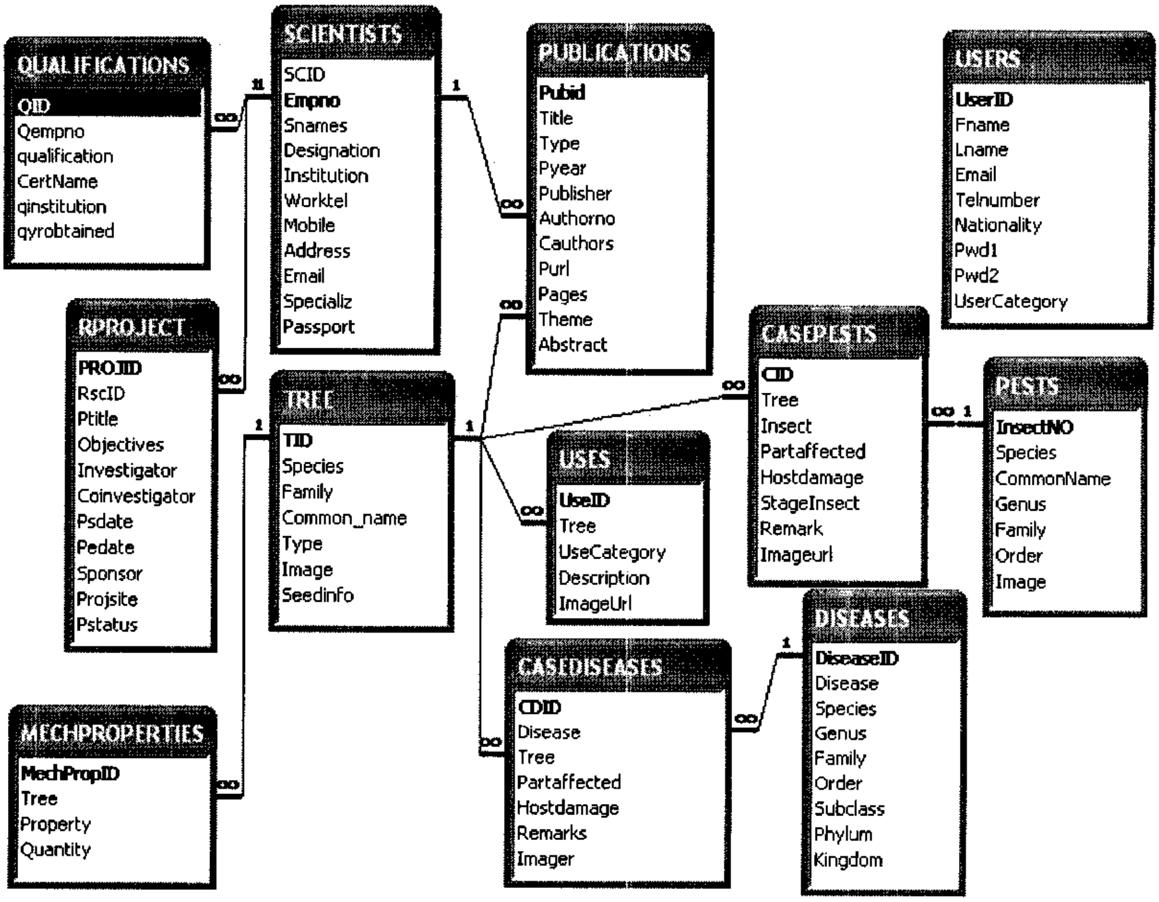

Figure: 3.8 Database design

3.4 Knowledge Engineering

Knowledge engineering is defined by (Akerkar 2005) as knowledge crafting and broadly involves

- Identifying and conceptualizing the problem. Conceptualism mean identifying the key concepts, relationships, procedures and special cases.
- Formalization, implementation, and testing.

This section explains how knowledge was extracted from forestry experts and how it was translated into database known as knowledge base, which contains all the collected knowledge, related to the problem to be solved. The knowledge engineering included the following activities: acquiring the knowledge, analyzing and modeling the acquired knowledge, and verifying modeled knowledge.

3.4.1 Conceptualization

The expert and knowledge engineer explain the key concepts, relation and information flow characteristics needed to describe problem-solving process in the given domain. They also specify subtasks, strategies and constraint related to problem solving.

The main activities that are carried out in this stage are:

Design: The DSS ensure that the specific interaction and relationships in the problem domain are understood and defined.

Determination: the key concept, relationships between objects and processes, and control mechanisms.

3.4.2 Knowledge Acquisition

The process of knowledge acquisition commenced in two forms, interview with forestry experts and references from (Harwood 1989). The questions below were directed to the domain experts and have guided the process of knowledge acquisition:

Question 1. Exactly what decisions do forestry experts make?

Experts and experienced farmers make decision on selection of suitable mother tree for seed collection, when the tree flowers and when to collect seeds, how to harvest the seeds, select suitable seedling for planting, interpret tree name in vernacular, decide when to harvest tree products, diagnose common insect pests and diseases. Researchers make decision on research concept to undertake.

Question 2. What resources or input are required to reach a decision?

The input required to reach a decision are:

- Region where the farmer comes from
- Activity required (Flowering or seed collection)

Question 3. What conditions are present when a particular outcome is decided?

For a particular out come to be decided, there must be a combination of condition (Activity and region mentioned above) that lead to a certain outcome designed in the form of a rule.

Question 4. At what point after exposure to influential input is a decision made?
A decision is made if and if all the influential input are provided else a null decision is reached where the system will provide an error message requesting the user to provide more information.

Question 5. How consistently do these conditions predict a given outcome?
The prediction of a given outcome given the condition is very consistent in this system because no given two inputs can have the same outcome.

Question 6. Given the particulars of a specific case, will the outcome predictions of the knowledge engineering team be consistent with those of the expert?

The outcome predictions of the knowledge engineering team are very consistent with those of the expert because all the expertise is elicited from the expert.

3.4.3 Domain Problems

3.4.3.1 Growth and yield Statistics of *Grevillea Robusta* taken over a period of 25 years.

From 1952 to 1977, (Kaumi 1980) produced growth statistics of various *Grevillea robusta* tree species at Muguga Aboretum. Plot of the species grown there consisted of 49 trees planted in square plots at 2.44 m square spacing, pruned and thinned as required. The experiment performed produced growth and yield data as shown below.

Age	Height of 10 tallest trees (m)	Mean diameter of survivors (cm)
1	1.2	
2	4.0	
3	4.7	
4	5.7	
5	7.0	8.89
7	7.9	12.45
9	10.4	14.99
11	12.2	20.07
15	14.3	25.07
20	16.5	27.22
25	15.0	27.2

Table 3.2 Growth and yield data of *Grivellea robusta* tree species.

The plant grew well in the nursery and averaged 50 cm in height after one year, at planting time. Growth varied uniformly, produced good vigor and the stem form was quite good except for some stems that leaned slightly to wind and many were slightly sinuous.

Some trees, which grew double leaders, were singled early in the first few years. Coppice growth was allowed to grow on reaching up to 5 m. Pruning to half height continued annually until 10 years and reaching about 4.5 m height. Flowering and fruiting were first seen in the fifteenth year. At 24 years the crown looked a bit bare at the tips; possibly wind flogging, but it may also have been due to prolonged dry weather that may have stopped height growth and shoot elongation.

3.4.3.2 Flowering and Fruit Development

Grevillea robusta Peak flowering is between January and February in Western Kenya, and between September and December in Eastern Province. Pollination may be by birds, bats or insects. Seed maturity takes about 2.5 – 4 months. Seeds can be collected from March – June or December – February in Western and Eastern Kenya Province respectively.

3.4.3.3 Seed Collection

Mature yellowish brown fruits (follicle) are collected from the ground or crown by shaking the branches to release the fruits.

3.4.3.4 Diagnosis of Insect Pests

Entomologists diagnose tree problems by observing the effect and damage insect pests cause on the hosts. Some pests will affect the tree by ring - barking, building soiled galleries and boring holes in plant stems. Activity of insect borers' attack is determined by observing frass exuding from the holes while active termite attack is detected by observing insect activity in the holes of the galleries.

3.4.3.5 Diagnosis of Tree Diseases

Pathologists diagnose tree problems by observing the effect and damage diseases causes on the hosts. Some diseases will affect grown trees or seedlings while others may affect specific part of the tree i.e. stem or trunks, young stems and leaves or whole tree. Host trees may die of disease infection and surviving plants growth is stunted. Cases of disease infection are usually reported to experts who observe and examine the problem and come up with diagnosis report indicating the pathogen responsible of causing diseases.

3.4.3.6 Model Volume Calculation

A forester determines the volume of a tree by measuring the tree height at breast height 1.3 meters above ground and measuring the diameter at both ends of the bole. The volume is calculated using the Smalian or the Huber's formulas by using a pen and a paper and of course mental calculation to estimate the tree volume. The height is measured using a clinometer instrument, which measures height in meters while the diameter is measured using diameter tape, and the instrument measures the dimensions in centimeters.

3.4.4 Design of the Expert Component

The design of the DSS expert component is based on the inputs. A decision tree is used to create a good design for each input. Decision trees are composed of nodes representing goals and links representing decisions. The advantage of decision trees is that they simplify the knowledge acquisition process. The following diagrams shows how the elicited knowledge was modeled into decision trees.

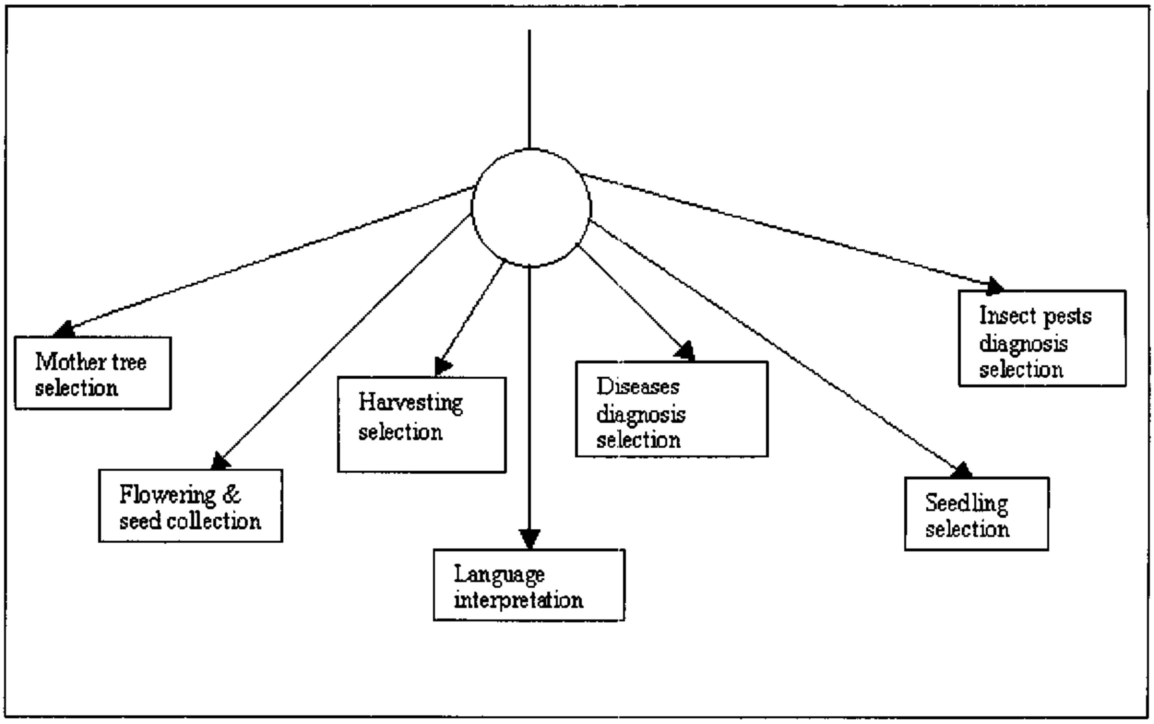

Figure: 3.9 Tree Management decisions

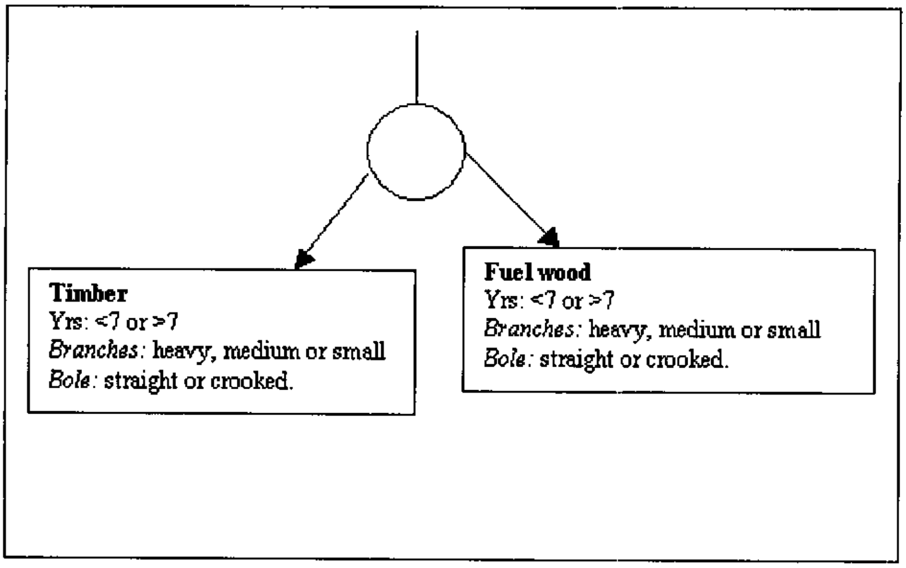

Figure 3.10 Selection of suitable mother tree

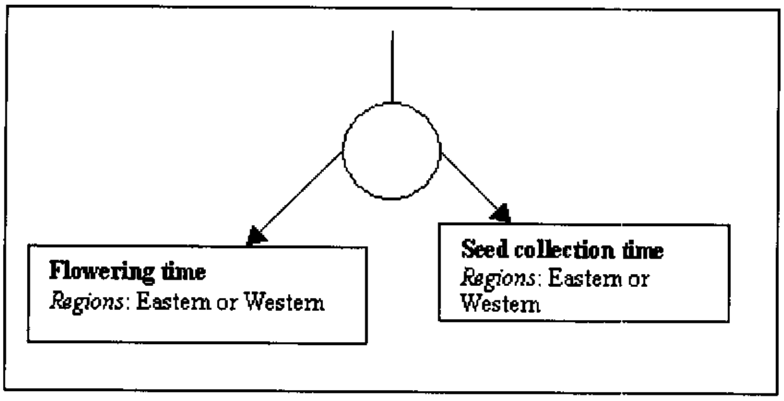

Figure 3.11: Flowering and seed collection decisions.

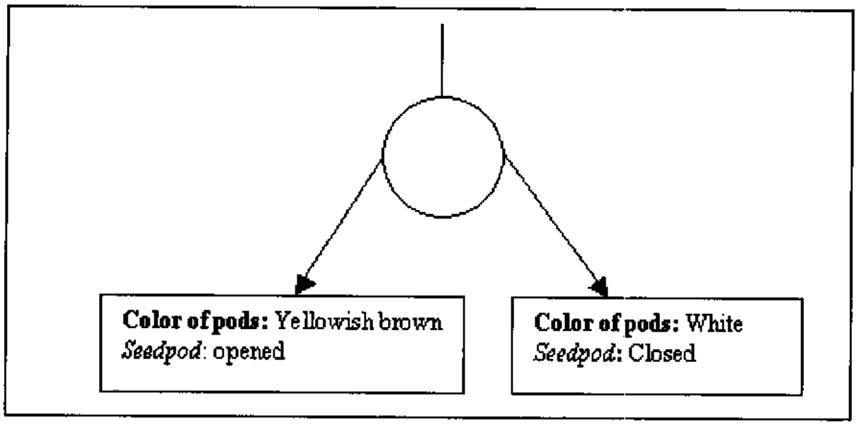

Figure 3.12 Seed harvesting.

Language Interpreter

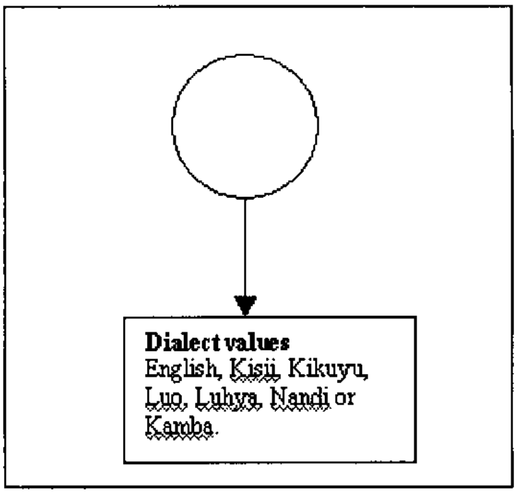

Figure 3.13 G. robusta tree species name interpreter.

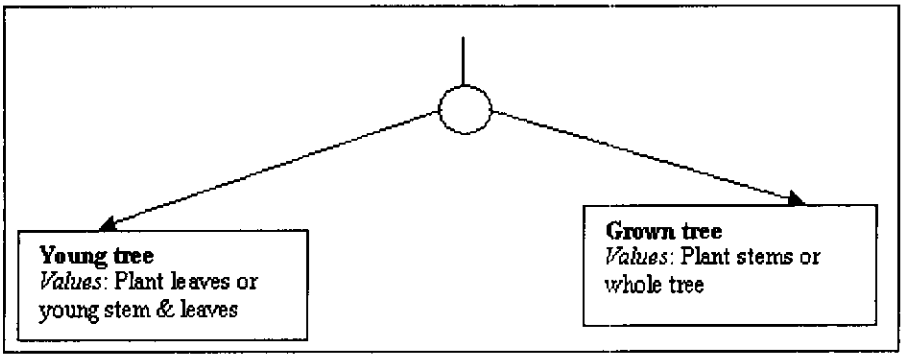

Figure 3.14: Diagnosis of *G. robusta* plant diseases.

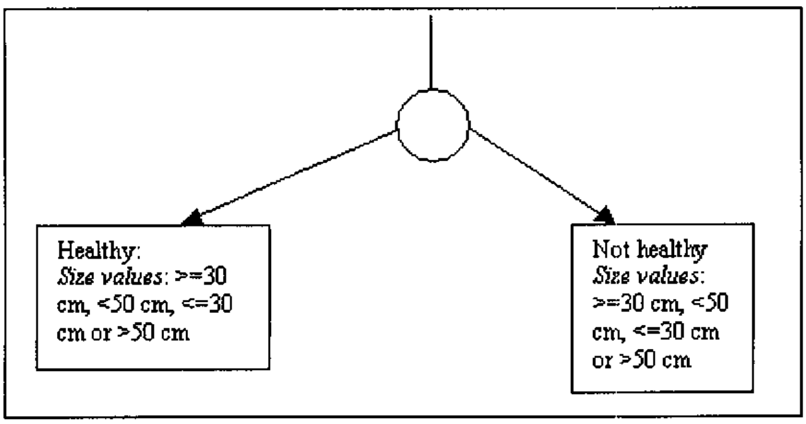

Figure 3.15: Seedling selection

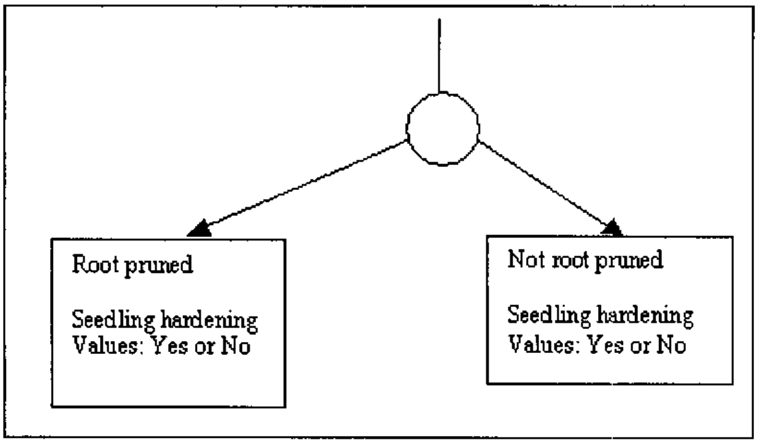

Figure 3.16: Seedling pruning and hardening decisions

Diagnosis of insect pest decision tree

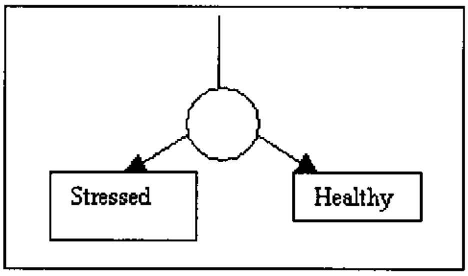

Figure 3.17: Identifying insect pests attack on trees first level.

Observation decision tree

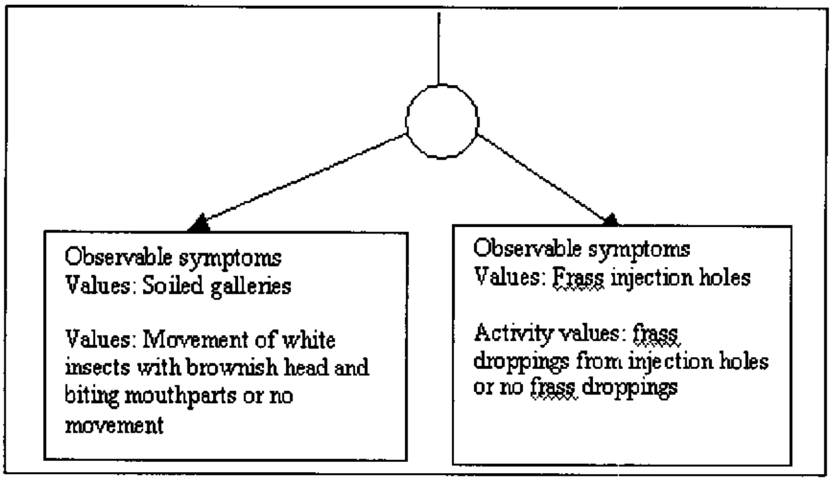

Figure 3.18: Identifying insect pests attack on trees second level.

3.4.5 Formalization

This concept involves mapping key concept and relation into a formal representation suggested by some expert system building tool or language. Therefore, the main activities undertaken here are: organizing the key concepts, sub problems, and information flow into formal representations.

Design of the program logic.

3.4.6 Production Rules

Production rules are ideal to represent knowledge that has been elicited. Rules offer a way of assessing information that more closely matches the way people think. A distinct advantage of using rules is that they are easier to maintain than other knowledge representation mechanisms. Rule representation is one of the widest known and implemented forms for knowledge representation in the development of decision support systems. Production rules have very simple syntax form, they are easily understandable, while their implementation offers a great degree of flexibility to the DSS, as they are easy to modify and update.

3.4.6.1 Constructing a Rule

A production rule has the form:

If <Condition(s)> Then Consequent>

3.4.6.2 Conditions

These are the inputs provided by the user in the form of facts observed from the field.

Some of the conditions examples that influence the consequent in this system include:

Management input options selection

Tree flowering

Seedling size

Color of pods

Region, e.t.c.

3.4.6.3 Consequent

This is the result produced by the combination of a number of condition(s). In this case, the consequent is the certain conclusion reached or advice and recommendation.

3.4.6.4 Values taken by the condition

Activity

Flowering & and seed collection

Region

Western, Eastern.

There are hundred and twenty possible configuration of these inputs. Each configuration is in form of a rule. Example of rules created are laid down in the coming section

3.4.7 Rules Examples

IF	THEN
Tree Is Grevillea Robusta And Color Of Pods Is White And Status Of Pods Closed	Seed Not Mature
Tree Is Grevillea Robusta And Color Of Pods Is Yellowish Blown And Status Of Pods Closed	Seed Mature & Ready For Harvesting
Tree Is Grevillea Robusta And Color Of Pods Is Yellowish Blown And Status Of Pods Open	Seed Dispersed Or Blown Away By The Wind

Table 3.3 Seed harvesting

IF	THEN
Tree Is Grevillea Robusta And Indigenous Language Is English	Silk Oak
Tree Is Grevillea Robusta And Indigenous Language Is Kisii	Omokabiiria
Tree Is Grevillea Robusta And Indigenous Language Is Kikuyu	Mubariti
Tree Is Grevillea Robusta And Indigenous Language Is Luo	Bolebolea
Tree Is Grevillea Robusta And Indigenous Language Is Luhya	Wakhuisi
Tree Is Grevillea Robusta And Indigenous Language Is Nandi	Kapkawet

Table 3.4 Language Interpreter Knowledge Base

Sample Rules in the Knowledge Base

```
Dim A, B, C, D
A = Request.Form("Health")
B = Request.Form("size")
C = Request.Form("prunned")
D = Request.Form("hardened")

If A="" OR B="" OR C="" Or D="" THEN
Response.Write "<center>"
Response.Write("You did not provide us with adequate information to ")
Response.Write "<br>"
Response.Write(" assist you in the selection of the seedlings")
Response.Write "</center>"
End if
'*******************************************************************************************
```

```
If A="Yes" AND B=">=30" AND C="Yes" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is suitable for planting")
Response.Write "</center>"
End if

If A="Yes" AND B=">=30" AND C="Yes" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant is not hardened.")
Response.Write "</center>"
End if

If A="Yes" AND B=">=30" AND C="No" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant is not root pruned.")
Response.Write "</center>"
End if

If A="Yes" AND B=">=30" AND C="No" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because ")
Response.Write "<BR>"
Response.Write(" the plant is not hardened and root pruned .")
Response.Write "</center>"
End if

'*************************************************************************
If A="Yes" AND B="<30" AND C="Yes" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting ")
Response.Write("because the plant size is too small.")
Response.Write "</center>"
End if

If A="Yes" AND B="<30" AND C="Yes" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because ")
```

```
Response.Write(" the plant size is too small and not hardened.")
Response.Write "</center>"
End if

If A="Yes" AND B="<30" AND C="No" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the ")
Response.Write(" plant size is too small and is not root pruned.")
Response.Write "</center>"
End if

If A="Yes" AND B="<30" AND C="No" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because ")
Response.Write "<BR>"
Response.Write(" the plant size is too small, not hardened and root pruned .")
Response.Write "</center>"
End if
```

3.5 Web Based DSS for Grevillea Robusta Design

3.5.1 Introduction

The purpose of this phase is to design a system that would meet specific users' requirements. The design process involves translating the functional specifications of computer-based system into a detailed design. The input to the system includes the functional specification and problem definition report from the analysis stage. In the design stage, the designer tries to model the reality (real world) into a form that can be subjected to and thus be processed by the rules of computer logic.

3.5.2 System Design Objectives

The objective of the system design stage include:

- To ensure that the design will meet the users' requirements
- Support the business process and mission for the system being developed
- To ensure the system is being engineered for ease of use by ensuring ergonomic design and user friendliness
- To provide detailed software development specification
- To ensure that the design conforms to the laid down standards

The design features to be designed are:

a) The input design
b) Output screen
c) Procedure design
d) Interface design

3.5.2.1 Input Design

This is the design of web interface for capturing data by the system. It shows the various web pages used, the consultation facility input, the data captured, the tables in which some of the data is extracted, and the table affected.

Scientists.html

<u>Purpose</u>

This page is used to input data of a new scientist

<u>Table affected</u>

Qualifications, Research Projects and Publications

Publications.html

Purpose

This page is used to input data of a new publication

Table affected

Publications

Projects.html

Purpose

This page is used to input data about research projects

Table affected

Research Projects

Tree.html

Purpose

This page is used to input data about trees

Table affected

Tree, Publications, Chemical properties, Uses, Case diseases and Case pests

Insect Pests.html

Purpose

This page is used to input data about insect pests

Table affected

Pests and Case pests

Diseases.html

Purpose

This page is used to input data about diseases

Table affected

Diseases and Case diseases

Case diseases.html

Purpose

This page is used to input data about cases of diseases on the hosts

Table affected

Case diseases

Case Insects.html

Purpose

This page is used to input data about cases of insect pests attack on *Grevillea robusta*

Table affected

Case insect pests

Uses.html

Purpose

This page is used to input data on uses of *Grevillea robusta* tree species

Table affected

Uses table

Mechanical Properties.html

Purpose

This page is used to input data of mechanical properties of *Grevillea robusta* tree species

Table affected

Mechanical properties table

Users.html

Purpose

This page is used to register new users of the DSS system

Table affected

Users' table

Management.html

Purpose

This page is used to select the tree management required by the user.

Result

G. robusta tree management option.

Langinterp.html

Purpose

This page is used to select the language of the user

Result

G. robusta tree name interpreted in vernacular language

Seedseltn.htm

Purpose

This page is used to select a suitable mother tree for seed collection for economic purpose needed.

Result

Advice and recommendation based on purpose, age, branches and type of bole selected

Flwcollection.html

Purpose

This page is used to select region, flowers and seeds collection

Result

Month in which the tree flowers and when to collect the seeds

Harvesting.html

Purpose

This page is used to select the color of seedpod and the status of the seed

Result

Advice based on color and status of seed

PredbyAge.html

Purpose

This page is used to select the age of the tree.

Result

Growth and yield prediction

DiagnoseProc.html

Purpose

This page is used to select class age and part of the plant affected by disease

Result

Diagnosis of the disease

Diagnplantleaf.html

Purpose

This page is used to select symptoms of young plant that affect young leaves.

Result

Diagnosis of plant disease

Diagnyoungstmleaf.html

Purpose

This page is used to select symptoms of young tree that affect young stems and leaves.

Result

Diagnosis of plant disease

Diagnstmtrunk.html

Purpose

This page is used to select symptoms of grown tree that affect tree stems.

Result

Diagnosis of plant disease

Diagnwhtree.html

Purpose

This page is used to select symptoms that affect grown tree

Table affected

Diagnosis of tree disease

Volume.html

Purpose

This page is used to input height and circumferences of both ends of the tree.

Result

Tree volume and areas of both ends of the bole

3.5.2.2 Output Screen

These are screen outputs that show information used during different processing by the system. The user will view information in pages and queries generated by the system. The page display data of records in single or more tables and typically contain links to other pages. Each page contains links to other pages. The output screen also display information processed by ASP file or inference module to provide various tree management information.

3.5.2.3 Procedure Design

In this phase the project uses a top-down design approach and hierarchical input processes (HIPO) technique to design the processes that the system performs. HIPO diagrams gives an advantage that separate modules that can be developed and tested independently before they are joined together to form the overall system.

3.5.2.4 Hierarchical Input Output Diagrams

HIPO design has been used in order to give a high level overview of the various processes performed in the system. This graphic tool has been used to show specifically what each module does including input and outputs.

Hierarchical Structures used here are:

- System Overview Diagrams
- Hierarchical Charts

3.5.2.4.1 System Overview Diagrams

The system overview diagram gives general information about input process steps and the output of the DSS system.

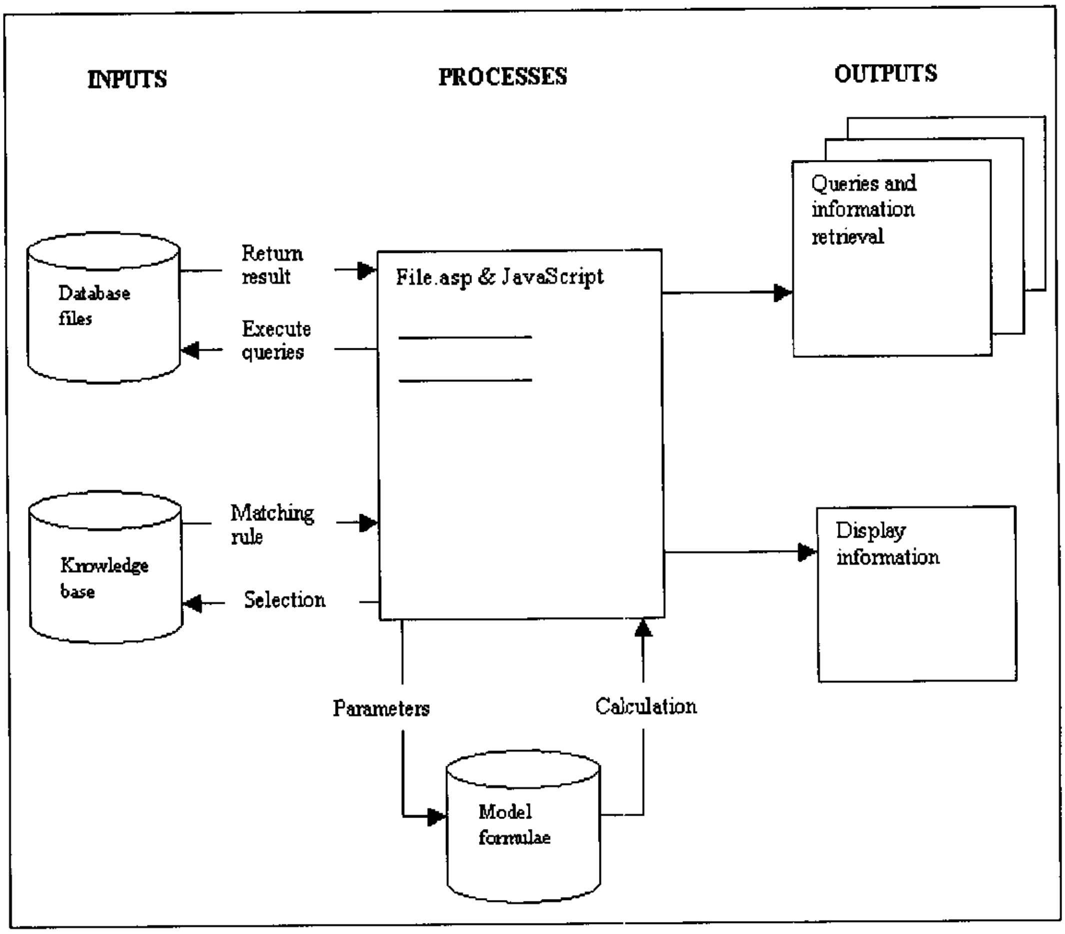

Figure 3.19 Input-output chart

3.5.2.4.2 Hierarchical Chart

This is a pictorial representation of the system functions that acts as the index of the DSS system.

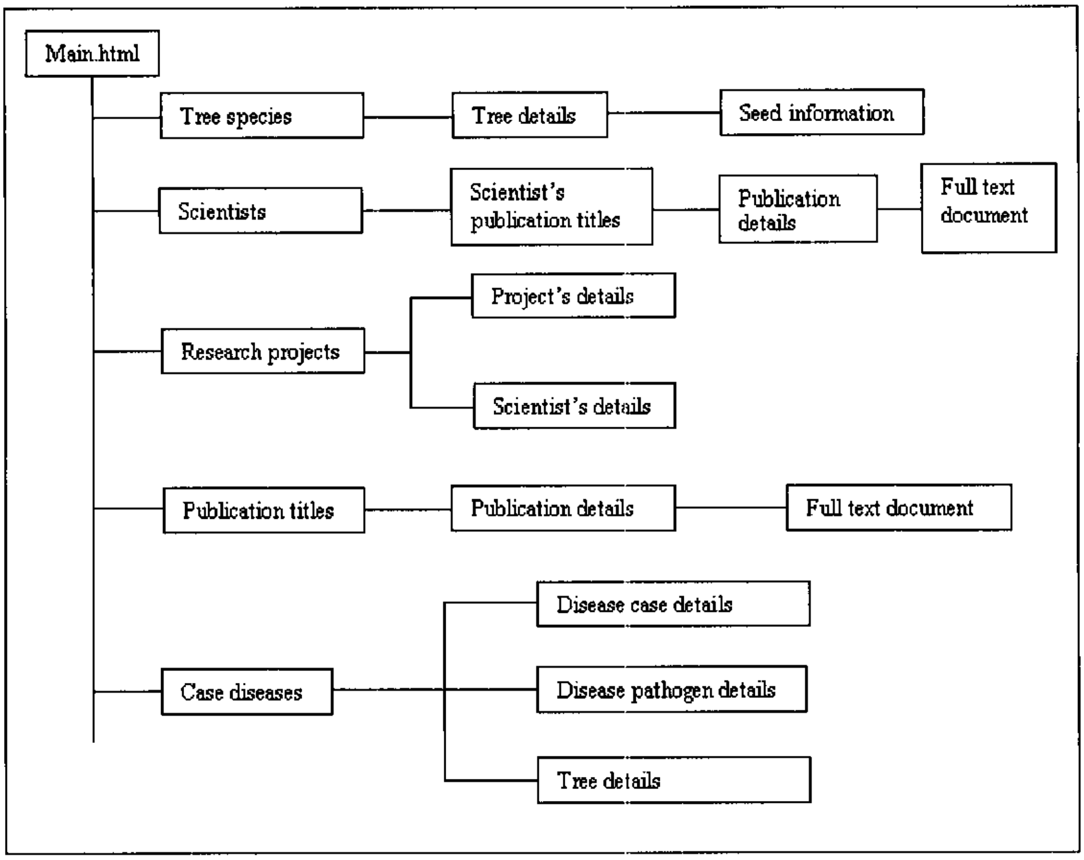

Figure 3.20: Hierarchical chart 1

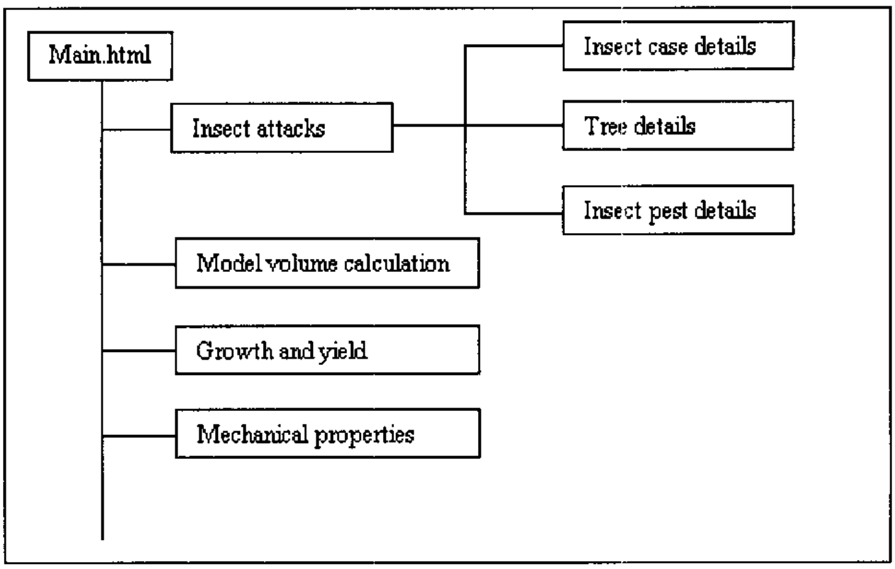

Figure 3.21: Hierarchical chart 2

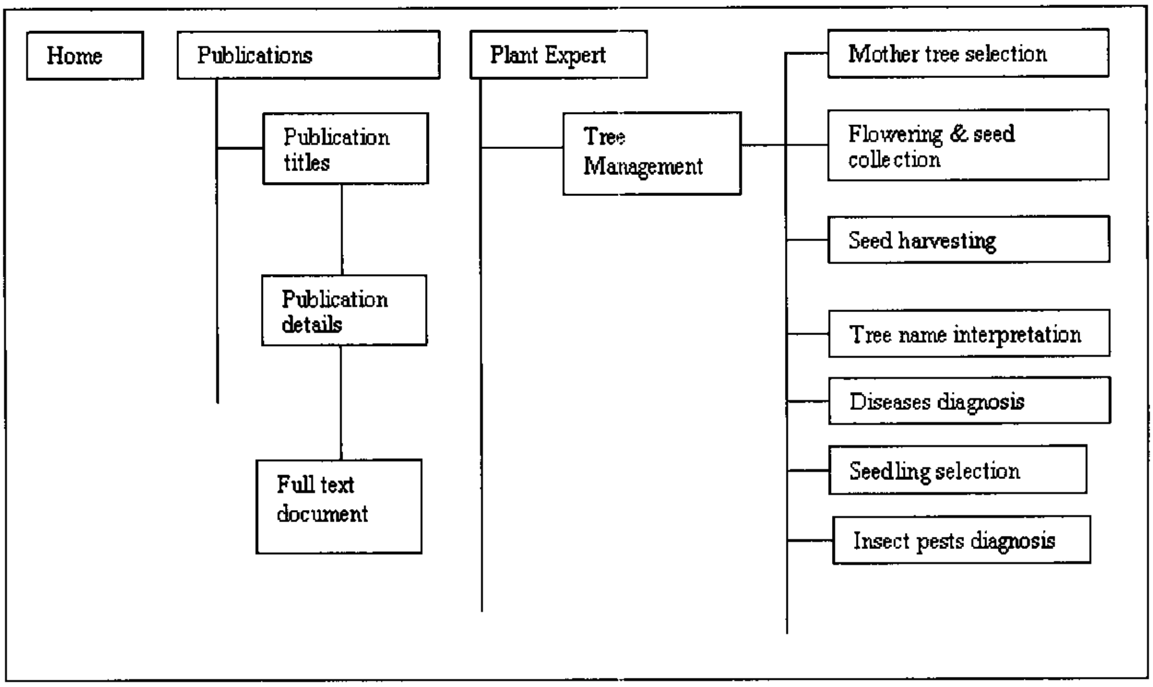

Figure 3.22 Horizontal hierarchical charts of plant expert module

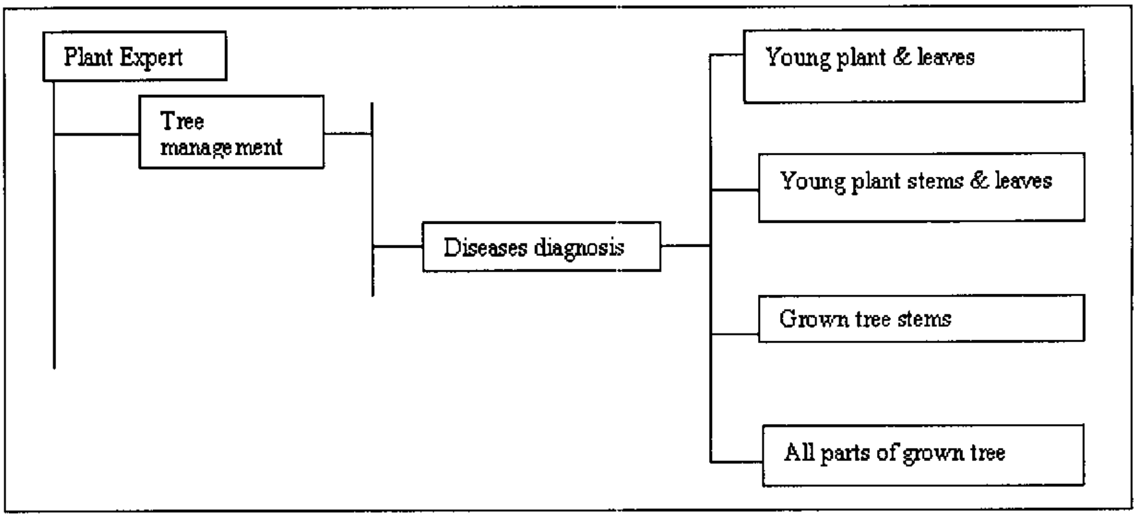

Figure 3.23 Horizontal hierarchical charts of diagnosis process.

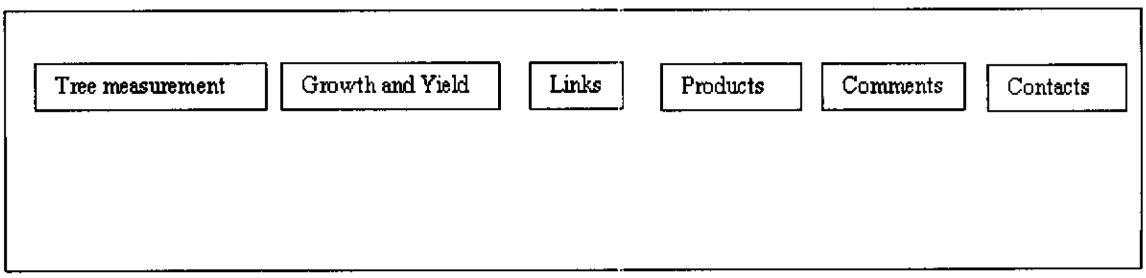

Figure 3.24: Horizontal Hierarchical Chart.

3.5.2.5 User Interface Design

This is the design of user interface. Meriam Webster's Dictionary (MWD) defines an interface as "the place at which independent and often unrelated systems meet and act on or communicate with each other" (MWD 2011). The interface allows interaction between users and the system when performing decision-making. Since, the interface is the only way an end user can access the system, we must take care to not only make the task easy for the user but also ensure that the user cannot modify the data. Much research and literature identifies what constitutes a good interface. Some of the important factors considered for web interface design has been discussed and the author explains how the interface design was achieved during the DSS development.

- Perform testing. Testing is a task that needs to be done before, during, and after writing the application. It is always a good practice to verify and validate the development process. Various forms of testing were performed on the DSS. We performed informal testing where the users of the system were asked for what they would use the system, whether the DSS satisfied their requirements after it was developed, did they need any additional or fewer features while the DSS was being developed. Formal testing included running queries where expected results were compared to actual results.

- Use meaningful tools. Radio buttons should be used only when one of the given sets of options is allowed. Checkboxes should be used when any number of options within a given set can be chosen. Drop down boxes can be used in place of radio buttons if screen space is a problem, but it is recommended that in such cases there is a default option. Multiple-choice drop down boxes can be used in place of checkboxes. Graphical buttons should be self-explanatory. All tools that are mentioned were used appropriately in the DSS for *G. robusta.* No tools perform duplicated function.

- Let the user see only what he is supposed to see: no more and no less. The DSS is solely designed for the purpose of aiding users with decision-making process for management of *G. robusta* tree. If the application is designed in the right way, no human keyboard intervention should be required for this task. This can be accomplished by eliminating text boxes or text fields for queries wherever possible. The only place that a user is allowed to enter anything in our application is when the users register, login and when they key in parameters or values when calculating bole volume.

- Differentiate between visited and unvisited links. Users always like the application to remember what links they visited earlier during their search process.

- Provide error messages only where necessary. Unexpected error messages intimidate the user. They should be used only when it is necessary. Error message is used only when validating user login and registration to ensure user details are keyed in correctly and when the user does not provide adequate information before a decision is made.

- Avoid deep leveling of pages. By the time the user is five levels deep, he forgets why he is there and for what he is there. The DSS application is at most four levels deep.

- Some pages have command buttons and keyboard alternatives for giving the various commands to the system. Clicking the command with the mouse causes the appropriate procedure to be executed. All pages have links for calling other pages. Pages are standardized for easy understanding and ease of use. Each page has a title and links to other pages.

This chapter has provided an overview of the design used in the implementation of *G. robusta* DSS. In the next chapter, we examine the implementation details of the system.

CHAPTER 4: SYSTEM IMPLEMENTATION, TESTING AND EVALUATION

4.1 Introduction

This chapter describes the implementation process of a web based DSS for *G. robusta* tree managment. The first section describes the implementation of the software. In the second section, simulation process is explained. This is how the prototype was tested with sample data collected from the field survey. The third section explains how the prototype was tested and evaluated.

4.1.1 Implementation

The front-end application was developed in a laptop with an Intel(R) Core (TM) 2 Duo CPU T7250, 2.00 GHz processor, 3.5 GB Ram memory, 120 GB hard disk, flash disk and CD drives. The computer runs Microsoft Windows XP Profession Version 2002, Service Pack 3 operating system. The web pages were hosted in this computer but will be migrated to Microsoft Windows 2007 server running Microsoft based Internet Information Server (IIS). The Windows XP was preferred because of its stability, has good graphical user interface that was noted as a requirement in the design phase.

4.1.2 Microsoft Access was used as the Relational Database Management System (RDBMS). The database was used because it is readily available and easy to use. In order to access the data in the database, a Data Source Name (DSN) less connection was used with the ASP code. The advantage of DSN less connection is that Active Data Object (ADO) does not have to perform a lookup registry. It improves performance of concurrent connections to the server. Data entry forms were implemented using Hypertext Markup Language (HTML) for online entries. HTML was the most suitable for input data entries of the DSS.

4.1.3 Microsoft Visual Studio 6.0 was used to create web pages. The tool is used in site development because it supports JavaScript and Cascading Style Sheets (CSS), along with other advanced functions. Active Server Pages (ASP) and VBScript were used during development, and were used to develop web-based interface to capture, post and retrieve information from the database. The ASP and VBScript were used to implement the knowledge base and inference functions.

4.1.4 Asynchronous JavaScript and XML (AJAX) is the art of exchanging data with a server, and update parts of web pages – without reloading the whole page, especially when displaying growth and yield data. JavaScript is a program language that allows the execution of commands from the client's side. The language was used because it enhances dynamisms and interactive features of the web pages. It gives the reader feedback to processes and action available on the HTML page, does calculations, check forms, add special effects and create secure passwords. These features were used to develop the DSS for *G. robusta.*

4.1.5 Microsoft Internet Explorer 8 was used as the browser, which enables multiple users to access database and get the information on a click of a button. This reduces the delay that set in while making reports. It also reduces paper work in printing reports. It was used to test pages running in the web server.

4.1.6 Microsoft Office tool, Microsoft Word 2003 and power point 2003 were used for documentation and presentation.

4.1.7 Flash disks and compact disks were used for backup and installation purposes.

4.2 Simulation

Simulation is very useful in a prototype development because when the system cannot deliver appropriate results, it would be unusable to users. As stated in part of report, one requirement of the DSS is to capture and display *G. robusta* tree information through the web interface. The requirement was tested by entering some of the records in the system.

4.3 System Testing

The modules were first tested independently to ensure that they perform according to specification before being integrated into the main modules. Integration was then tested as group to ensure that there exists total coordination in the system. The data in the DSS is stored in files and was converted and transferred into the system at this stage. It should be noted that the system testing is still not yet completed at the time of writing this document. During testing different combination of data were used to ensure errors were detected and corrected to stop them from going into the system.

4.4 Prototype Evaluation

The evaluation phase is one of the most crucial parts on a system's life cycle because it is an indicator of the degree of success. The fundamental principle of testing is to ensure that the developed application meets the specifications defined in the earlier stages of analysis and design. An evaluation was arranged with specific user group – tree growers, foresters, extensions officers, researchers and other stakeholders in forestry sector. Various tests were carried out on the application and the following issues were of major concern during the testing of the system. The goal of the evaluation was to assess the quality of information given by the DSS system.

4.4.1 Testing the Plant Expert Module

Previous works on the DSS systems were surveyed on their usability for evaluating Web Based DSS. The surveys reveal that comparison with human expert has been recommended for determining the appropriateness of the approach taken for implementation (Grogon et al. 1993). The DSS expert component was evaluated using similar technique. On the basis of these, specifically the results from the system were compared with human experts.

An experiment was designed to compare the performance of the plant expert module of the DSS with that of recognized experts, therefore, all the sub – modules were tested. Five human subjects were selected for comparison for each test case. A forest pathologist, two entomologists, forester, tree bleeder, phenologist and a taxonomist. Each member of the team was asked to demonstrate how he or she perform specific task related to the DSS functions. The experts' judgments were noted and compared to the advice and recommendations given by the DSS system. The result obtained from the DSS compared favorably with those given by forestry experts at Kenya Forestry Research Institute in Muguga.

4.4.2 Testing the Model Manager

An experiment was designed to compare tree log volumes calculated by the system and the one calculated by a forester. Samples of *Grevillea robusta* trees height and diameter at breast height (DBH) were measured and recorded in table 4.1 shown below. The symbols Tno, means Tree number, D1 the DBH, C1 circumference at breast height, D2 top diameter, C2 is top circumference and H, height in meters.

TNo	D1 (cm)	C1 (cm)	D2 (cm)	C2 (cm)	H (m)	Forester V (m^3)	DSS V (m^3)
T1	32.40	101.83	26.00	81.71	8.00	**0.54**	**0.5426**
T2	41.50	130.43	38.00	119.43	7.00	**0.87**	**0.8711**
T3	17.60	55.31	8.00	25.14	9.00	**0.13**	**0.1322**
T4	18.00	56.57	5.00	15.71	8.50	**0.12**	**0.1166**
T5	41.20	129.49	34.00	106.86	11.75	**1.32**	**1.3178**
T6	38.00	119.43	28.00	88.00	13.50	**1.18**	**1.1821**

Table 4.1 Volume Measurements

A forestry expert was asked to calculate the volume of a selected sample trees using the parameters collected from field survey and results recorded as shown in table 4.1 above. The DSS calculated the volume using the circumference and the result compared with those of the forester. The results indicate that both forester and the DSS had similar results except that the system gave the accuracy of the log volumes in four decimal places while that of the forester was given in two decimal places.

4.4.3 Testing Growth and Yield of *Grevillea robusta* Tree

An experiment was designed to test and compare growth and yield of *Grevillea robusta* tree to that the system predicts. The DSS prediction is based on (Kaumi 1980) growth and yield statistics. Samples of trees planted in 1988, 1989, 2003 and 2005 were measured from four different forest stands. The data was collected and tabulated in tables 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 shown below.

Forest Stand 1: 1988

Tree No	Height (m)	DBH (cm)
T1	28.25	31.50
T2	26.75	35.30
T3	23.50	29.70
T4	24.00	29.60
T5	25.50	35.10
T6	25.50	37.10
AVG	**25.58**	**33.05**

Table 4.2 Height and DBH averages of forest stand 1.

Forest Stand 2: 1989

Tree No	Height (m)	DBH (cm)
T1	20.50	35.80
T2	26.50	30.30
T3	26.25	41.40
T4	27.50	33.80
T5	24.00	31.70
T6	20.75	39.40
AVG	**24.25**	**35.40**

Table 4.3 Height and DBH averages of forest stand 2.

Forest Stand 3: 2003

Tree No	Height (m)	DBH (cm)
T1	16.25	16.80
T2	16.75	19.20
T3	15.50	15.80
T4	16.00	17.20
T5	14.75	17.60
T6	16.00	19.70
AVG	**15.88**	**17.72**

Table 4.4 Height and DBH averages of forest stand 3.

Forest Stand 4: 2005

Tree No	Height (m)	DBH (cm)
T1	15.75	16.50
T2	15.00	18.70
T3	14.50	15.50
T4	13.00	17.60
T5	13.00	15.20
T6	14.25	17.80
AVG	**14.25**	**16.88**

Table 4.5 Height and DBH averages of forest stand 4.

Year	Forest Stand	Height (m)	DBH (cm)
1988	Forest Stand 1	25.58	33.05
1989	Forest Stand 2	24.25	35.40
2003	Forest Stand 3	15.88	17.72
2005	Forest Stand 4	14.25	16.88

Table 4.6 Height and DBH averages of all forest stands.

Age (yrs)	DSS H1 (m)	Forester H2 (m)	DBH1 (cm)	Forester DBH2 (cm)
1	1.20			
2	4.00			
3	4.70			
4	5.70			
5	7.00		8.89	
6		14.25		16.88
7	7.90		12.45	
8		15.88		17.72
9	10.40		14.99	
11	12.20		20.07	
15	14.30		25.07	
20	16.50		27.22	
22		24.25		35.40
23		25.58		33.05
25	15.00		27.20	

Table 4.7 Comparison of growth and yield data of *Grevillea robusta* after testing in the field.

The results of the tree growth and yield for *Grevillea robusta* were tabulated as shown in table 4.7 above. According to the table, the DSS prediction varies from those measured from forest stands. The height varied according to age though the values were less than those measured in the field. The same case was observed for DBH that varied according to age however, there was slight variation at 23 years where the DBH was observed to be less than 22 years. The DBH values were less than those measured in the forest stands. The reasons why there was this variation was properbly because of intercropping trees with agricultural crops, genetic improvement and site of tree stands could have contributed to high growth rate compared to similar information given by the DSS.

4.4.4 Data Analysis

A sample of twenty-eight (28) users was selected to evaluate the DSS system using a questionnaire attached in the appendix. The DSS website was hosted in a Local Area Network (LAN) using Microsoft Internet Information Server (IIS) as the web server. ICT personnel were trained on the DSS and then requested to train other users on how to use the system including registration and login in the system. After training, users were requested to evaluate the system.

Results

The results showed that 64% of the respondents were male as compared to 36% female. In addition, 66% of the respondents were working in research organization and 34% as full time farmers. Of these, majority (43%) had tertiary level of education as compared to university and secondary education (figure 4.1). This implies that the literacy level among the respondents was high and will have knowledge on the use of computers. This was further evidenced with most of the respondents (93%) who adequately accessed computers as compared to 7% whose access was inadequate. This strengthened the relevance of the respondents in evaluating the DSS.

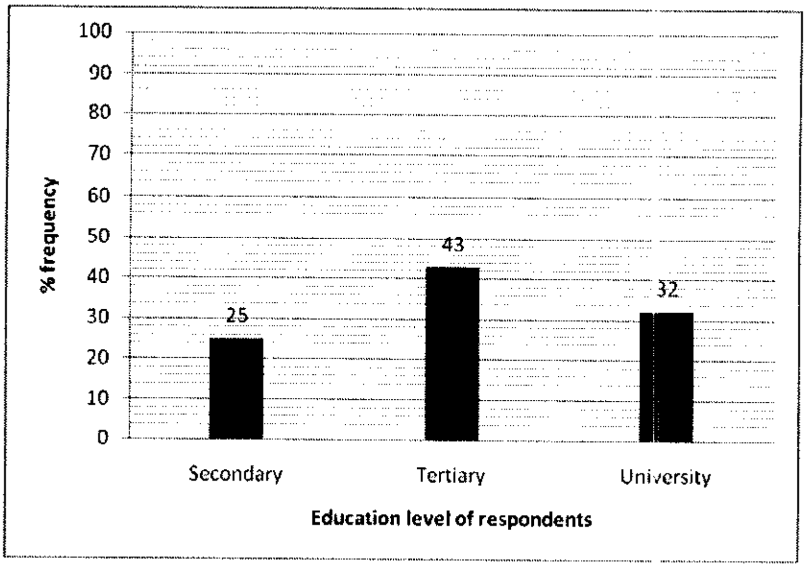

Figure 4.1 Education levels of respondents

Moreover, majority (54%) of respondents were quite often interacting with computers connected to the internet resulting to a mean score of 4.4 providing an overall rating of often (Figure 4.2). This implied that chances were higher of the target group to propagate the use of DSS in the institutions and areas of operation.

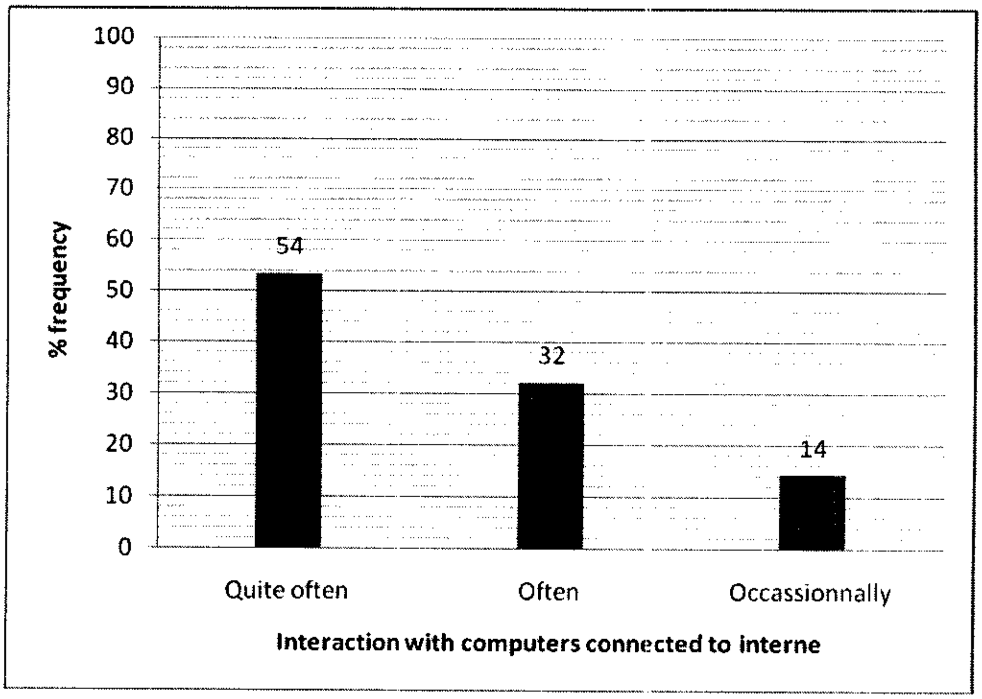

Figure 4.2 Rating of interaction with computers connected to the Internet.

On the other hand, various reasons were provided for rating often or rarely with computers connected to the Internet. The main reason was that the respondents had work related to the Internet connectivity (Table 4.8)

Reasons for rating often or rare interaction	Frequency	% Frequency
Availability of modem	2	15
Mobile phone has Internet connection	2	15
Work related to Internet connectivity	8	62
Sharing of computers	1	8
Total	**13**	**100**

Table 4.8 Reasons for often or rare interaction with computers connected to the Internet.

Use of Web Based Decision Support Systems

Of the interviewed respondents, 61% have used the DSS as compared to 39% who weren't. When asked to rate the DSS on whether it provided accurate information, 61% and 39% rated the system as acceptable and excellent, respectively. Similarly, 61% and 39% rated ease of use as acceptable and excellent, respectively. In addition, 68% and 32% rated assistance of DSS in decision making as acceptable and excellent, respectively. All of these were not significantly different (p>0.05) among and between the types of users. This implied of the selected farmers and respondents from the research institutions were of the view that DSS is useful, easy to use, provide accurate information and important in decision making processes. Furthermore, 46%, 46% and 7% rated the relevance of information content in the DSS website as quite relevent, relevant and fair, respectively, giving a mean score of 3.4. This correspond to relevance in the overall rating. Therefore it implied that the information content in the DSS website was relevant to the respondents. This again was not significantly different (p>0.05) between farmers and respondents from research organizations. In addition, 43%, 43% rated the DSS as quite suitable, suitable respectively in dissemination and forestry technology transfer (Figure 4.3). Overall, this gave a mean score of 3.25 corresponding to suitable implying that respondents sampled found the DSS suitable in dissemination of research information. A number of reasons were given for the suitability as in Table 4.9.

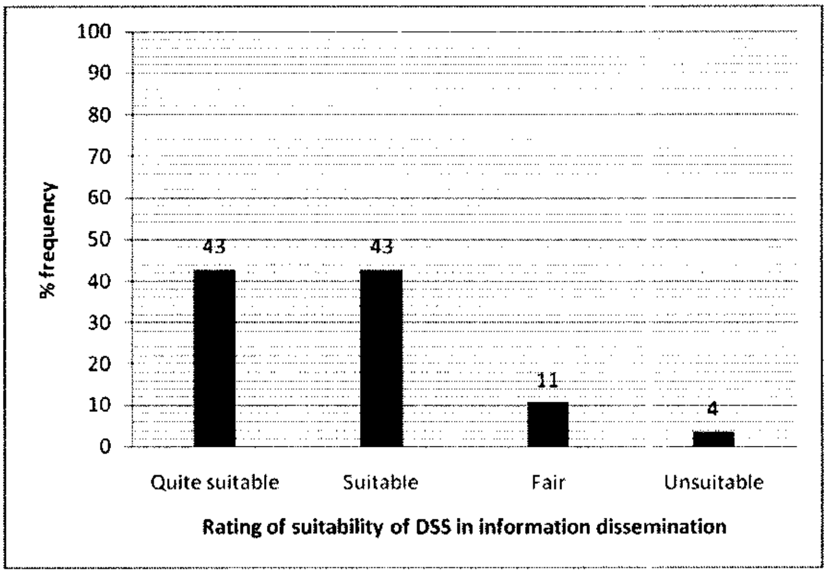

Figure 4.3: Rating the suitability of the DSS in dissemination of information and technology transfer.

Reasons for suitability	Frequency	% Frequency
Information about *Grevillea robusta* is available at click of a button	4	17
Site provide important information about forestry	5	22
The site has information for all types of users in forestry	4	17
Site is suitable, relevant for decision making	8	35
The site has digitized publications information about *Grevillea robusta*.	2	9
Total	**23**	**100**

Table 4.9 Reasons for suitability

Conseqently, the rating on the performance standards were rated on higher scale of strongly agree and agree for fast response and presentability of the user interface, respectively (Table 4.10).

	Rating of standards					
Performance	**SD**	**MA**	**Agree**	**SA**	**Total% (n)**	**Mean score**
The system responds fast		4	42	54	100 (26)	5
User interface is presentable and elicits the ambience of NRM		13	46	42	100 (24)	4

Table 4.10 Rating the performance of DSS

However, the following were provided as possible ways to improve the DSS.

How to Improve the DSS	**Frequency**	**% Frequency**
Site should work with other browsers	2	11
Plant expert module should have links to navigate to other pages	2	11
Should have sign out button	1	5
The website should give growth and yield of *Grevillea robusta* according to different geographical sites.	2	11
Should cover other tree species in Kenya	5	26
Incorporate mobile interface	1	5
Educate users about use and importance of DSS	4	21
Registration details should be very minimal	1	5
Additional of more background information	1	5
Total	**19**	**100**

Table 4.11 Suggestions on how to improve the DSS

In this evaluation, relevancy was defined as the opinion of the respondents about the suitability of the information provided by the Decision Support System to the users' situation. The results indicate that the DSS is able to provide information suitable to users' resources and appropriate to the users' needs. These results are in agreement with the findings of (Helen & Kaleel 2009).

CHAPTER 5: RESULTS AND FINDINGS

This chapter gives the readers summary of the system appraisal, matched against the project objectives, problems encountered, conclusion and suggestion for further work.

No	Objective	Description	Observed Result	Comments
1	To determine if the DSS can perform on par with recognized experts, i.e. scientist or forester with extensive experience of rising and management of *G. robusta* tree species in Kenya.	The objective was to survey and compile knowledge for management of *Grevillea robusta* and compare the quality of advice given by the DSS to that of the recognized experts.	The performance of the DSS compares favorably with that of forestry experts.	System meet criteria
	To develop tools to aid in building decision support systems in forestry sector	The objective was to develop tools to build web based decision support system that could be used to build other DSS in the forestry sector rather than that of *Grevillea robusta.*	The web based DSS for *Grevillea robusta* contain hundred and twenty (120) pieces of knowledge, three models and forty-six (46) research publications and other data files. The system was developed using fourth generation languages, such as Active Server Pages (ASP), Hypertext Markup Language (HTML), Cascading Style Sheet (CSS), AJAX and JavaScript. The author has successfully demonstrated that the above-mentioned tools could be used to build decision support systems.	System meet criteria
	To design and develop decision support system based on farm forestry to assist	The objective was to design and develop decision support system to assist users of *Grevillea robusta*	The author has succeeded in building a web based decision support system for *Grevillea robusta* tree prototype that has undergone thorough testing and evaluation	System meet criteria

	users when making decisions.	tree species when making decisions.		
	To model the characteristics of *Grevillea robusta* tree species based on growth and yield.	The objective was to model tree growth and yield to assist farmers when making decisions.	The author has succeeded in modeling tree growth and yield based on previous growth and yield statistics.	System meet criteria
	To consult with forestry practitioners the suitability of the system in technology transfers.	The main task here was to consult with forestry practitioners on the suitability of the DSS in forestry technology transfer.	The system was evaluated using a questionnaire and the result indicate that the system is suitable for processing and storage of knowledge in *Grevillea rousta,* the DSS also acts as a tool through which information can be disseminated to stakeholders.	System meet criteria
	What are the diseases that affect *G. Robusta*? How do we model and simulate the role of an expert in the diagnosis of tree pests and diseases?	The objective was to survey and identify the diseases and pests that affect *Grevillea robusta* tree species. Develop rules to assist farmers diagnose common insect pests and diseases.	The DSS can diagnose four common diseases that affect young and grown up trees. The system is able to recognize four effects of insect pest tree host damages.	System meet criteria
	How do tree growers, foresters and researchers make decisions? Is it possible to model decision support tool to help them make decisions more	The objective was to find out how tree growers, foresters and researchers make decision in *Grevillea robusta* tree species and develop DSS tool that would assist them make decisions	A web based DSS tool consisting of a database to keep and maintain research information in form of publications and other related data, models to calculate and predict tree growth and yield and knowledge base for problem solving in relation to *Grevillea robusta* tree species management.	System meet criteria

	efficiently?	more efficiently.		

Table 5: Result and discussion

5.1 Problem Encountered

Despite the successful completion of the project, there were problems encountered. It was difficult to scan and convert all the documents into digital format because of confidentiality and workload involved in processing such documents. There was budget constraint, problem of time, the project was limited to a period of six months and this was a short time.

Learning software tools and making codes work as required in this project consumed a considerable amount of time. These included Microsoft Access Database, CSS, ASP, Ajax, Visual Studio, JavaScript, HTML, and Internet Information Server (IIS) setup. There were also problems of software installation and configurations.

5.2 Conclusion

The evaluation has shown that the system is suitable for capturing, organizing, processing and dissemination of knowledge and information to farmers, tree growers, researchers, foresters, extension officers and other forest stakeholders. The system demonstrated how a web based decision support system could be formulated and implemented in the form of a database, model and rules to provide decision making in a forestry sector to compile and manage research knowledge in *Grevillea robusta* tree species in Kenya. Even though evaluation and testing of the prototype was done during implementation it is advisable to test it with different sets of data in different environment before being put into use.

5.3 Suggestion for Further Work

Apart from the existing functions, the DSS can be extended to include silviculture practices that would help improve *G. robusta* tree management. Some of these practices may include: Pruning, weeding, land preparation est. Knowledge base can also be modified to include treatment and diagnose more cases of disease and pests. It can also become available for use over the Internet.

From the previous work done by Kaumi, the growth and yield of *Grevillea robusta* is lower compared to the current growth rate as observed from the field. This was as a result of farmers appreciating new monitored qualities e.g. growers planting tree species with good mother genes however, there is need to collect new and current growth of *Grevillea robusta* tree according to different geographical sites. The data should be used to model the growth and yield in order to give more accurate information. The farmers can use the model to predict future growth and yield based on the age of the tree, and assist them when making decisions.

As the DSS database grows, the number of publications, pest and diseases cases will grow. Also, an increasing number of users will quickly make the system unusable with Microsoft Access. To handle a large quantity of data and large number of users, the database needs to be ported to an Oracle or Microsoft SQL database.

Another recommendation is that the expert component code and the interface is revised so that advice and recommendations information is designed such that the interface look as if displayed in the same page and hide the user from the complexities of viewing information in another page. Updating the DSS and including other facilities by integrating multimedia technology will dramatically enhance its usage and improve user friendliness.

CHAPTER 6: APPENDIX

This chapter list the sources of information used in this project, as well as the samples of pages, reports and codes used as evidence of work done and for future references.

Appendix 6.1: Data Dictionary

Number	Field Name	Description	Format	Size
1	CDID	Unique case disease identification number	Auto number	
2	Disease	Disease number	Number	
3	Tree	Tree number	Number	
4	Partaffected	Part of the tree effected the disease	Text	50
5	Hostdamage	Description of host damage caused by the disease	Text	Memo
6	Remarks	Remarks	Text	Memo
7	Imager	Image of the host damage	Text	50

Table 6.1 Casediseases

Number	Field Name	Description	Format	Size
1	CID	Unique insect case identification number	Auto number	
2	Tree	Tree number	Number	
3	Insect	Insect number	Number	
4	Partaffected	Part of the tree effected by insect pest	Text	50
5	Hostdamage	Description of host damage caused by the insect pest	Text	Memo
6	Remarks	Remarks	Text	Memo
7	Imageurl	Image of the host damage uniform resource locator	Text	35

Table 6.2 Casepests

Number	Field Name	Description	Format	Size
1	DiseaseID	Unique disease identification number	Auto number	
2	Disease	Disease description name	Text	35
3	Species	Species of the pathogen	Text	35
4	Genus	Genus of the pathogen	Text	35
5	Family	Family of the pathogen	Text	35
6	Order	Order of the pathogen	Text	35

7	Subclass	Subclass of the pathogen	Text	35
8	Phylum	Phylum of the pathogen	Text	35
9	Kingdom	Kingdom of the pathogen	Text	35

Table 6.3 Diseases

Number	**Field Name**	**Description**	**Format**	**Size**
1	MechpropID	Unique Mechanical properties identification number	Auto number	
2	Tree	Tree number	Number	35
3	Property	Tree mechanical properties	Memo	
4	Quantity	Mechanical property quantity of measure	Text	20

Table 6.4: Mechproperties

Number	**Field Name**	**Description**	**Format**	**Size**
1	InsectNO	Unique Insect identification number	Number	
2	Species	Species description	Text	45
3	CommonName	Common Name	Text	40
4	Genus	Genus of the pathogen	Text	35
5	Family	Family of the pathogen	Text	35
6	Order	Order of the pathogen	Text	40
7	Image	Uniform resource locator of the image	Hyperlink	

Table 6.5 Pests

Number	**Field Name**	**Description**	**Format**	**Size**
1	Pubid	Unique publication identification number	Auto number	
2	Title	Disease description name	Memo	
3	Type	Type of publication	Text	35
4	Pyear	Year of publication	Number	
5	Publisher	Name of the publisher	Text	100
6	Authorno	Author number	Number	
7	Cauthors	Other authors	Text	80
8	Purl	Publication uniform resource locator	Hyperlink	
9	Pages	Number of pages of a publication	Number	
10	Theme	Number of the tree species	Number	
11	Abstract	Abstract of the publication	Memo	

Table 6.6 Publications Table

Number	Field Name	Description	Format	Size
1	QID	Unique qualification identification number	Auto number	
2	Qempno	Employment number	Number	
3	Qualification	Qualification description	Text	25
4	CertName	Certificate Name	Text	50
5	Qinstitution	Institution of learning	Text	45
6	Qyrobtained	Year in the qualification was obtained	Number	

Table 6.7 Qualifications

Number	Field Name	Description	Format	Size
1	RPROJID	Unique research project identification number	Number	
2	RscID	Scientist identity	Number	
3	Ptitle	Research project title	Memo	
4	Objectives	Research project objective	Memo	
5	Investigator	Research project investigator	Text	60
6	Coinvestigator	Research project co-investigator	Text	60
7	Psdate	Research project start date	Date/time	80
8	Pendate	Research project end date	Date/time	
9	Sponsor	Research project sponsor	Text	
10	Projsite	Research project site	Text	40
11	Pstatus	Research project status	Text	30

Table 6.8 Rproject

Number	Field Name	Description	Format	Size
1	SCID	Scientist identity	Number	
2	Empno	Scientist employment number	Number	
3	Snames	Scientist's names	Text	50
4	Designation	Scientist designation	Text	30
5	Institution	Scientist's research institution	Text	45
6	Worktel	Scientist work telephone	Text	20
7	Mobile	Scientist mobile phone number	Text	20
8	Address	Scientist official address	Text	50
9	Email	Scientist email address	Text	50
10	Specializ	Scientist area of specialization	Memo	40
11	Passport	Scientist passport photograph	Hyperlink	30

Table 6.9 Scientists

Number	Field Name	Description	Format	Size
1	TID	Tree identity	Auto number	
2	Species	Tree species name	Text	45
3	Family	Tree order/family names	Text	50
4	Common_name	Tree common name	Text	45
5	Type	Tree type	Text	12
6	Image	Image uniform resource locater	Hyperlink	
7	Seedinfo	Seed information link	Hyperlink	

Table 6.10 Tree

Number	Field Name	Description	Format	Size
1	UserID	User identity	Auto number	
2	Fname	User first name	Text	30
3	Lname	User last name	Text	30
4	Email	User email address	Text	50
5	Telnumber	Telephone number	Text	12
6	Nationality	User's nationality	Text	45
7	Pwd	User password	Text	12

Table 6.11 Users

Number	Field Name	Description	Format	Size
1	UseID	User identity	Auto number	
2	Tree	Use tree identity	Number	
3	UseCategory	Tree use category	Text	20
4	Description	Tree use description	Memo	
5	ImageUrl	Imager uniform resource locator	Hyperlink	

Table 6.12 Uses

Appendix 6.2: User Manual

The users manual provides guidelines on how to use the web based DSS system for *Grevillea robusta* tree. The manual provides the users with adequate information on the operation and maintenance of the DSS.

6.2.1 System's Requirements

The system runs on the platform satisfying the software and hardware requirements described in the earlier chapter. These requirements are:

a) A computer running Microsoft Windows XP, Vista, or Windows 7 for hosting Microsoft Access 2003 Relational Database Management System (RDBMS).

b) A computer with Intel core 2 duo, 2.0GHz, 2GB ram and 80GB hard disk capacities and flask disk or compact disk (CD) drive running Windows XP operating system (or a later version), and connected to the computer hosting the database through a Local Area Network (LAN).

c) Alternatively, a powerful computer running Microsoft Windows 2007 Server or Unix/Linux and hosting the database (on Microsoft SQL 2007 Server for workstation version) and the front-end application.

d) Internet Information Server (IIS) for serving the web pages. (You can also use Personal Web Server, but this one is best for use in an Intranet and not the Internet. IIS is desirable for use even in the Internet. Other servers like Apache Web Server for Microsoft Windows Operating Systems can also be an alternative.

6.2.2 How to Install the DSS System

a) Make sure the requirements above are met.

b) Install the web server separately. Leave the default configurations during the installation e.g. C:\Inetpub\wwwroot as the home directory and the C:\webpub as the publishing directories

c) Then install the main system using the following steps. (The system comes in flash disk or a CD. It's advised to leave the default configuration during installation).

6.2.3 How to Install the DSS System from flash disk

- Insert disk in your computer flash drive or your USB port
- Run the setup program using your operating system environment, e.g. type E:\setup (and press enter) in command prompt.
- Follow the instructions.

6.2.4 How to Install the DSS System from a CD

- Insert the CD in the CD drive.
- Run the set up program using your operating system environment e.g. type D:\setup (and press enter) in command prompt and follow the instruction.
- Configure the web server to use C:\Inetpub\wwwroot\ project as the home directory and 'main.html' as the home page.

6.2.5 How to run the System

- Click start button on the task bar
- Click the Internet Explorer browser to access the system on the LAN

- Type 'http://localhost/main.html' if browsing from the local machine. If browsing from another machine in a local area network, type the Internet Protocol (IP) address of the machine hosting web server e.g. 'http://10.10.1.14/main.html' and the main page of the web site will load.

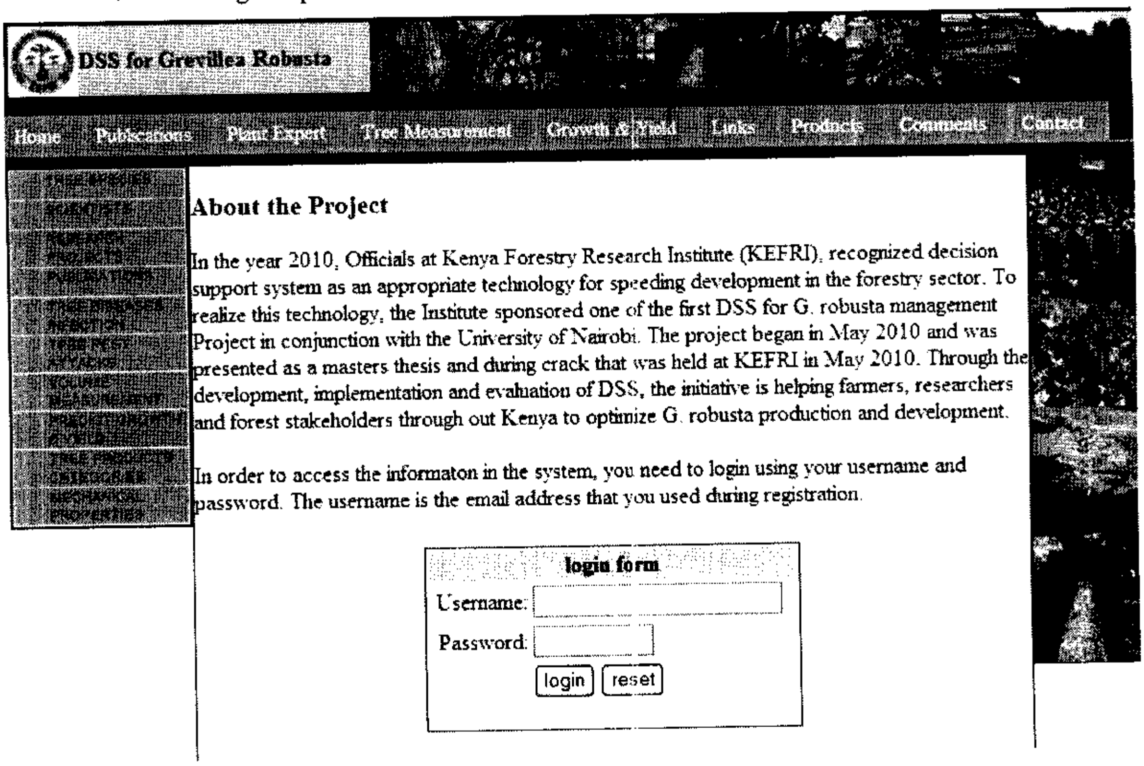

Figure 6.1 Login Form

Type your username and password and click login command button. To cancel or reset, click 'reset' button and the login details will disappear. If this is your first time, then you have to register by clicking on 'registration form'. The system will ask you to key in registration details including email address, your password and confirm password. The email address will become your username and you will be required to give your password that you used during registration.

The DSS main window appears as shown below.

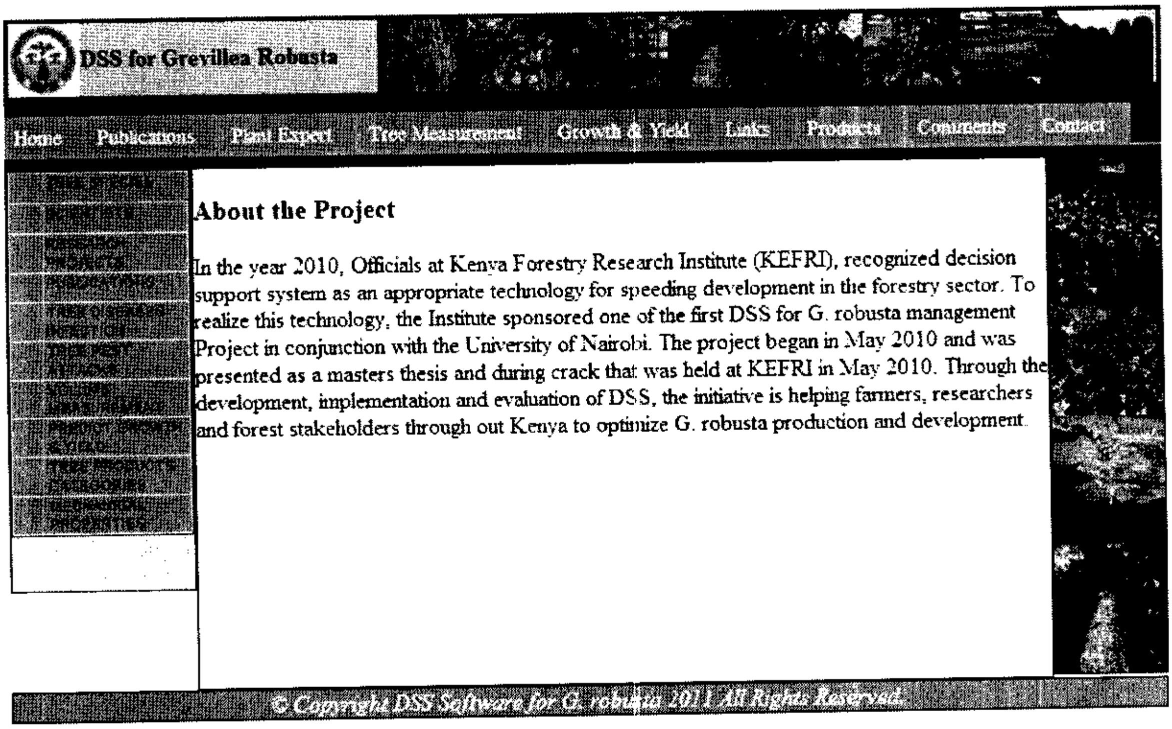

Figure 6.2 Main page

The window has links for the various operations of the DSS system. Every link opens a new page.

Appendix 6.3: Sample Web Pages

The users interact with the system through the forms and web pages especially when keying new data entries in the database. Forms are used as an easy user-friendly way to manipulate the database. Form are used to update and edit the database. Most of the forms in the system are similar and appear as in the diagram below. The operations that typically done in forms is described below.

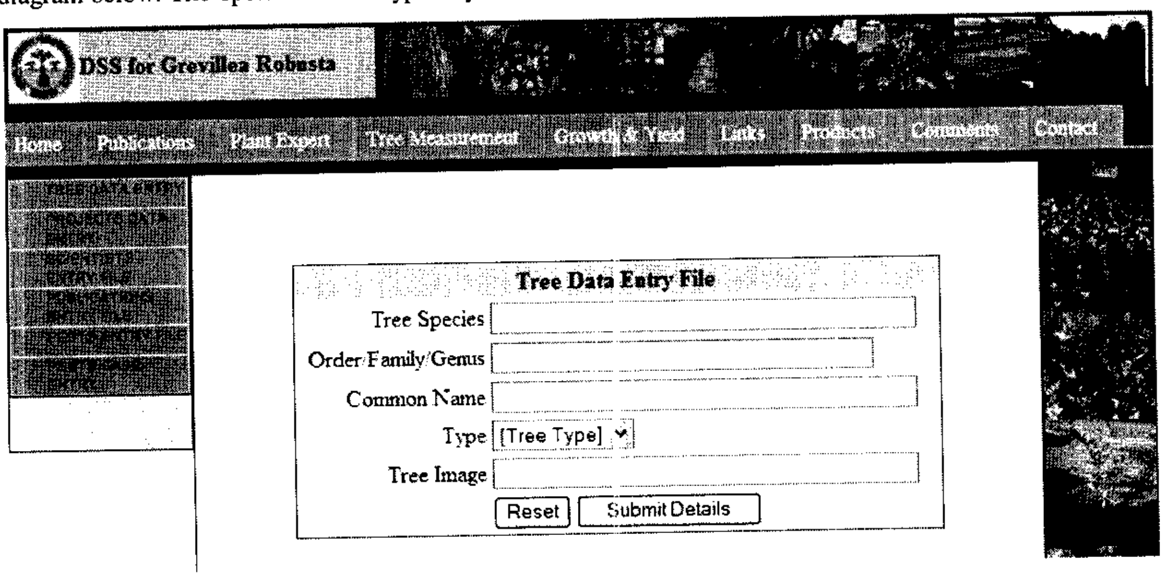

Figure 6.3 Tree data entry form

Typical elements of a form are; title bar (showing the title of the form – Tree data entry file in this case), command buttons, operation buttons. Examples, reset and submit details buttons. The data input area consist of labels and text boxes in a frame. Each label describes the data in the corresponding text box. Each text box displays data of single field of a record. The labels enclosed in braces describe the optional text box entries. All other text box entries are mandatory. Buttons are used for various operations on the table data.

6.3.1 Operations

To open a page

- When the main page is opened, click at the appropriate link to open page with the appropriate form.
- Once the form is open, it automatically displays field ready for data entries.

To move to a page

Click the link with the appropriate name depending on the information required.

To submit record

Click on the submit button to submit a record.

To cancel a record

Click on reset button to cancel or to reset the record.

To make a selection

Click an option button to choose an appropriate option.

To make different selections

Click check boxes to choose different options.

6.3.2 Sample data entry forms

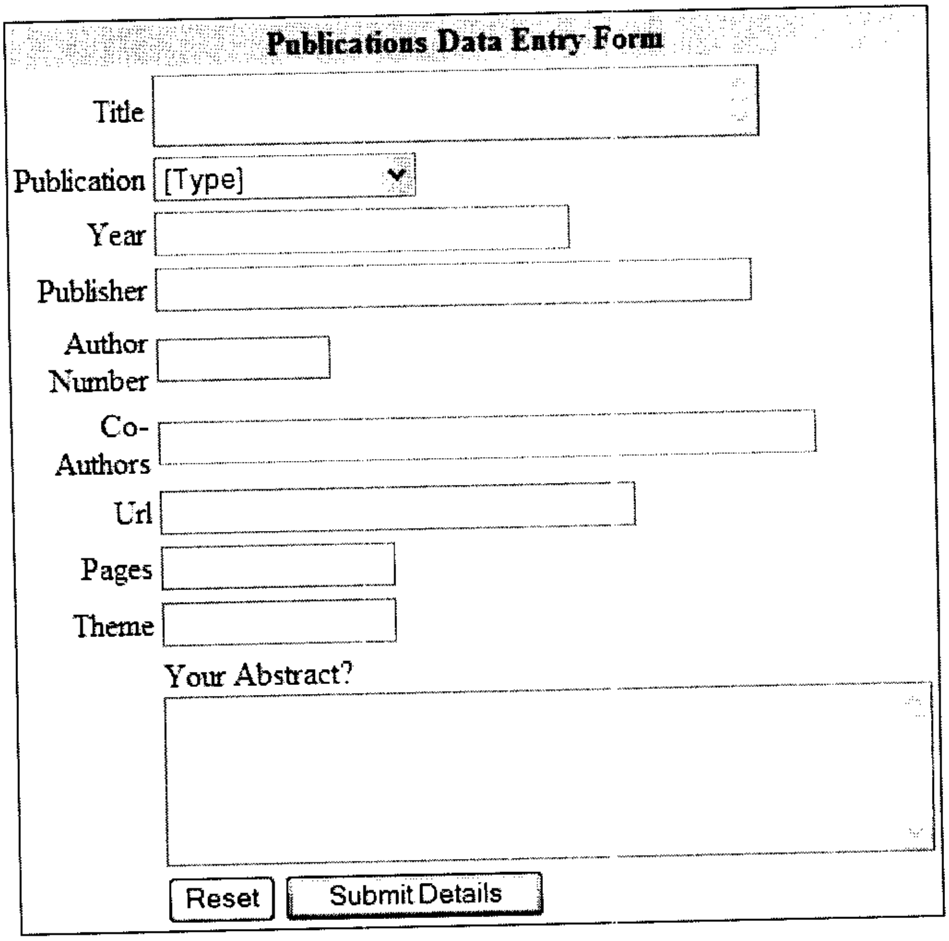

Figure 6.4 Publication Entry Form

6.3.3 Sample data selection form using option buttons

Select the area you wish to consult your tree expert!

- ○ Select suitable mother tree for seed collection
- ○ Flowering and seed collection time
- ○ How to harvest seeds from mother tree?
- ○ Interprete tree species' name in vernacular?
- ○ Diagnose common diseases in your farm?
- ○ Select suitable seedling(s) for planting?
- ○ Diagnose common insect pests in your farm?

[Submit] [Reset]

Figure 6.5 Single data selection form

6.3.4 Sample multiple data selection form using check box buttons

Select the symptoms that you observe in the tree(s)!

- ☐ Signs of wilting and falling of leaves
- ☐ Tree branches is/are left bear
- ☐ Trees dies in patches
- ☐ Dead bark has clumps of hyphae
- ☐ Bark can be peeled off easily
- ☐ Internal wood is killed
- ☐ Presence of scattered orange postule bearing unicellular hyaline spores

[Submit] [Reset]

Figure 6.6 Multiple data selection form

Appendix 6.4: Sample Codes

6.4.1 Code For Inserting Data

```
<%dim rsT, dbPath, conn, SQL
  dim sp, ofm, cmn, typ, img
  dim MyDate
```

```
'*******************************************'
'******Connect to the  Database*********
dbPath ="C:\Inetpub\wwwroot\DSS.mdb" '******Database path**************'
Set conn = Server.CreateObject("ADODB.Connection")
conn.Open "PROVIDER=MICROSOFT.JET.OLEDB.4.0;DATA SOURCE=" & dbPath
'*******************************************'
sp=Request.Form("tspecies")
ofm=Request.Form("tofamily")
cmn=Request.Form("tcmname")
typ=Request.Form("type")
img=Request.Form("timage")

SQL="INSERT INTO TREE(tspecies, tofamily, tcmname, type,timage)VALUES('"&sp&"','"&ofm&"','"&cmn&"','"&typ&"','"&img&"')"
on error resume next
set rsT = Conn.Execute(SQL)

if err<>0 then
  Response.Write("No update permissions!")
else
  Response.Write("<h3>" & recaffected & " record added</h3>")
end if
conn.close
%>
```

6.4.2 Sample Code For Querying the Database

```
<%
Dim sql, conn, rsP, id, tt
pid=Request.Form("Pubid")
'******Connect to the  Database*********
dbPath ="C:\Inetpub\wwwroot\DSS.mdb" '******Database path**************'
Set conn = Server.CreateObject("ADODB.Connection")
conn.Open "PROVIDER=MICROSOFT.JET.OLEDB.4.0;DATA SOURCE=" & dbPath
'*******************************************'

sql="SELECT PUBLICATIONS.Pubid, PUBLICATIONS.Title FROM PUBLICATIONS order by Pubid asc"
```

```
on error resume next
set rsP = Conn.Execute(sql)

%>
<table width="580" style="margin:2px; cellspacing:2px padding:0px; border-collapse:collapse;">
  <tr bgcolor="#DAECA4">
        <th width="50">No</th>
        <th width="530">List of Publiation Titles</th>
  </tr>
 <%
noofPres=0
DO UNTIL rsP.eof
id=rsP("Pubid")
tt=rsP("Title")
'noofPres=noofPres+1
%>
```

6.4.3 Code For Plant Expert

```
<%
Dim A, B, C, D
A = Request.Form("Health")
B = Request.Form("size")
C = Request.Form("prunned")
D = Request.Form("hardened")

If A="" OR B="" OR C="" Or D="" THEN
Response.Write "<center>"
Response.Write("You did not provide us with adequate information to ")
Response.Write "<br>"
Response.Write(" assist you in the selection of the seedlings")
Response.Write "</center>"
End if

'***********************************************************************************
If A="Yes" AND B=">=30" AND C="Yes" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is suitable for planting")
```

```
Response.Write "</center>"
End if

If A="Yes" AND B=">=30" AND C="Yes" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant is not hardened.")
Response.Write "</center>"
End if

If A="Yes" AND B=">=30" AND C="No" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant is not root prunned.")
Response.Write "</center>"
End if

If A="Yes" AND B=">=30" AND C="No" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because ")
Response.Write "<BR>"
Response.Write(" the plant is not hardened and root prunned .")
Response.Write "</center>"
End if

'*************************************************************************
If A="Yes" AND B="<30" AND C="Yes" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting ")
Response.Write("because the plant size is too small.")
Response.Write "</center>"
End if

If A="Yes" AND B="<30" AND C="Yes" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because ")
Response.Write(" the plant size is too small and not hardened.")
Response.Write "</center>"
End if
```

```
If A="Yes" AND B="<30" AND C="No" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is suitable for planting because the ")
Response.Write(" plant size is too small and is not root prunned.")
Response.Write "</center>"
End if

If A="Yes" AND B="<30" AND C="No" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because ")
Response.Write "<BR>"
Response.Write(" the plant size is too small, not hardened and root prunned .")
Response.Write "</center>"
End if

'*****************************************************************************

If A="Yes" AND B="<=50" AND C="Yes" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is suitable for planting")
Response.Write "</center>"
End if

If A="Yes" AND B="<=50" AND C="Yes" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant is not root prunned.")
Response.Write "</center>"
End if

If A="Yes" AND B="<=50" AND C="No" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant is not hardened.")
Response.Write "</center>"
End if

If A="Yes" AND B="<=50" AND C="No" AND D="No" THEN
```

```
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because .")
Response.Write(" the plant is not hardened and root prunned.")
Response.Write "</center>"
End if
'***********************************************************************************************
****************
If A="Yes" AND B=">50" AND C="Yes" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling not suitable for planting because the plant is overgrown.")
Response.Write "</center>"
End if

If A="Yes" AND B=">50" AND C="No" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling not suitable for planting because the  ")
Response.Write(" plant is overgrown and is not hardened.")
Response.Write "</center>"
End if

If A="Yes" AND B=">50" AND C="Yes" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling not suitable for planting because the plant  ")
Response.Write(" is overgrown and is not root prunned.")
Response.Write "</center>"
End if

If A="Yes" AND B=">50" AND C="No" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling not suitable for planting because the plant is ")
Response.Write(" overgrown, not hardened and root prunned.")
Response.Write "</center>"
End if

'*************************************************************
'*************************************************************
If A="No" AND B="<=50" AND C="Yes" AND D="Yes" THEN
```

```
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant is not healthy")
Response.Write "</center>"
End if

If A="No" AND B="<=50" AND C="No" AND D="Yes" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant ")
Response.Write "<BR>"
Response.Write(" is not healthy and not root prunned.")
Response.Write "</center>"
End if

If A="No" AND B="<=50" AND C="Yes" AND D="No" THEN
Response.Write "<center>"
Response.Write("Seedling is not suitable for planting because the plant ")
Response.Write "<BR>"
Response.Write(" is not healthy and not hardened.")
Response.Write "</center>"
End if
```

6.4.4 Code For Model Manager

```
<SCRIPT LANGUAGE="JavaScript">
<!-- This script calculate bole area and  volume of Grevillea Tree -->
<!-- Begin
function Volume(){
C2 = document.FORM1.CirmBGinput.value;
C2sq = eval(C2*C2);
A2 = eval(1/(4*Math.PI)*C2sq)
roundA2 = Math.round(A2);
C1 = document.FORM1.CirmSMinput.value;
C1sq = eval(C1*C1);
A1 = eval(1/(4*Math.PI)*C1sq)
roundA1 = Math.round(A1);
document.FORM1.CodeBiggerArea.value =
 'Abg = C^2/4PI\r'
+'Abg = 1/(4PI) x '+ C2+'*'+ C2 +' \r'
```

```
+'Abg = 1/(4PI) x '+C2sq+'\r'
+'Abg = '+A2+' \r'
+'Abg = '+roundA2;

document.FORM1.CodeSmallArea.value =
 'Asm = C^2/4PI\r'
+'Asm = 1/(4PI) x '+ C1+'*'+ C1 +' \r'
+'Asm = 1/(4PI) x '+C1sq+'\r'
+'Asm = '+A1+' \r'
+'Asm = '+roundA1;

H = document.FORM1.Heightinput.value;
At = eval(H*(A1+A2));
At = eval(H*0.0001*(A1+A2));
Vol = eval(1/2*At);
roundVol = Math.round(Vol);

document.FORM1.CodeVolume.value =
 'Vol = H*1/2(A1+A2)*0.0001\r'
+'Vol = 1/2'+'*'+'0.0001('+A1+ '+'+A2+') X '+H+'\r'
+'Vol = '+Vol+' \r'
+'Vol = '+Vol.toFixed(4);
}
function resetval(){
document.FORM1.CirmBGinput.value = 'Bigger end size (cm)';
document.FORM1.CirmSMinput.value = 'Smaller end size (cm)';
document.FORM1.Heightinput.value = 'Bole height (m)';
document.FORM1.CodeVolume.value = '';
document.FORM1.CodeBiggerArea.value = '';
document.FORM1.CodeSmallArea.value = '';
}

// End -->
</script>
```

Appendix 6.5: Questionnaire

USER SATISFACTION SURVEY

Questionnaire number__________________ Date of Interview_______________

Interviewer____

Gender of the respondent: ☐ Male ☐ Female

No	User/Stakeholder	Specific Name
1	Farmers/Tree Growers	
2	Research organizations (Regional/International)	
3	GOK Departments	
4	Learning Institutions	
5	Private Sector	
6	NRM Institutions	
7	Media Organizations	
8	Donor Organizations	
9	General Public	
10	Business Firms	
11	Other	

Q1. Education level (Secondary, Tertiary, Post Graduate) state...

Q2. Please rate your accessibility to a computer connected to the Internet

☐ Adequate ☐ Inadequate

Q3. Rate how you interact with a computer connected to the Internet

☐ Quite often ☐ Often ☐ Occasionally ☐ Rarely ☐ None

Q4. Please give reasons for rating **often** or **rarely**..

....

Q5. Have you used a web based decision support system (DSS) before?

☐ Yes ☐ No

Q6. DSS provide accurate information?

☐ Excellent ☐ Acceptable ☐ Unsatisfactory

Q7. Rate DSS ease of use?

☐ Excellent ☐ Acceptable ☐ Unsatisfactory

Q8. Rate how the DSS would assist in decision – making processes?

☐ Quite relevant ☐ Relevant ☐ Fair ☐ Not relevant

Q9. Rate the relevance of information content in the DSS website?

☐ Quite relevant ☐ Relevant ☐ Fair ☐ Not relevant

Q10. Rate the DSS suitability in dissemination and forestry technology transfers of such information?

☐ Quite suitable ☐ Suitable ☐ Fair ☐ Unsuitable

Q11. Please give reasons for your rating...

....

....

Q12. Provide your opinions on the following **performance of the DSS.**

Standards	Rating: *1. Strongly disagree (0-50%) 2. Disagree (51-60%) 3. Moderately agree (61-70%) 4. Agree (71-79%) 5. Strongly agree (80-100%)*
1. The system responds fast	
2. The user interface is presentable and elicits the ambience of NRM	

Q13. What are your general comments regarding further improvements of DSS system?

i)..

....

ii)..

....

END.

Thank you for taking your time with us.

Appendix 6.6: References

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