



**ADDIS ABABA UNIVERSITY**  
**FACULTY OF INFORMATICS**  
**DEPARTMENT OF INFORMATION SCIENCE**

**APPLICATION OF KNOWLEDGE BASED SYSTEM FOR WOODY  
PLANT SPECIES IDENTIFICATION**

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University in partial fulfillment of the requirements for the Degree of  
Masters of Science in Information Science

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## ABBREVIATIONS

AAU	Addis Ababa University
AI	Artificial Intelligence
API	Application Programming Interface
ES	Expert System
GREEN	Gymnosperms Remote Expert Executed Over Networks
IDE	Integrated Development Environment
KA	Knowledge Acquisition
KE	Knowledge Engineer
KBS	knowledge Based System
NH	National Herbarium
SPEX	Species Selection Prototype Expert System
TAXEX	TAXonomic EXpert System
VB	Visual Basic

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## ABSTRACT

Finding the correct identity of trees is the beginning of any inventory and management activities as well as any studies regarding the tree species. Identification of plant species in Ethiopia is conducted only in the National Herbarium. At present, the centre is not supported by information systems, which makes the identification process and dissemination of information inefficient and difficult.

The need of KBS for technical information transfer and efficacy in dendrology can be identified by recognizing the problems in using the current system for technical information transfer and by proving that KBS can help to overcome the problems addressed, and are feasible to be developed. This study attempts to design prototype KBS for woody plant species identification. As compared to existing way of identification we come up with new knowledge/rules with minimum features that registers comparable performance. By using this system, users can get access to expert knowledge and will be able to identify woody plant species like taxonomists do/judge. Using taxonomic KBS in different forestry research centers, high-paid taxonomists will reduce the costs of scientific research and will allow many researchers to conduct their research more independently (without going to the National Herbarium for identification).

This research is conducted in a step-wise manner. After problem selection, knowledge acquisition process is conducted. In this process, a key informant interview is held with experts (two taxonomists and one researcher). In addition to the key informant interview,

manuals and books used in woody plant species identification are also consulted. The knowledge extracted from the experts' and relevant documents that uses to solve a problem is modeled in hierarchical or laddering technique.

Based on the final knowledge modeled in decision laddering, domain knowledge is represented using production rules in prolog to construct the knowledge base. The system is developed to load the knowledge base and starts to infer from the knowledge base based on the users input/ facts. The prolog built in backward inferring mechanism is used for the identification of the species. The user interface is designed in vb.net. Finally, the system is tested and evaluated by the users. The result shows that, the system identifies the woody plant species correctly and can be applicable in woody plant species identification.

**Key words:** *knowledge based system, prolog, tree species identification, knowledge acquisition, knowledge modeling, and KBS evaluation.*

# CHAPTER ONE

## 1. INTRODUCTION

### 1.1 Knowledge Based System

Knowledge based systems (KBS) are one of the sub disciplines of artificial intelligence, which is dictated for solving problems beyond the reach of conventional computer programs (Chabris, 1989). It is an expert system (ES) that can solve problems by simulating the expert's knowledge and enabling to update the knowledge of the system. KBS contains vast knowledge and experience of experts in a certain domain. Thus, it can apply experts' knowledge and methods used in problem solving, and simulate the decision procedure that experts can do, and then used to resolve the complicated problem in the domain (Norrige and Russel, 2003).

Expert system has been applied to problems in many fields, such as electronics, engineering, law, manufacturing, mathematics, medicine, meteorology, geology and physics (Schmoltdt and Martin, 1989). The first successful expert system called DENDRAL, was developed by Feigenbaum, Buchanan and Lederberg in 1965 (Norrige and Russel, 2003). The program simulated an expert chemist's analysis and decision-making capability. A number of expert systems in different domains such as geological exploration, medical diagnosis were also developed using the concepts presented by Feigenbaum in DENDRAL (Krishnamoorthy and Rajeev, 1996). The next expert system in the area of medical diagnosis was the MYCIN in the 1970s, developed for diagnosing blood infectious diseases (Norrige and Russel, 2003).

Expert systems have also wide application in agriculture and forestry.

*'An Agricultural Expert System is a Decision Support System for Agricultural Extension Agents who has to decide what advice to be offered to farmers who have to decide what action to take based on it'*  
(Rao, 2008).

Some of such expert systems developed in agriculture includes: Cucumber Crop Production (Cuptex); Citex for Orange Production; Neper Wheat for Irrigated Wheat Management; Tomatex: for Tomatoes; and Limex a Multimedia Expert System for Lime Production (Prasad and Babu, 2006); MANAGE an expert system to diagnose pests and diseases for rice crop and suggest preventive/curative measures; AGREX to help the agricultural field personnel give timely and correct advice to the farmers (Rao, 2008).

In the forestry sector, expert systems have been developed for different applications like GREEN (which is an expert system for the identification of Iberian Gymnosperms), that allows online queries to be made (Contrerasa et al, 2003). Rauscher, an expert system developed to recommend silvicultural prescriptions for individual tree stands found in Minnesota, US. PREDICT expert system that diagnoses a disease of a tree species called *Pinus resinosa* (Schmoldt and Martin, 1989). A web-based expert system developed for advising on herbicide use in Great Britain (Thomsona and Willoughby, 2003). A prototype expert system called SPEX designed for species selection (Abduselam, 2001). TAXEX is a series of taxonomic expert systems, which are developed to help scientists to professionally identify living organisms (Lelekoy and Lyakh, 2008).

## 1.2 Tree/ woody plant Species Identification (Dendrology)

With the diverse climatic condition, due to the varied topographic features and wide range of altitude, Ethiopia is one of the important genetic diversity centers in Africa in terms of endemism of wild native plant and animal species (EFAP, 1994). Remnants of forests of the country hosts such diverse flora and fauna. In addition, the forests of the country and trees on other land uses provide diverse production and protection functions.

Finding the correct identity of trees is the beginning of any inventory and management activities as well as any studies regarding the tree species. Identification of a given tree species, which involves naming and classification, enables to retrieve appropriate facts from the (classification) system to be associated with the specimen at hand (Hedberg and Edwards, 1998). Trees can be recognised by observing their vegetative characteristics like habitat, and morphology such as form, bark, branches and twigs, leaves, fruits and flowers (Bekele et al, 1993; Thirakul, 1993). Studying of these characteristics so as to distinguish between tree species is called dendrology.

*'Dendrology is a forestry science which studies the silvicultural and morphological characters of trees. However, through common use, dendrology means particularly the taxonomy of woody plants, i.e. identification and systematic classification of trees, shrubs and lianas'*  
(Thirakul, 1993).

The procedure of tree species identification could be accomplished either by expert recognition and determination, comparison or using the characteristic keys or combination of

these stated procedures (see section 2.4) (Harlow et al, 1978; Hedberg and Edwards, 1989; Thirakul, 1993).

According to the experts in the National Herbarium, In Ethiopia, plant specimens (samples) were sent abroad for identification before the establishment of the Addis Ababa National Herbarium, in 1980. Currently, the National Herbarium is performing plant identification tasks and providing information for scientific based utilization and conservation of the country's plant resources.

### **1.3 Statement of the Problem**

As described in the previous section, tree species identification in Ethiopia is carried out only in the National Herbarium of Addis Ababa University. The task is accomplished by experts through comparison of specimens collected for identification with illustrations in the "Flora of Ethiopia", matching of specimens with those in the herbarium and using some identification keys published in the "Flora of Ethiopia". The task, identification of plant species is a complicated job that requires knowledge, experience, and judgement of experts.

The taxonomists and technicians in the herbarium are currently not supported by computerized decision support system to facilitate their activities. Activities such as plant species identification, the storage of description of the species, and dissemination information about the species to users are all done manually. This leads to inefficient and prone to human error in identifying species, loss of information and inefficient way of information transfer. This limitation coupled with the limited number of taxonomists and technicians make the identification procedure time consuming and costly. In addition, researchers and forestry

technicians in the different parts of the country need to bring specimens to the National Herbarium in Addis Ababa for identification. As a result, they have to travel long distances whenever there is a need for identification of tree species. Moreover, the current system may lead to poor decisions, due to the problems posed by damaged specimens and inexperienced taxonomists.

Knowledge based systems are most successful in addressing specific problems in well-defined areas in which experts can articulate the required knowledge (Latin and Traves, 1991). Knowledge based system development based on the available domain knowledge can contribute to tackle the aforementioned problems in the field of tree species identification. It also provides easy identification procedures which will be accessible for forestry technicians and researchers with less cost and higher accuracy. The knowledge based system provides efficiency; it increases throughput and decrease personnel costs. Although knowledge based systems are expensive to build and maintain, they are inexpensive to operate and make use of it. Development and maintenance costs can be spread over many users and this KBS are also valuable as a constant source of expertise of woody plant species identification, available at all times to all users. The overall cost can be quite reasonable when compared to expensive and scarce human experts in the field. The KBS can also explain (justify) their line of reasoning during species identification and error can be minimized.

In addition, there is a possibility to incorporate images of essential identification features to make the identification procedure readily accessible for the users and the system can be updated with new knowledge when new tree species is introduced.

The only expert system developed in Ethiopia in the field of forestry is SPEX (prototype species selection Expert Systems). SPEX is developed to check what sorts of plants are recommended in the respective area (Abduselam, 2001).

There are various expert systems and KBS developed abroad for plant species identification and other tasks in the field of forestry. It is difficult to adopt such expert systems in our country because there are hundreds of indigenous and endemic woody plant species in Ethiopia. These species have unique features, and hence to identify them different knowledge/rules from their characteristic features need to be identified and developed to come up with comparative performance through few selected features with the existing way of identification.

Therefore, this study is initiated to develop, test and evaluate the application of a knowledge based system for the identification of woody plant species found in Ethiopia.

#### **1.4 Research Questions**

This research work is set up or conducted to answer the following basic research questions.

- How do we extract the required knowledge for developing KBS that can be used for species identification?
- Can we optimize features used for creating appropriate model that bring comparable performance with the existing way of identification?
- What are the appropriate modelling and inferencing techniques to implement the KBS for woody plant species identification?

#### **1.5 Objective of the Study**

The general and specific objectives of the study are stated as follows.

### **1.5.1 General Objective**

The general objective of this study is to extract knowledge and model it to construct new knowledge/rule with smallest sets of taxa and design and develop knowledge based system for woody plant species identification and to explore its performance and potential application.

### **1.5.2 Specific Objectives**

The specific objectives of the study are:

- To review literature on related research works.
- To extract the domain knowledge used in identification of woody plant species from experts and available literature.
- To model domain knowledge and construct structured domain knowledge to gain new knowledge or rule with the smallest sets of taxa that bring comparative performance.
- To select techniques and procedure for designing knowledge based system for woody plant species identification.
- To develop a prototype KBS that performs woody plant species identification.
- To test and evaluate the performance of the system based on the view of experts and potential users in the field.
- To provide recommendation for further research in the area of woody plant species identification.

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## **1.6 Methodology**

The various methods of knowledge acquisition from different sources, knowledge representation and system development that have been used in this study are discussed as follows.

### **1.6.1 Methods of Data Collection**

For documentation of concepts and relevant techniques in the development of knowledge based system in relation to domain area, primary and secondary data sources, such as interview, literature review and group discussion is used.

#### **1.6.1.1 Key Informant Interview**

Interview is the most important knowledge acquisition method in building the knowledge based system. Key informant interview is conducted with experts, who have first hand information about woody plant species identification. In this study, the key informants are taxonomist working in AAU National Herbarium and forest technicians in the Forestry Research Centre (FRC). The interview is conducted for the extraction and elicitation of the domain knowledge and procedures used in tree species identification.

#### **1.6.1.2 Secondary Data Collection**

In addition to the key informant interview conducted with experts, the available information that is currently being used to support experts in tree species identification is collected from books and manuals. Some of these secondary data source include, "Flora of Ethiopia and

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#### **1.6.1.2 Secondary Data Collection**

In addition to the key informant interview conducted with experts, the available information that is currently being used to support experts in tree species identification is collected from books and manuals. Some of these secondary data source include, "Flora of Ethiopia and

Eritrea” (eight volume books); “Dendrology Manual” and “Useful Trees and Shrubs for Ethiopia”.

### **1.6.1.3 Demonstration and Group Discussion**

Before testing and evaluating the application of the system, it is demonstrated for a group of researchers, technicians and taxonomists. Their views and comments raised during group discussion is documented and used to improve the knowledge base of the system.

### **1.6.1.4 Knowledge Modeling**

Knowledge elicited from the experts should have to be structured and modelled to create new knowledge with few features for identification that bring comparative performance and to code it to computer understandable format. In this study, domain knowledge extracted from taxonomists and technicians is modelled in hierarchical (laddering) knowledge modelling technique. The detailed account of the knowledge modelling technique is presented in section 4.4.

## **1.6.2 Methods of System Development**

For the development of the knowledge based system, the following prototype development methods and programming tools are used.

### **1.6.2.1 Prototype Development**

As discussed in the background, one of the procedures followed to identify tree species is using identification key. According to Hedberg and Edwards (1989) and Thirakul (1993), the common type of key used is dichotomous keys. The prototype developed in this study is based on the dichotomous key by simulating the way in which Taxonomists and Technicians work in

the National Herbarium with the smallest sets of the taxa. Dichotomic keys of the type IF-THEN are used for the identification of plant species in which, each key leads to either another key or a plant species. In this way, when a taxonomist wants to classify a particular species, it is possible to distinguish:

- A source of knowledge comprising all the available information on each plant species in the form of dichotomic rules.
- A process of the use of this knowledge in order to solve the particular problem such that keys are searched until a particular species is identified.

This description coincides perfectly with that of a knowledge-based system and more specifically with that of a rule-based expert system, as pointed in application of expert system in botanical taxonomy (Contrerasa et al, 2003). In rule-based expert system, knowledge base stores knowledge about the domain of the problem in the form of rules and an inference engine extracts information from the knowledge base.

The backward inference engine fits to the problem at hand and is used in this study. It provides the knowledge based system with the reasoning mechanism. It combines the input fact from the user with knowledge in the knowledge base thereby responding to users query.

The prototype system is developed to explain line of reasoning during plant identification process through the 'why'; 'how' and 'whynot' explanation facilities. The system also adds user support modules, to make it extremely easy to use with the support of images of part of the tree. Finally, the system provides the correct species name with its short description with its interface to the user.

### **1.6.2.2 Programming Tools**

In literature, there are many programming tools used to develop knowledge based system including Lisp, Prolog, and Clips (Aronson and Turban, 2004). Owing to its built-in backward chaining inference engine, which can be used to partially implementation of the knowledge based system; Amzi! Prolog + Logic Server is used in this study. Prolog codes are used for the representation knowledge in knowledge base (KB), and the backward prolog inference engine is used to derive conclusions from the KB.

Prolog code can be easily embedded to other application environments through the logic server to develop user interface. The logic server interface providing natural access to the prolog code from various languages (C++, Java, Delphi, Visual Basic, and C #) and tools (Access, Excel, PowerBuilder). In the present research, the user interface is developed using VB.net.

### **1.6.3 Testing and Evaluation**

The system is tested and evaluated by eight users; 4 technicians and 4 researchers from FRC and NH. Total of 40 trails (5 trials by each evaluator) is performed by the potential users to identify the intended woody plant species using this new system by using smallest set of taxa / features of the species. This is to test the performance of the system. Users are also completed the questionnaire to evaluate its usability and applicability to the domain area. For this, the structured questionnaire is prepared to obtain the usability and applicability of the system.

## 1.7 Scope and Limitation of the Study

The scope of this study is developing prototype KBS and evaluating its application for tree species identification for the selected woody tree species found in Ethiopia. There are over thousand tree and shrub species in Ethiopia both indigenous and exotic. Exotic species refer to those species that are adopted from abroad and naturalized in the introduced areas. The types of the plant species found in the country include; woody tree, large and small shrubs, tall grasses, lianas, giant herb, fruit and crop plants (Bekele et al, 1993).

Due to the high diversity of resources available in the country, we are unable to accommodate all plant species/flora in this study because of the limited time available. This work mainly dealt with the most important selected woody species (trees and shrubs) in the country both indigenous and exotic. The selection compromised representing most important species since the selection has been done with the experts. Once a prototype system is developed and tested for its application, it will be a simple task to include all floras for entire identification and description of flora in the country.

The knowledge based system consists of the inference engine, knowledge base (rule base), rule based reasoning mechanism, explanation facilities such as 'how', 'why' and 'whynot' and the user interface that supports displaying images of the tree.

Due to unavailability of complete data about the characteristics features of woody plant species forced the researcher to develop the rule manually, it is time taking method. If the data were complete, the rule used to identify woody plant species could automatically be built using the id3 algorithm, which is a data mining classification technique.

Even though the inferring mechanism and knowledge base of this system is separate module in different file, this system has limitation in automatic updating of the knowledge base by the user when the new woody plant species is introduced. Due to time limitation, automatic updation of the knowledge base with new knowledge is not developed in this study.

## **1.8 Organization of the Thesis**

This study is organized in to six chapters. The first chapter contains introductory part: the background information about dendrology and KBS, statement of the problem and justification of the study to conduct the research, objectives of the study, methodology used and scope of the study.

Review of literatures is presented in the second and third chapters. In the second chapter, the history of plant taxonomy, nomenclature, tree species identification procedures, and flora of Ethiopia project is presented. While the concept of knowledge based system, components and architecture and application of knowledge based system in general and its application to forestry is given in chapter three.

Chapter four discusses in detail the methodology used for knowledge acquisition from the expert (taxonomist and technicians), knowledge modeling techniques.

In chapter five, the development of the system: the architecture, knowledge base, inferencing mechanism, user interface, testing and evaluation are presented and discussed. Finally, the concluding remarks and recommendations are presented in the last chapter.

## **CHAPTER TWO**

### **2. TREE SPECIES IDENTIFICATION (DENDROLOGY)**

#### **2.1 Introduction**

The first step in knowing about a plant, its properties, distribution and significance, is to ascertain its identity (Womersley, 1981). Its correct name is the means of access to much information. Since there are several hundred thousand plant species in the world, species identification is often not an easy matter. Knowledge of the name of trees, their habits, and principal botanical features is basic to studies in forestry and environmental sciences (Harlow et al, 1978; Womersley, 1981). In this respect, finding the correct identity of trees is the beginning of any forest inventory and management activities as well as any studies regarding the tree species. Identification of a given tree species, which involves naming and classification, enables to retrieve appropriate facts from the (classification) system to be associated with the specimen at hand and previous works (Hedberg et al, 1989). Thus, identification is an integral part of all taxonomic works.

#### **2.2 History of Plant Taxonomy**

According to Harlow et al (1978), the classification of plants dates back to ancient Greek civilization, when Theophrastus (372-287 BC) described and classified about 480 kinds of plants. By many, he is considered as a father of botanical science. However, the work of Theophrastus was mainly focused on the differentiation between woody and herbaceous forms. Large number of plants was classified by Caesalpino (1519-1603) in the sixteenth century

based on the nature and structure of their seeds. Modern plant classification was, however, started in the seventeenth century from the extensive works of the Swedish botanist Carolus Linnaeus (1707-1778). Linnaeus is considered as the father of modern plant taxonomy since his “Genera Plantarum” and “species Plantarum” works are the starting points for modern plant taxonomy. He grouped plants by a ‘sexual system’, using the number and placement of stamens and pistils to separate the various kinds into workable groups. The current binomial system of nomenclature in which each species is referred to by two names, the genus and specific epithet, started based on the work ‘species Plantarum’.

### **2.3 Nomenclature**

Nomenclature deals with naming of plant species. Tree species usually have different local names in different regions. Thus, it is necessary to have universal systems which can be used to avoid confusions in common names. Scientific names have been in common use since the middle of the eighteenth century following Linnaeus’ publication of “Species Plantarum” (1753). Currently naming of tree species follow binomial nomenclature which consists of combination of generic name and species name. The complete designation for a tree or other plant consists of three parts: a generic name, a specific name, and the full or abbreviated name of the person/s responsible for the original published plant description (eg. *Cordia africana* Lam.). As a rule generic names always appear first and are always capitalized, while specific names (specific epithet) follow the generic name and begin with small letters. In common practice, the author’s name is omitted except in scientific writing, where it is used at least once when the species is first mentioned (Harlow et al, 1978).

## 2.4 Tree Species Identification Procedures

Trees can be recognised by observing their vegetative characteristics like habitat, and morphology such as form, bark, branches and twigs, leaves, fruits and flowers (Bekele et al, 1993; Thirakul S., 1993). The study of these characteristics so as to distinguish between tree species is called dendrology. Literally, dendrology means 'the study of trees', but through the common usage it has come to signify the taxonomy of woody plants. Taxonomy is concerned with the classification, nomenclature, and identification of natural objects like insects, trees, birds, reptiles etc.

*'Dendrology is a forestry science which studies the silvicultural and morphological characters of trees. However, through common use, dendrology means particularly the taxonomy of woody plants, i.e. identification and systematic classification of trees, shrubs and lianas'*  
(Thirakul S., 1993).

Identification of a tree species may be accomplished in a number of ways. The current common practices of tree species identification are generally accomplished by three procedures namely: expert recognition and determination; comparison with herbarium specimens; using the characteristic keys; or combination of these stated procedures (Thirakul S., 1993; Hedberg et al, 1989).

Expert recognition and determination involves using the experience of professional taxonomists for a given group or floristic area. Although this procedure result in the most

reliable and accurate identification; there are only few experts (taxonomists) available in Ethiopia. Getting experts abroad is also costly and time consuming.

Comparison with herbarium specimens on the other hand, entails comparison of the unknown material with named specimen, illustrations and descriptions. The reliability of this procedure greatly depends on the availability of adequate illustrations, descriptions and how reliable the named specimens were determined. However, apart from being a time-consuming method, identification through comparison can result in someone unfamiliar with the terms used or the peculiarities of the groups being compared making quite erroneous judgement. In order to get reliable results, this method requires a great deal of time and care must be taken.

The third procedure uses characteristic keys and similar devices. Identification keys are special type of taxonomic literature, in which each statement consists of short phrases which attempt to describe the characters to be observed in as concise way as possible. The common type of key used is called dichotomous barracked type because it consists of a pair of contrasting statements; each pair is called Couplet, which appears one under the other.

Keys are the quickest and most accurate means of identifying unknown plants. Use of keys becomes easier with practice and familiarity. Careful examination of the specimen and full consideration of both statements always makes key use easier. Finding that a particular difficult specimen actually matches its description is a reward in itself.

The major parts of a tree, such as the crown, branches, twigs, leaves, bole and roots, and vegetative characters are useful in identification (Hedberg et al, 1989). Trees display characteristic patterns of leaves. Thus leaves are considered as key identification morphological features in taxonomy among with other organs as flower, seeds, bark, thorns etc. The most important leaf parameters of considerable value for identification includes: leaf arrangement (opposite, alternate and whorled), leaf composition (simple or compound), leaf shape (Acicular, scalelike, linear, oblong, lanceolate, ovate, oblanceolate, obovate, elliptical, oval, orbicular etc), and leaf margin (entire, serrate, denitae, etc) (Hedberg et al, 1989; Thirakul, 1993).

## **2.5 Ethiopian Flora Project**

The Ethiopian Flora Project in the Biology Department of Addis Ababa University started in 1980 and is still going on, all with the support of the Swedish Government. The main aim of the Project is to publish a modern Flora for the country. The secondary aims are to develop the human resources to carry out research and write and update the Flora locally, and to develop the institutional capacity for making and caring for the plant collections and undertaking research into the flora of Ethiopia and its neighbouring countries (Hedberg et al, 1989).

In Ethiopia, before the establishment of the Addis Ababa University National Herbarium, plant specimens were sent abroad for identification. Currently, the National Herbarium is serving plant identification tasks and providing information for scientific based utilization and conservation of the country's plant resources. The taxonomists' use the specimens collected in the Herbarium for comparison and use the description of the plants on the eight volume published flora (Flora of Ethiopia and Eritrea). The National Herbarium, in which the Project

is housed, had a collection of only about 14,000 plant specimens in 1980; now it has over 70,000 (<http://tcdc.undp.org/sie/experiences/vol3/Capacity%20Ethiopia.pdf>, 2008).

A printed Flora is the most widely accepted method for making available the means to name the plants of an area along with the consolidated and synthesised information on those plants. The publication of Floras started in the last century and continues today. Ethiopia was one of the first Third World countries to have a Flora. *Tentamen Florae Abyssinicae* was written in Paris by Achille Richard and published between 1845 and 1851. Thus, the flora of Ethiopia has an important place in the scientific exploration of the plants of eastern Africa (Hedberg et al, 1989).

According to the experts, infrequently new woody plant species, which is not found in the national herbarium, may come for identification. In this case, study will be conducted on that species about its characteristics feature to name it and the species will sent abroad for further study where there are huge collections of plant species in their National Herbarium such as Denmark or England herbarium.

Identifying the plant species is prerequisite to conduct various researches and any inventory and management activities concerning the tree species. Identification of plant species is a complicated task that requires knowledge, experience, and judgement of taxonomists and technicians. Trees can be identified by expert recognition and determination; comparison with herbarium specimens; using the characteristic keys or combination of this stated procedures.

Plant species identification in the country is performed only in the National Herbarium housed in AAU. All agricultural and forestry research centres in the country make use of National

Herbarium for plant species identification. According to the experts in the centre, to identify the plant species it may take several days. Currently the existing system is not supported by computerised information system. Computerised decision support systems can provide the expertise of the domain expert to users and used for decision making. The computer in the centre is used only for word processing. To solve some problems existed in the current system and to bring efficiency, systems that work in place of/ support domain expert are required. Knowledge based system, one of artificial intelligence computerized decision support system, fits for systems that require knowledge, experience and judgement of experts.

## CHAPTER THREE

### 3. KNOWLEDGE BASED SYSTEM

#### 3.1 Introduction

Artificial intelligence (AI) is behavior by a machine that, if performed by a human being, would be called intelligent (Aronson and Turban, 2004). It is the scientific foundation for several technologies. The major areas are knowledge based system, expert systems, machine learning, robotics, game playing, natural language processing, and computer vision.

Knowledge-Based System (KBS) represents a relatively new approach and methodology that has evolved and is still evolving as an important sub-area of Artificial Intelligence (AI) research. The most prevalent application of KBS, which emerged in recent times, has been various types of diagnosis, identification and troubleshooting. The KBS approach is promising for these domains, as it captures expertise, guides human operators in rapid fault detection, explains the line of reasoning to users, and supports modification and refinement of the process of knowledge as experience is gained.

In this chapter, the basic concepts: definitions, components, structure and basic features of the knowledge based systems are explained. In addition, comparison with conventional programs is briefly described as well. Finally, related works on applications of knowledge based systems in forestry are reviewed.

### 3.2 Defining knowledge Based System

Most authors' use the term knowledge based system and expert system interchangeably and emphasize on rule based systems. Some of the definitions of Knowledge based systems are the following.

*'Knowledge based system or expert system is a software that attempts to reproduce the performance of one or more human experts, most commonly in a specific problem domain, and is a traditional application and/or subfield of artificial intelligence'* (Krishnamoorthy and Rajeev, 1996).

*'Knowledge based systems are computer program designed to act as an expert to solve a problem in a particular domain. KBS achieves intelligence behavior by using fairly simple algorithms with a large body of specific and commonsense knowledge, rather than applying powerful and complex algorithms with little domain specific information and KBS learns from experiences'* (Chabris, 1989).

*'Knowledge base system is a decision-making or problem-solving software package that can reach a level of performance comparable to or even exceeding that of a human being in some specialized and usually narrow problem areas and it can update and refine the knowledge base of the system'* (Aronson and Turban, 2004).

According to the above definitions, the basic idea of knowledge based system is an application of artificial intelligence in which expertise is transferred from the expert to a computer. This knowledge is then stored in the computer, and users call the system on the computer for the specific conclusion. Then, like human consultant, it advises and explains both non-experts and experts on specific domain. The KBS update and refine its knowledge base, when there is new knowledge and change in knowledge in the domain area.

### **3.3 Structure of Knowledge Based System**

Knowledge based system consists of a number of major system components having various roles. The components of the knowledge based systems can be viewed from the consultation environment (used by expert and non-expert to obtain expert knowledge and advice) and development environment (used by the builder to construct components and stores knowledge) (Aronson and Turban, 2004). The three main components of KBS are knowledge base, inference engine and user interface. It also contains the following additional components: knowledge acquisition subsystem, blackboard (workplace), explanation subsystem (justifier), knowledge refining system and user(s) as shown in Figure 3.1 (Aronson and Turban, 2004; Chignell and parseye, 1998) and each of these components are briefly discussed in the following sections.

#### **3.3.1 Knowledge Acquisition Subsystem**

Knowledge acquisition (KA) is the accumulation, transfer, and transformation of problem-solving expertise from experts or documented knowledge sources to a computer program for constructing or expanding the knowledge base (Chignell and Parsaye, 1998). Potential sources

of knowledge include human experts, textbooks, multimedia documents, database, special research reports, and information available on the web.

According to Aronson and Turban (2004), there are three methods of KA: manual, semi-automated and automatic. Manual methods are basically structured around some kinds of interview. The knowledge engineer elicits knowledge from the experts or other sources, structures and then codes it in the knowledge base. The most commonly used manual KA method in the development of KBS is the face-to-face interview and observation. Interviewing consists of asking the domain expert questions about the domain of interest and how they perform their tasks. In semiautomatic methods, knowledge engineer acquires and refines the knowledge from the experts with computer-aided (interactive) approaches. In automatic methods, knowledge is extracted from the database through knowledge discovery and data mining techniques. In this case, the roles of both the expert and the knowledge engineer are minimized or even eliminated.

### **3.3.2 Knowledge Base**

The knowledge base contains the domain specific knowledge, which is relevant knowledge necessary for understanding, formulating and solving problems (Krishnamoorthy and Rajeev, 1996). It includes two basic elements (Aronson and Turban, 2004):

- (1) Facts such as the problem situation and the theory of the problem area.
- (2) Rules that direct the use of knowledge to solve specific problems in a particular domain.

Knowledge can be organized in a knowledge base in several different configurations, to facilitate fast inferencing or reasoning. The most commonly used methods of knowledge representation, invented and developed during the latest decades, are discussed as follows (Alfonseca, 1989; Aronson and Turban, 2004; Krishnamoorthy and Rajeev, 1996).

#### **3.3.2.1 Production Rules**

Production rules are simple and powerful forms of knowledge representation providing the flexibility of combining declarative and procedural representation for using them in a unified form. Production rules are constructed in a kind of IF condition THEN action, which is used for rule-based inference. The action of the selected rule is activated when the rule is being applied. The action may typically add some assertion to the working set of hypotheses. Rules are convenient for representing heuristic knowledge and are structured into rule sets. Each rule set is intended to evaluate some goal variable (or assertion). A few typical examples are given below:

1. IF raining

AND have an umbrella

THEN can go outside.

2. IF the stop light is red

AND you have stopped

THEN a right turn is okey.

Each production rule in a knowledge base implements an autonomous chunk of expertise that can be developed and modified independently of other rules. In reality, knowledge-based rules are not independent. They quickly become highly interdependent. In KBS adding new rule may conflict with an existing rule, or it may require a revision of attributes or rules. There are two types of rules in KBS: Knowledge and inference. Knowledge rules, or declarative rules, state all the facts and relationships about a problem. Inference rules or procedural rules on the other hand, advice on how to solve a problem given that certain facts are known.

### 3.3.2.2 Frames

A frame is a data structure that includes all the knowledge about a particular object. It is a hierarchical knowledge structures convenient for representing knowledge on concepts and their relationships. A frame consists of its name and a set of slots or attributes. Each of the slots has its own name and value that can be a reference to some other frame or frames. For example, in the TABLE frame, there are Files, Drawers and Legs slots.

Frame TABLE

Files: 0, 1, 2

data in working storage (Peter, 1989). This component provides directions that organizes and controls the steps taken to solve problems whenever consultation takes place (Aronson and Turban, 2004). The control program decides which rule to investigate, which alternative to take, and which attribute to match (Krishnamoorthy and Rajeev, 1996). The process of inferencing can be forward chaining or backward chaining or combination of the two.

### 3.3.4.1 Backward Chaining

Backward chaining is a Goal-driven reasoning in which it starts from an expectation of what is going to happen (hypothesis) and then seek evidence that support your expectation (Aronson and Turban, 2004). It is an efficient way to solve problems that can be modeled as "structured selection" problems. That is, the aim of the system is to pick the best choice from many enumerated possibilities. For example, an identification problem and diagnostic systems falls in this category (Peter, 1989). Backward chaining inference draws conclusion as follows in the given example.

If  $a=2$

$b=3$

Then  $c=8$

If  $c=8$

Then  $d=4$

The backward chaining starts with the goal of finding a value for  $d$  and uses the two rules to reduce to the problem of checking value for  $a$  and  $b$ .

### **3.3.4.2 Forward Chaining**

Forward chaining is data-driven approach. It starts from available information or from a basic idea, and then it tries to draw conclusions (Aronson and Turban, 2004). The data driven approach, or forward chaining, uses rules similar to those used for backward chaining, however, the inference process is different. The system keeps track of the current state of problem solution and looks for rules which will move that state closer to a final solution (Chignell and Parsaye, 1998). For the above example, forward chaining starts inferencing with the data of  $a=2$  and  $b=3$  and use the two rules to reach to the conclusion  $d=4$ .

During inferencing the problem facts that are generated are stored in the area of working memory or blackboard. It contains the data which is specific to a problem being solved. It is also used for recording intermediate hypothesis and decision. According to Aronson and Turban (2004), three types of decision can be recorded on the blackboard: a plan (how to attach the problem), an agenda (potential actions awaiting execution) and a solution (candidate hypothesis and alternative course of action that the system has thus far).

### **3.3.5 User Interface**

This is the part of the knowledge based system that requires interaction with the user. Knowledge based system contains a language processor for friendly, problem-oriented communication facility between the user and the computer. This communication can be best

carried out in a natural language. It is also supplemented by menus, mouse operations, buttons, electronic forms and graphics to facilitate use of the KBS (Chignell and Parsaye, 1998). Whether or not knowledge based system achieves success may be determined by the nature of its user interface. Even the most powerful KBS will not be applied if it requires too much effort on the part of the user (Latin and Traves, 1991). For this reason, it is important to make the knowledge based system as easy for the user to operate as possible.

### **3.3.6 Explanation Subsystem (Justifier)**

A very important feature of the KBS is the ability to explain its reasoning. This means the user can ask the system for justification of conclusions reached or questions asked at any point during/after consultation (Peter, 1989). According to Peter (1989); Aronson and Turban (2004), there are three major types of explanations commonly used in rule based KBS: 'why', 'how' and 'whynot'.

#### **The WHY explanation**

A typical 'why' question is posed by the user to the system after it asks the user to provide some information. Each time the system asks the user for an input, the user has the option of asking the system to explain the rationale for the question before answering the question. If the user chooses this option, the system will display the sequence of rules that were used to reach the current state in the design process. This will give the user a general idea of the line of reasoning followed by the system.

### **The How explanations**

A typical 'how' question is posed by users when they would like to know how a certain conclusion or recommendation was reached. The 'how' explanation, unlike the 'why', can only be asked at the end of a successful conclusion. It is invoked if the user wishes to know exactly how a particular conclusion was reached. The system will provide a list of the rules that were fired and were found to succeed. The rules are listed in the sequence in which they were called. This is useful in explaining a conclusion since it shows each intermediate step that was taken in reaching the final answer.

### **The WHYNOT explanations**

'Whynot' questions can determine why an expected result was not reached. The 'whynot' explanations are invoked in a similar fashion to the 'how' explanations but only if a design session has ended unsuccessfully. The user may wish to know why the design failed. 'Whynot' explanations are very useful in this case since they display a list of the rules which failed.

### **3.3.7 The Human Element in KBS**

In the development and use of the KBS the participants are the following (Chignell and Parsaye, 1998):

- Domain expert - the individual or individuals who currently are experts in solving the problem the system is intended to simulate and solve;
- Knowledge engineer - the individual who extract, structure and encodes the expert's or domain knowledge in a declarative form that can be used by the KBS;

- User - the individual, who will be consulting the system to get the necessary advice which would have been provided by the domain expert.

### **3.4 Uncertainty**

Most tasks requiring intelligent behavior have some degree of uncertainty associated with them. The type of uncertainty that can occur in knowledge-based systems may be caused by problems with the data such as data might be missing or unavailable, data might be present but unreliable or ambiguous due to measurement errors, the representation of the data may be imprecise or inconsistent and data may just be user's best guess. Given these numerous sources of errors, most knowledge-based systems and expert systems require the incorporation of some form of uncertainty management (Krishnamoorthy and Rajeev, 1996; Chignell and Parsaye, 1998).

The first uncertainty management scheme was proposed by Shortliffe, in the 1970s (Krishnamoorthy and Rajeev, 1996), which was tailored to be used with knowledge-intensive rule based system. A number of techniques are proposed by researchers to handle uncertain knowledge and carry out inexact reasoning. The major methods are Probabilistic reasoning, certainty factors and Dempster-Shafer theory based on mathematical theory of evidence (Krishnamoorthy and Rajeev, 1996). But handling uncertainty is not significant for an identification problem (Peter, 1989).

### **3.5 KBS and Traditional Program**

The principal distinction between KBS and traditional problem solving programs is the way expertise related to the problem is coded. In traditional applications, expertise is encoded in

both program and data structures. In the KBS approach, the entire problem related expertise is encoded/ incorporated into a knowledge base. Traditional problem solving techniques contains procedural knowledge, a sort of "knowing how," encodes knowledge as process, asserting that a procedure for solving a problem is the knowledge of how to solve it. Where as KBS techniques contains declarative knowledge, "knowing what," which describes the information necessary to solve the problem in a general way, without providing a direct method for its solution (Chabris, 1989).

### **3.6 Applications of Knowledge Based System**

A knowledge based system is a computer program designed to simulate the problem-solving behavior of an expert in a narrow domain or discipline. Expertise of KBS is usually restricted to a very specific domain.

Various prototype expert systems/ KBSs have been developed in Ethiopia by students of AAU since 1996 for different domain area. Expert systems developed in human resource management domain areas are a prototype expert system for personal selection and promotion for federal civil service commission of Ethiopia (Gadissa, 1996) and an expert system human resource management system in dealing with selection, training and performance evaluation measure for ministry of capacity building (Yihune, 2006). Expert systems/KBS developed in medical domains are prototype knowledge based system in antiretroviral therapy (Anteneh, 2004) and design and development of a prototype KBS for HIV pre-test counselling (Rediet, 2006). Expert system developed in library science domain area is for reference advisory system for Ethiopian studies (Azebe, 1996). Expert systems developed for legal advisor are a rule based / neural network hybrid legal advisor expert system for providing legal advise on

criminal cases under Ethiopian law (Seifu, 2005) and expert system for the legal regime governing women in Ethiopia using the revised family code and labour law of Ethiopia (Tadele, 2005). A prototype web based expert system for route finding to the road network of Addis Ababa (Daniel, 2005) and building decision support and expert system for potable water management for Ethiopia (Tsegaye, 2005).

Expert systems or KBS have been applied to problems in sub fields of forestry including plant pathology, entomology, horticulture, plant selection and plant identification into a framework that best addresses the specific, on-site needs of researchers, taxonomists, technicians and farmers. KBS in such area combines the experimental and experiential knowledge with the intuitive reasoning skills of a multitude of specialists to aid the involved parties for making the best decisions. In this section, various KBS applied in sub disciplines of forestry and their domain knowledge, techniques, methods and tools used in the system is review and compared.

### **3.6.1 A web-based Expert System for Advising on Herbicide Use in Great Britain**

This system was developed to advise on the relative efficacy of different herbicides for mixes of weed and crop species at different times of the year in forestry or farm forestry setting in Great Britain by (Alan and Thomson, 2003). A herbicide use decision includes assessing an existing problem or predicting a potential problem (for pre-emergence treatments); diagnosing and identifying causal agents; examining attributes of possible non-chemical and chemical control methods; determining the appropriate control method based upon efficacy, cost and

potential risks to operators and the environment; determining the appropriate formulation; identifying the most suitable method for applying the method; and assessing treatment results.

The original system was based on floppy disk technology. Even though, it is now possible to deliver and maintain expert systems operationally over the World Wide Web, the rationale and user knowledge requirements for the system have not changed.

Knowledge base of the expert system is represented in rule base and contains herbicide properties including name, crop tolerance, timing, and valid uses (forestry, arbor forestry, pre-emergence, and post-emergence). These properties are represented in a prolog and processed by a prolog-based inference engine (backward inferencing). The system is provided with the web-based user interface. The web interface is developed through Perl. The perl program can read the knowledge base files, which are simple ASCII files, and construct HTML select list of herbicides.

The main feature of this design is that a common file is used as the basis of both the interface and the reasoning system. The file format is dictated by the prolog format for facts and rules, while the text-processing power of perl facilitates the parsing of this file into entities that can be embedded in the HTML code written by the perl script. As new information is added, or if information is changed, the interface adapts automatically.

### **3.6.2 Prototype Species Selection Expert System (SPEX)**

SPEX is the only prototype expert system developed in the forestry areas in Ethiopia (Abduselam, 2001). SPEX is a prototype expert system developed for advising extension workers and farmers in plants selection recommendable for the given respective areas.

Knowledge-pro is used to develop the system. Knowledge base of the system is developed using the existing rules and facts. Knowledge is represented in the production rule. Certainty factor is attached to show the degree of confidence of the system in providing recommendation. Inference engine used in the system is backward chaining. The system also provide why and how explanation facilities. The system has windows based user friendly environment to its user.

### **3.6.3 TAXEX: TAXonomic EXPert System**

TAXEX is taxonomic expert system, developed to help scientists to professionally identify living organisms (Lelekoy and Lyakh, 2008). TAXEX is used for the purpose of solving: loss in expertise necessary for the identification and inventory of biota and poor state of knowledge of many aquatic and terrestrial organisms. It provides scientists with different taxonomic information, including taxon descriptions and diagnosis, geographic distributions, scientific nomenclature, identification keys and illustrations; it creates a tool for interactive identification of living organisms and trains new taxonomists on the Black Sea and Azov Sea region.

TAXEX has been developed since the end of 1980s at the Institute of Biology of the Southern Seas. The first version of TAXEX is run on ms-dos and its knowledge base is organized using frame. The description of frames and the different rules on how to use them were so specific for every group of organism such that the creation of a common method for forming frames descriptions became difficult. A more universal model on the process of taxonomic identification was developed in 1994. These expert systems work under MS Windows and manage taxonomic knowledge that is stored in a database. TAXEX are redeveloped using java language and can be accessed in the intranet and Internet. The knowledge base includes specific taxonomic information, a glossary of terms, references, etc. The knowledge base and computer identifiers together constitute the Taxonomic Expert System.

#### **3.6.4 Applications of Expert Systems to Botanical Taxonomy**

Plant taxonomy is a complex, meticulous science which allows taxa to be identified by retrieving information contained on them in a classification system. GREEN (Gymnosperms Remote Executed over Networks), a pioneering system in the application of artificial intelligence techniques to the field of botany (plant species identification), that was developed by Contrerasa, et al, (2003).

The system contains Knowledge base represented in production, Inference engine, an uncertainty processing module fitting the nature and subjectivity of the observer, a justifier module, online user support interface and a multimedia database to reference known species.

Knowledge base of GREEN consists of 46 taxa of groups of Gymnosperms found in Iberian Peninsula. In addition to the Knowledge Base, multimedia database provides images and data about its distribution and ecology and a glossary of botanical terms. This makes the arduous task of species identification easier and more enjoyable.

One of the problems in GREEN is knowledge acquisition and elicitation. They gathered and summarized their information, thereby producing a list of diagnostic characters (descriptors or attributes) at family, genus, species and subspecies level. The most important taxonomical characters in Gymnosperms have been divided into different groups: general aspect of the taxon, characteristics of the leaf, branches, shoots, monoecious or dioecious, characteristics of the fructification (cone and 'berry' cone), of the seeds, and ecology of the taxon. With these characters, decision tables have been compiled, which gather the identifying diagnostic characters for each taxon.

One of the unique features of this system is obtaining a set of rules (represented in the Knowledge Base) by using the decision tables. For this, they apply Artificial Intelligence learning techniques (Machine Learning); in particular the ID3 algorithm. The artificial intelligence learning technique provides minimum set of diagnostic key, by avoiding other. This enables quicker identification than dichotomous key used by taxonomist.

In GREEN, uncertainty is modelled using certainty factors. This module is capable of handling inconsistencies occur during knowledge acquisition and elicitation. Inference engine of the GREEN is designed through ignizio's BASELINE with forward chaining model. The

web based interface of the GREEN system provide two methods of entering query: basic, the user has a set of options, so that the use of certainty factors is clear and in the advanced mode, the user must manually enter the certainty value of the observation.

Computerized decision support is new to plant identification in Ethiopia. This KBS is used for identification of important woody tree species found in Ethiopia by using key morphological features of the species. Domain knowledge is extracted from the experts and relevant documents. This knowledge is modelled in hierarchical laddering techniques to construct rules with minimum length excluding irrelevant knowledge. This enables to develop KBS with smallest sets of key features that bring comparative performance with techniques currently taxonomist used. KB of this work is represented in production rule. The KBS is developed in Amzi! Prolog + logic server programming tools. The system interface is designed in VB.net. Prolog provides backward inferencing mechanism. The system provides short description and images of the known/ identified species from the multimedia database and the HOW, WHY and WHYNOT explanation facilities are important for training new taxonomists about identification of woody plant species found in Ethiopia.

In developing the KBS domain problems needs to be clearly defined first and domain knowledge modelled to gain few key important features for identification required to solve the problems. Domain knowledge then structured with the appropriate model to code it to computer understandable format. The extraction, structuring, selection of key features and models of domain knowledge from the experts and relevant document are presented in the next chapter.

## CHAPTER FOUR

### 4. KNOWLEDGE ACQUISITION

#### 4.1 Introduction

In building KBS, usually the facts, rules, and frame structure of problem domain are not initially available or well identified and must be sought out. Seeking out the knowledge required by KBS is referred to as knowledge acquisition. Knowledge acquisition is the process of extracting, structuring and organizing knowledge from one or more sources necessary for problem solving. Knowledge is typically implicitly contained in the minds of the domain expert and in large collections of unstructured documents. Knowledge may be specific to the problem domain or to the problem solving procedures, it may be general knowledge, or it may be metaknowledge meaning information about how experts use their knowledge to solve problems and problem solving procedures in general (Chignell and Parsaye, 1998).

Knowledge acquisition is the most important and difficult process in KBS development. It is a difficult process mainly due to: an expert may find it very difficult to express his or her experience about the process, or, else, an expert may have no time or unwilling to cooperate, methods of knowledge elicitation may be poorly defined. As a result, knowledge may be incomplete and hence knowledge builder may attempt to collect documented to supplement knowledge from experts (Aronson and Turban, 2004).

*'Generally, the knowledge acquisition task is often complicated by the fact that human experts have not analyzed the contents of their thoughts, so that they are not explicitly aware of the structure of their knowledge. As a result, the intermediate steps in their reasoning seem obvious to them and they cannot eloquently provide an overall account of how their decisions are made at the levels of detail required by a machine reasoning process'* (Chignell and Parsaye, 1998).

Knowledge acquisition is a two step process: knowledge elicitation and structuring. In the following section how the relevant knowledge is extracted from expert (taxonomist) and manuals used for woody plant species identification and the way how these acquired knowledge is structured and organized is discussed.

#### **4.2 Knowledge Elicitation**

Knowledge Elicitation methods have been used to obtain the knowledge required to solve problems. The elicitation of knowledge from the experts can be done manually or with the aid of computers. The type of method chosen and applied in this research is the manual methods because domain knowledge used is available on domain experts and manuals. The techniques used within manual methods are unstructured face-to-face interviews and observations.

In eliciting knowledge about the woody plant species identification, key informant interviews are conducted with two taxonomists and one technician from AAU National Herbarium and Forestry Research Center. Taxonomists in the National Herbarium use manuals and plant specimens during the identification and nomenclature of woody plant species for the

comparison of characteristic identification features. Hence, these relevant manuals are consulted, in addition to the interviews with key informants, to acquire the relevant knowledge or information.

Prior to the in-depth key informant interview, informal communication and observations has been held with the taxonomists and technicians to be familiar with woody plant species identification. Then in-depth interview has been conducted to acquire knowledge about how woody plant species are identified and basic characteristics keys or features used for the identification process and checklist of the question raised during interview are attached in Appendix III.

Since there are thousands of plant species available in the country and a lot of unique key features are required to identify those species, the work of experts is supported by relevant manuals. Thus, interview alone can not be enough to gain/ acquire all the required knowledge. Hence, relevant manuals such as the eight volumes of “Flora of Ethiopia”, “Manual of Dendrology”, and “Useful trees and Shrubs of Ethiopia” are reviewed to extract identification features with the support of the involved parties in the sector (Figure 4.1).

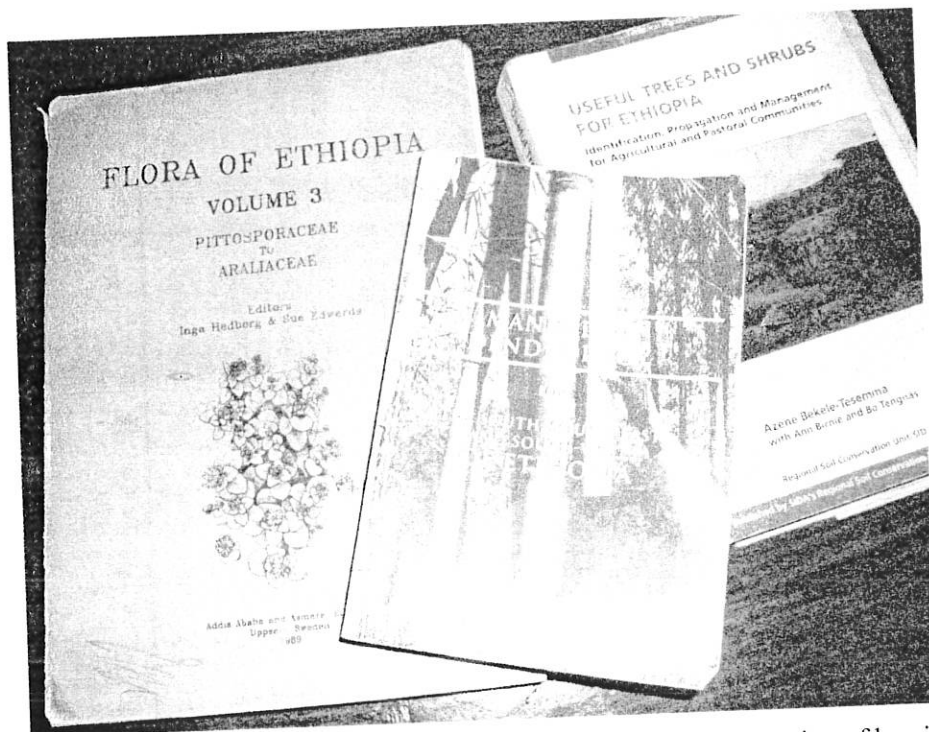


Figure 4.1 An Overview of the manuals consulted for the extraction of key identification features.

According to taxonomist in the National Herbarium, there are about more than 300 woody plant species found in Ethiopia both indigenous and exotic. Among those species, 105 tree and shrub species (about 35%) from 50 families are considered for this study (Table 4.1). The complete list of the tree and /or shrub plant species considered for the study is presented in appendix I.

More than hundred woody plant species (trees and shrubs) are taken as a sample and their description are examined to extract characteristics key features for identification. The samples are taken in such a way to fairly represent the different plant families and compromised

representing most important woody plant species since the selection has been done with the experts. Both indigenous and exotic tree and shrub species are considered during sampling.

Table 4.1 Number of tree and shrub species considered from different plant families

No.	Plant Family	Number of tree and shrub species
1.	Anacardiaceae	4
2.	Apocynaceae	1
3.	Araliaceae	5
4.	Balanitaceae	1
5.	Barbeyaceae	1
6.	Bignoniaceae	2
7.	Burseraceae	3
8.	Caesalpiniodeae	3
9.	Capparidaceae	2
10.	Celastraceae	1
11.	Combretaceae	8
12.	Cupressaceae	1
13.	Ebenaceae	2
14.	Ericaceae	1
15.	Euphorbiaceae	1
16.	Gramineae	1
17.	Hypericaceae	1
18.	Guttiferae	1
19.	Loganiaceae	2
20.	Meliaceae	5
21.	Meliantaceae	1

Knowledge models include: symbolic character-based languages, such as logic, diagrammatic representations, such as networks and ladders, tabular representations, such as matrices, structured text, such as hypertext (Milton, 2003).

#### **4.4 Knowledge Models**

One of major achievements of AI is the development of a range of ways of representing knowledge. A thorough understanding of different knowledge representations is a vital part of AI, since the ease of solving a problem is almost completely determined by the way how the problem is conceptualized and represented. The same is true for the task of communicating knowledge. A well-chosen analogy or diagram can make all the difference when trying to communicate a difficult idea to someone, especially a non-expert in the field (Milton, 2003; Chignell and Parsaye, 1988).

Knowledge engineers make use of a number of ways of representing knowledge when acquiring knowledge from experts. These are usually referred to as knowledge models. According to Milton, (2003) and Haase et al, (2006), there are different important types of knowledge models such as laddering and networks diagram. Network diagrams show nodes connected by arrows. Depending on the type of network diagram, the nodes might represent any type of concept, attribute, value or task, and the arrows between the nodes any type of relationship. Ladders are hierarchical (tree-like) diagrams. Laddering has been widely used in knowledge acquisition activities in recent years (Haase et al, 2006).

Some important types of ladders are concept, composition, decision and attribute ladder (Milton, 2003). A concept ladder shows classes of concepts and their sub-types. All relationships in the ladder are the 'is' a relationship, e.g. car is a vehicle. A concept ladder is more commonly known as a *taxonomy* and is vital to representing knowledge in almost all domains. A composition ladder shows the way a knowledge object is composed of its constituent parts. All relationships in the ladder are the 'has part' or 'part-of' relationship, e.g. wheel is part of car. A composition ladder is a useful way of understanding complex entities such as machines, organizations and documents. A decision ladder shows the alternative courses of action for a particular decision. It is a useful way of representing detailed process knowledge. An attribute ladder shows attributes and values. All the adjectival values relevant to an attribute are shown as sub-nodes, but numerical values are not usually shown. For example, the attribute colour would have as sub-nodes those colours appropriate in the domain as values, e.g. red, blue and green. An attribute ladder is a useful way of representing knowledge of all the properties that can be associated with concepts in a domain.

#### **4.5 Knowledge Modeling for Woody Plant Species Identification**

After gaining some understanding of key concepts used in plant species identification, a concept ladder of the resulting knowledge to provide a broad representation of the knowledge in the domain is created. A concept ladder is used to produce a set of questions which cover the essential issues across the domain and which serve the goals of the knowledge acquisition. Again and again the semi-structured interviews and consultation of manuals are conducted and analyzed the resulting protocol for the knowledge types present. Typically, these would be concepts, attributes, values, relationships, tasks and rules. These knowledge elements are represented using the most appropriate knowledge models of ladders. Process is repeated, the

analysis, model building , selecting best features and acquisition sessions until the expert and knowledge engineer are happy that the goals of the study have been realized. Finally, validation of the knowledge acquired with expert and modifications are conducted.

Plant species are identified by their morphological features/concepts like leaves, forms, flowers, habit, fruits, wood and barks. Knowledge or concepts used in plant identification is modeled in concept ladder as shown in the Figure 4.2.

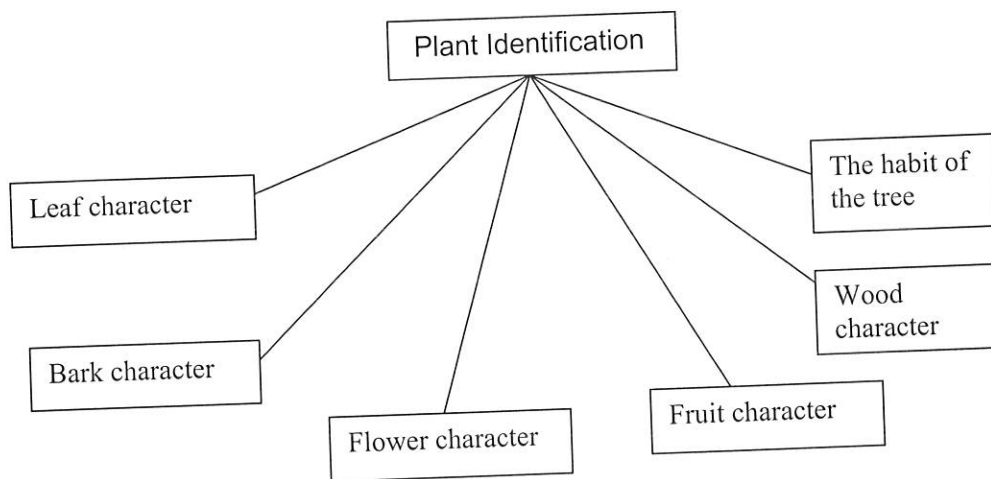


Figure 4.2 Concept ladders for plant species identification

According to the experts, mostly woody plant species are identified one another through their leaves and barks of the tree/shrubs morphological features. This study only considers the basic features from the bark and leaves. These key identification morphological features are described, organized and related to one another and modeled using the appropriate ladders as follows.

### 4.5.1 Leaves Character

Leaves are temporary organs which are concerned mainly with the manufacture (photosynthesis) of plant food, respiration, and transpiration (Thirakul, 1993). Since they display certain characteristics patterns, they are of considerable value in taxonomy. The arrangement of the leaves, types of leaves, types of venation of the blade, the forms of the blade, the apex of the blade, margins of the blade, the surface of the blade and textures of the blade are important feature of leaves used in identification.

A complete list of leaf contains three parts: the foliar base or point of attachment of the petiole to the twig which carrying dependencies (stipules and ligules), the petiole which resembles a small twig and the blade which is the functional part. Parts of leaves are modeled through composition ladder as follows, since they have has part relationship (Figure 4.3).

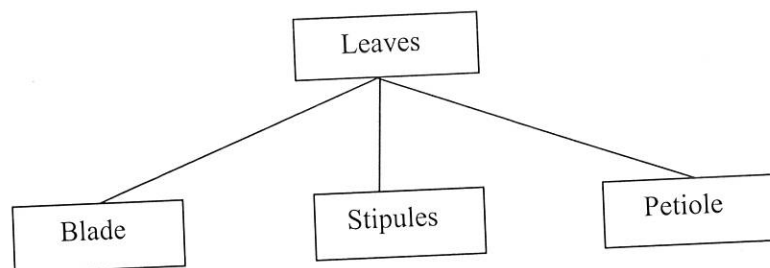


Figure 4.3 Leaf character parts in composition ladder

#### 4.5.1.1 The Foliar base (stipules)

Stipules are small green laminae arranged in pairs at the base of the petiole, either symmetrical on both sides, at the axil and called axillary, between the petioles of opposite leaves and are called interpetiolar, at the very base of the petiole called interpetiolar, or above the axil and are called superaxillary. The key object in this part that is used in woody plant identification is presence or absence of interpetiolar (Figure 4.4).

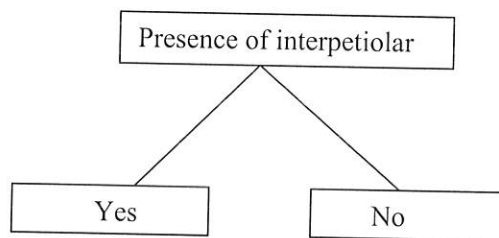


Figure 4.4 Presence of interpetiolar in attribute ladder.

#### 4.5.1.2 Petiole

A petiole is a rigid base that extends from the foliar base to the blade. It can be described by its length, its section and its surfaces. Leaves with petioles are called petiolate, while leaves without petioles are called sessile (Figure 4.5).

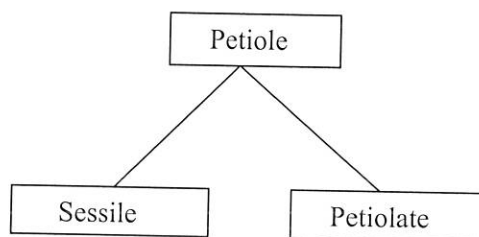


Figure 4.5 Petiole in attribute ladder

### 4.5.1.3 Blade

The central part of leaves is characterized by the following features: the type, shape, margin, surface feature and venation attribute. Each of these attributes are given values and represented in attribute ladder model of knowledge as shown in Figure 4.6. Each of the leaf attributes are then further represented in attribute ladder.

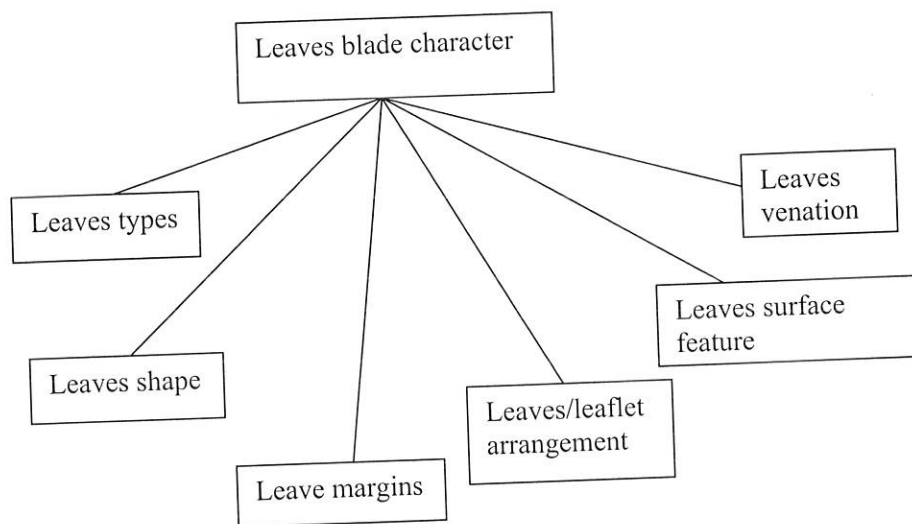


Figure 4.6 Attributes ladder of the blade of the leaves

#### A. Types of leaves

There are two basic types of leaf depending on the complexity of the division of the blade: simple and compound. A simple leaf has only one leaf stalk, in the axil of which can be found a bud, branch, and flower. The leaves of some trees consist of three or more blades attached to a common stalk. Leaves of this type are compound and the individual blades are leaflets or pinnae. The stalk supporting the leaflets is the rachis. The ladder of types of leaves is presented in Figure 4.7.

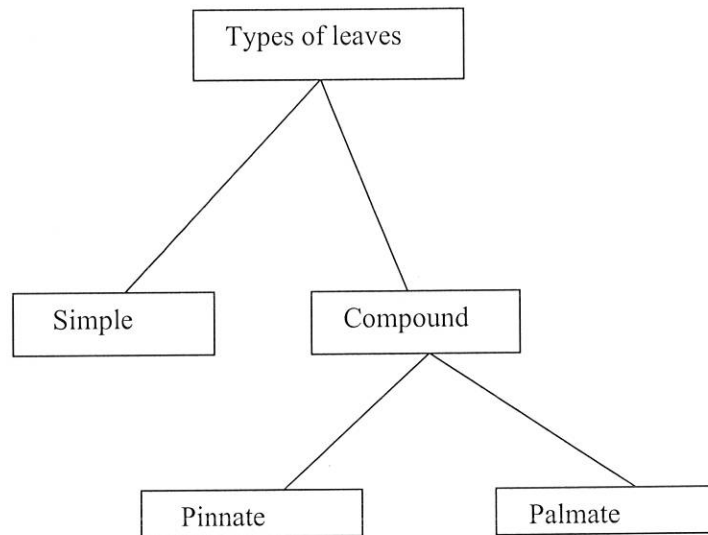


Figure 4.7 Leaves type in concept ladder

## B. Leaf/leaflet arrangement

The leaves are usually arranged in one of three definite ways:

1. If they are paired at the same height, one on each side of the twig, they are opposite.
2. When more than two are found at the same node, they are whorled
3. Where only a single leaf is attached to each node, close inspection will show that the leaves are arranged in spiral about the twig and are in this case alternate.

In general, leaves and leaflets may be arranged either opposite (2 per node), alternate (1 per node), whorled (more than 2 per node) or clustered as depicted in Figure 4.8.

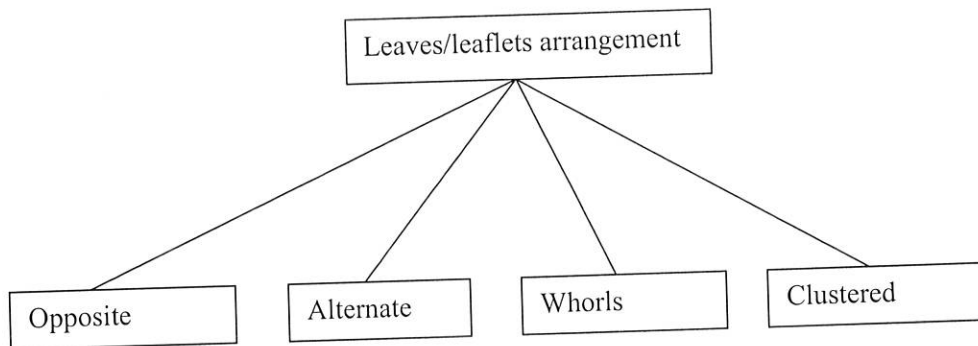


Figure 4.8 Leaves/ leaflet arrangement in concept ladder

Depending upon the arrangement of the leaflets, two types of compound leaves can be distinguished: the pinnate and the palmate. Depending upon the number and the arrangement of leaflets on the rachis, one can distinguish between paripinnate leaves, that is pinnate leaves ending with a pair of leaflets and imparipinnate, which is pinnate ending in a single leaflet. Certain leaves are several times compounded, that is the lamina itself divided. Then one speaks of the number of subdivision of bipinnate leaves (doubly pinnate), tripinnate leaves (triplly pinnate). When the pinnae of bipinnate leaf end in a single foliole, the leaf is biimparipinnate but when ending in a pair of folioles, the leaf is biparipinnate. When a pinnate leaf has only one folioles, it is called bifoliolate. In palmate leaves, the folioles are always inserted at the same point on the principal petiole and are arranged like the fingers of a hand. Type of palmate may be distinguished as: trifoliolate, that is having three folioles and digitate, that having more than three folioles. The arrangement of pinnate and palmate in concept ladder is shown in Figure 4.9.

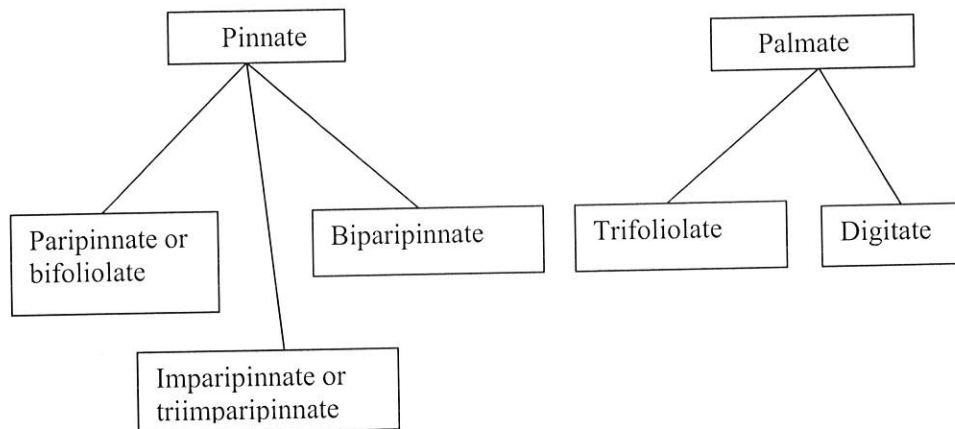


Figure 4.9 Pinnate and palmate leaves arrangement in concept ladder.

From the above description, it is possible to create an artificial group using the characteristics features: leaves type (simple, compound), arrangements of simple leaves (opposite, opposite-decussate, ternate or whorls of 4 and clustered) and arrangements of compound leaves (paripinnate or bifoliolate, imparipinnate or triimparipinnate, biparinnate, compound-digitate or trifoliolate). Accordingly, nine artificial groups are created with the consultation of taxonomists in the Herbarium. Then, the species considered are grouped under one of the artificial groups. Decision ladder of artificial group is presented in Figure 4.10.

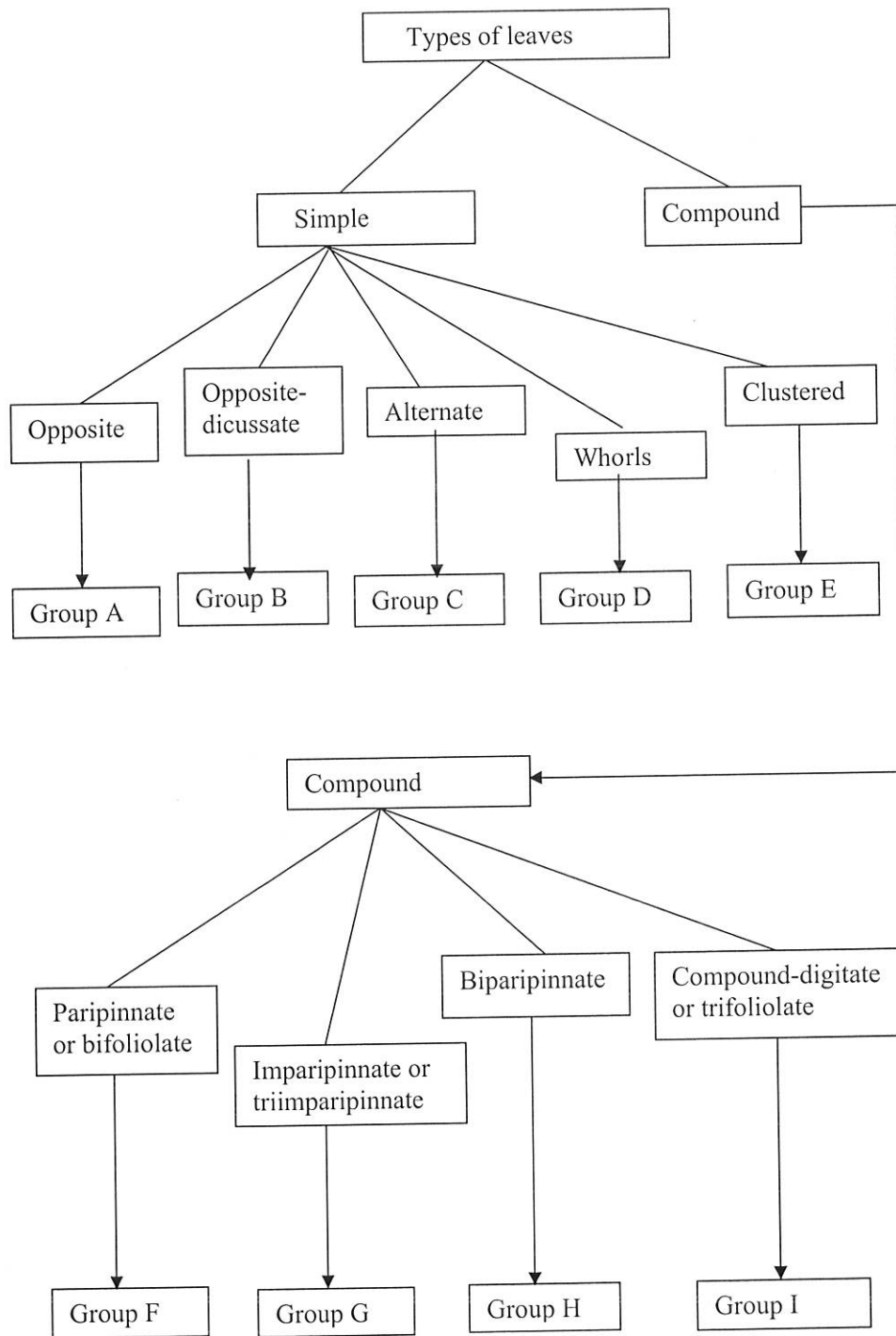


Figure 4.10 Decision ladder for artificial group

### C. Leaves Venation

Depending upon the arrangement of the veins (venation), venation can be penninerved when secondary veins branching off at interval from the primary veins, pedale in which secondary veins curve and run almost parallel to the leaf margin, palmatinerved when three or more secondary veins branch radically from the base of the leaf, and parallelinerved in which the veins run nearly parallel to each other from the base to the apex of the leaf. Leaves venation model is shown in the Figure 4.11.

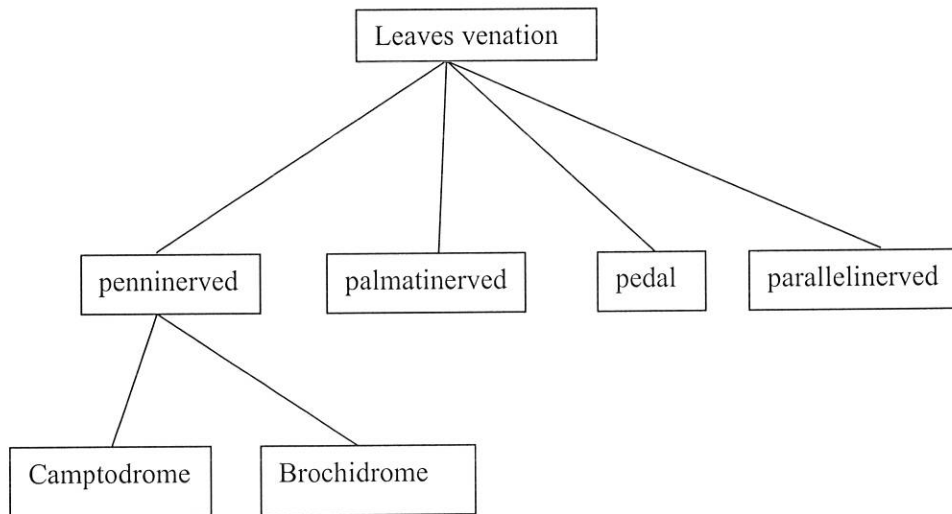


Figure 4.11 Leaves venation in concept ladder

### D. Leaves/leaflets shape

The shape of a leaf or leaflet is usually characteristics of a tree species. The some of the shape of the leave/ leaflet are acicular, which is needlelike shape, ovate (egg-shaped), deltoid, that is shaped like the Greek letter delta, lanceolate (Lance-shaped), elliptic, which is shaped like an ellipse with sloping ends, oblong shape longer than broad, and with sides nearly parallel,

Rhomboid, that is shaped similar to a rhombus and oblanceolate, which is inversely lanceolate.

Attributes of leaves/leaflets shape is depicted in the Figure 4.12.

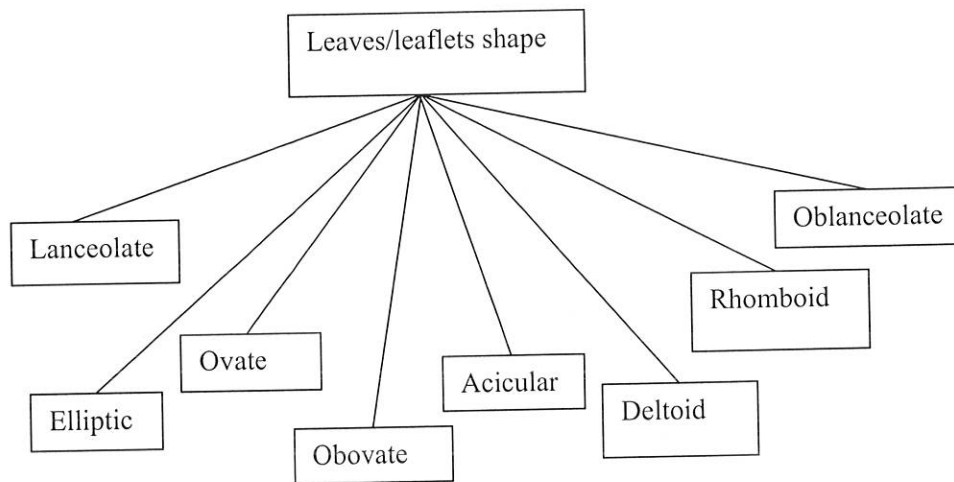


Figure 4.12 Leaves/leaflets shape in attribute ladder.

### **E. Leaves/leaflets margin**

Margin is the edge of a leaf blade. Margin of the leaves or the leaflets can be entire, which is smooth without lobes or teeth, dentate with sharp teeth pointing outward, serrate with sharp teeth pointing toward the apex, serrulate, which is coarsely serrate, the teeth margins again serrated, undulate having a wavy margin and rippled surface, crenulate with rounded to blunt teeth, serrate-dentate, crenulate-serrulate. Margin of leaves/leaflets is shown in attribute ladder in the Figure 4.13.

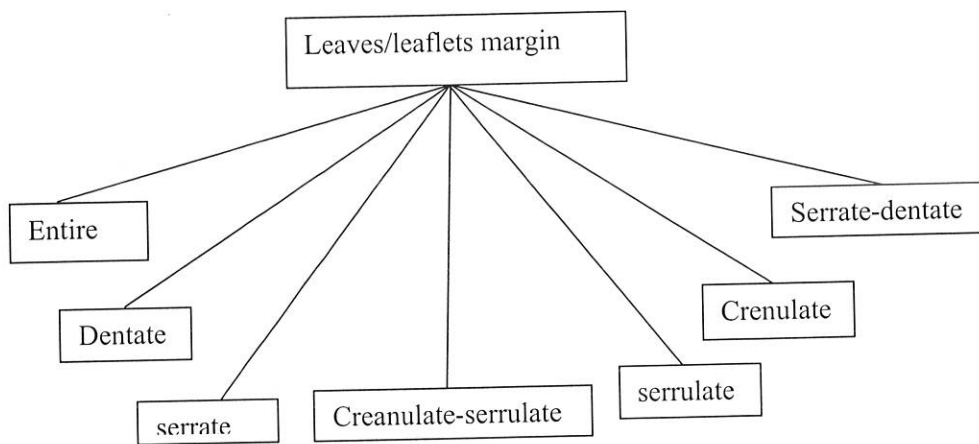


Figure 4.13 Leaves/leaflets margin in attribute ladder.

#### F. Surface of the blade

A surface of the leaves without hair of any sort or smooth is termed as glabrous. A surface of the leaves with fine, soft and short hairs is glabrescent (non glabrous). Attribute ladder of surface of the blade is shown in the Figure 4.14.

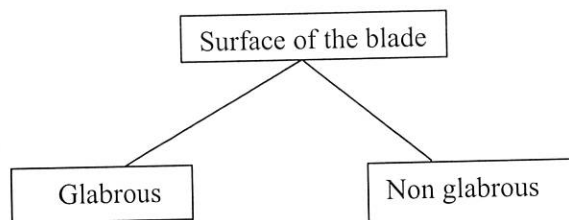


Figure 4.14 Surface of the blade in attribute ladder.

#### 4.5.2 Bark Character

The bark is one of the parts of the tree or shrubs that can always be observed directly. Its appearance is related to the age of the tree or shrubs and its habitat varies considerably from one tree to another. However each species has, at maturity, a distinctive character that must be

recognized. The key objects in the parts of bark used for identification are color of blaze and slash, exudation and presence of latex on the bark.

#### 4.5.2.1 Color of the blaze and slash

Depending on the species, color of the blaze and slash of the bark may vary. Possible colors encountered are greyish, cream, brownish, yellowish, reddish and pinkish as shown in the Figure 4.15.

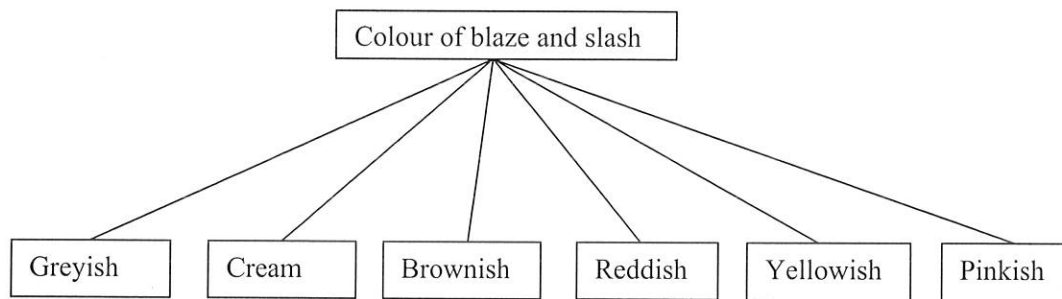


Figure 4.15 Color of blaze and slash of the bark in attribute ladder.

#### 4.5.2.2 Exudation

The presence or absence of exudation in the blaze, its provenance, its color and its texture are characteristics that make it possible to identify several species. Exudation may be colorless, white, yellow, orangish, reddish, brownish, and sometimes greenish. Here the key objective used for identification is presence of exudation and its color as depicted in the Figure 4.16.

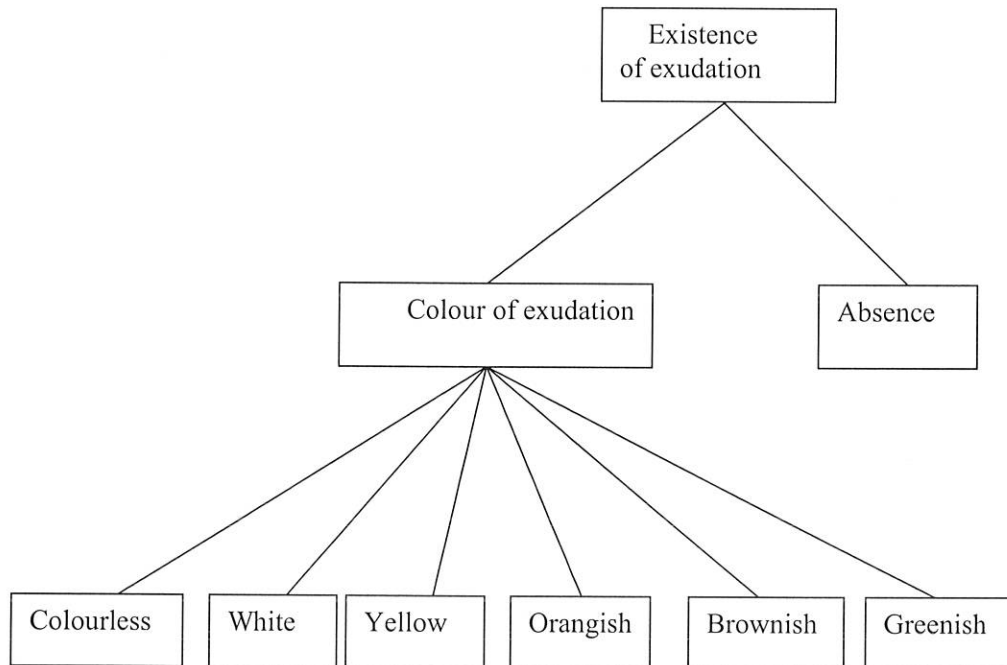


Figure 4.16 Color of exudation in attribute ladder.

### 4.5.2.3 Texture

Depending on the composition and the arrangement of the various structures that make up the bark, three types of texture can be distinguished, namely: fibrous barks which is a texture consisting of long fibrous groupings of cells, corky barks which is very light, more or less smooth bark and granular barks which is crumbling into small blocks of cells with long splinter-like pieces. Bark texture in attribute ladder is presented in Figure 4.17.

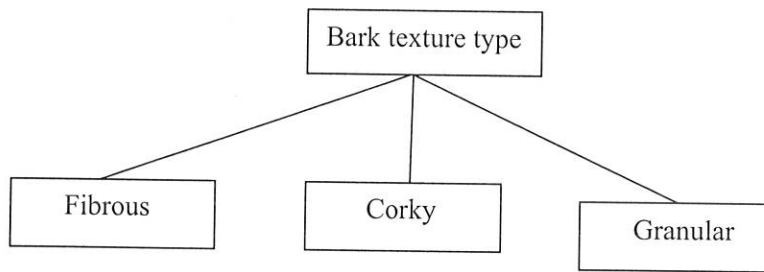


Figure 4.17 Bark texture type in attribute ladder.

#### 4.5.2.4 Prickles

Prickles are sharp outgrowths from the stem, branch or leaf readily detaching off without breaking the bark. Accordingly, prickles length (0.5, 2 and 4 cm), prickle type (straight and recurved), prickle pair (yes, no), prickle color (black, dark brown, brown and reddish) are taken as key characteristics features used for identification particularly for acacia genera.

There are also other key objects (concepts) used for identification of woody plant species, it is difficult to show the model all of concepts used in this study such as petiole length, odor on bark, twigs of the leaves. Finally, the basic concepts are modeled under each the nine artificial group (group A to I) to arrive at woody plant species in decision ladder knowledge modeling. Knowledge model of taxonomy of woody plant species in Ethiopia under group A is shown in decision ladder as follows using key concepts or objects as continuation of Figure 4.10.

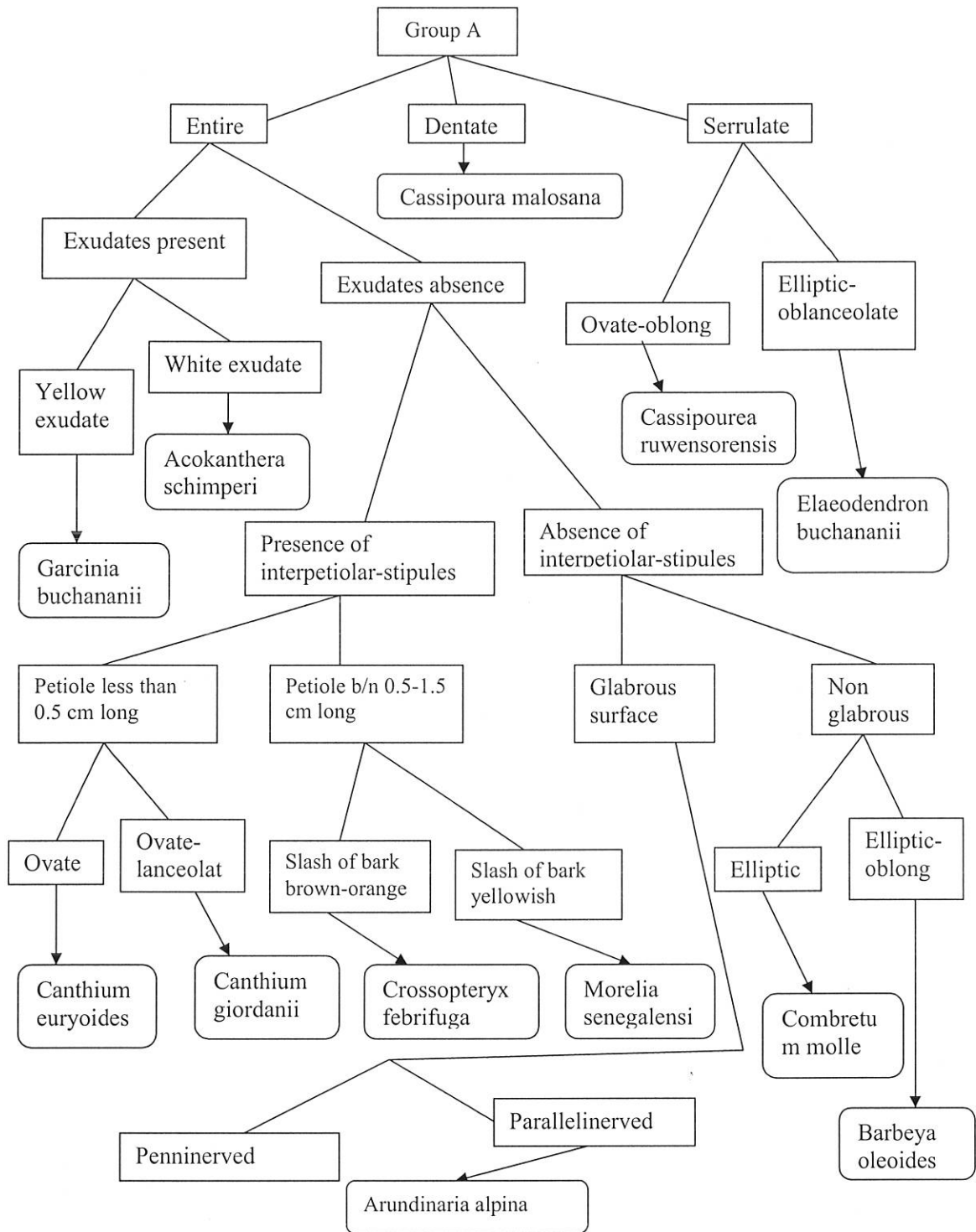


Figure 4.18 woody plant species identification under group A in decision ladder.

Applied ladder modeling and structuring techniques determine the minimum set of diagnostic characters in order to recognize the different taxa. Modeling allows us to find determining features and this enables quicker identification than that provided by the traditional method; taxonomist uses identification keys, description and sample for illustration.

A set of rules (represented in the Knowledge Base) is obtained directly from the final decision ladder for each artificial group. Ladder modeling techniques allows us to obtain one rule per objective with smallest set of features. In this way, optimized rules are created which exclude irrelevant knowledge used by taxonomist.

Although initially knowledge elicitation from the taxonomist and relevant document of this type supposes greater effort than using dichotomic keys directly, this investment is easily compensated for since these will enable us to apply ladder modeling techniques in order to obtain keys which are different from the standard ones that bring comparative performance. This enables quicker identification than dichotomous key used by taxonomist.

## CHAPTER FIVE

### 5. KBS DEVELOPMENT

#### 5.1 Introduction

The KBS infers solution by running the knowledge base through an inference engine, a software program that interacts with the user and processes the results from the rules and facts in the knowledge base. In the previous chapter, the domain knowledge has been extracted from the experts and modeled using hierarchical structure of laddering knowledge modeling techniques. Knowledge representation technique, inferencing mechanism, explanation facilities and development of the user interface and evaluation of woody plant species identification prototype KBS is discussed in this chapter.

#### 5.2 KBS Architecture (Design)

KBS has knowledge acquisition subsystem, knowledge base that contains facts and rules, backward inferencing mechanism, graphic user interface and explanation facilities components as shown in the Figure 5.1. The knowledge acquisition subsystem that performs the eliciting and structuring of knowledge from the taxonomist and relevant document is presented in the previous chapter.

The main program that contains the inferencing mechanism, requests user to load the knowledge base and starts the identification process. The backward inferencing mechanism identifies the species through asking the characteristics features of the species.



The input from the users is in the form of answering the KBS's multiple choice questions. The questions are related to the characteristics of the woody plant species. The goal of the questions is then to determine the adequacy of the unique feature of the woody plant species.

The KBS presents questions to acquire the characteristic feature of woody plant species. The system is able to determine the specimen based on the key characteristics' and display the correct name of the identified species and provide explanation facilities.

Once the intended species is identified, the system can provide the description of that identified species from the database through the user interface. The database contains multimedia information (i.e. description of the features of the woody plant species and their image). Microsoft Access is used to create the database and the choice of Ms-access is mainly because of its simplicity, familiarity and connected to the Vb.net to design the user interface.

### **5.3 Software Requirement for Development KBS**

This system is developed by the software called Amzi! Prolog + Logic server with Eclipse IDE, and Java on Windows' XP. The Eclipse IDE requires Java 1.4 or later. The Amzi! Prolog Logic Server comes with several APIs. In this study, amzinet.dll is used for vb.NET interface (Version 1.0.3705.288 (Service Pack 2)). The Amzi! Net.dll requires the Microsoft .net framework 2.0. Ms-access is used to develop the database for the description of the known woody plant species.

## 5.4 Knowledge Representation

A variety of knowledge representation schemes have been developed over the years. The most commonly used methods of knowledge representations are production rule, frame and network. Knowledge captured from experts and other sources must be organized in such a fashion that a computer inferencing program enables to access this knowledge whenever needed and draw conclusions. In this prototype KBS, production rules are used, since it permits the relationships that make up the knowledge base to be broken down into manageable units. In addition, new rules may be added and old ones deleted usually independently of other rules (Aronson and Turban, 2004).

The knowledge acquired from the experts, is represented by production rules (IF THEN). Knowledge from the decision ladder in the previous chapter was hence, converted into IF THEN forms as follows for the artificial group (sub goal) in woody plant identification KBS.

### Rule 1

if leaves type is simple and  
leaves arrangement is opposite  
then group is A

### Rule 2

if leaves type is simple and  
leaves arrangement is opposite\_decussate  
then group is B

### Rule 3

if leaves type is simple and  
leaves arrangement is alternate  
then group is C

**Rule 4**

if leaves type is simple and  
leaves arrangement is ternate or in whorls of 4  
then group is D

The woody plant species rule that can drive the main goal is constructed in the form of IF THEN and connected to the artificial group (sub goal) as follows.

**Rule 5**

If group is A and  
Leaves margine is entire and  
Presence of exudates and  
Color of exudates is yellow  
Then plant species is *Garcinia buchananii*

**Rule 6**

If group is A and  
Leaves margine is entire and  
Presence of exudates and  
Color of exudates is white  
Then plant species is *Acokanthera schimperi*

### **Rule 7**

If group is A and

Leaves margine is entire and

Absence of exudates and

Presence of interpetiolar stipules and

Forms of blade is ovate

Then plant species is *Canthium euryoides*

## **5.5 Knowledge Base**

Rules used for identification are represented hierarchically. These include rules for identifying the artificial group (sub goal) and the woody plant species (main goal). IF THEN rules for woody plant species identification are represented in prolog. The syntax of the prolog is THEN IF, and the normal right hand side and left hand side appear on opposite since the built in backward inferencing mechanism of prolog start inferring from the goal or THEN part. The representation is shown below.

### **Rules for the artificial group in the knowledge base**

#### **Rule 1**

group(a):-

leavestype(simple),

arrangement(opposite).

#### **Rule 2**

group(b):-

leavestype(simple),  
arrangement(opposite-decussate).

**Rule 3**

group(c):-  
leavestype(simple),  
arrangement(alternate).

**Rule 4**

group(d):-  
leavestype(simple),  
arrangement(ternateorinwhorlsof4).

**Rules for the woody plant species in Knowledge base**

**Rule 5**

species('Garcinia buchananii '):-  
group( a),  
leavesmargine(entire),  
exudate(presence),  
colorofexudate(yellow).

**Rule 6**

species('Acokanthera schimperi'):-  
group( a),  
leavesmargine(entire),  
exudate(presence),  
colorofexudate(white).

### Rule 7

species('Canthium euryoides'):-  
group(a),  
leavesmargin(entire),  
exudate(absence),  
interpetiolarstipules(presence),  
formsofblade(ovate).

From the rule of artificial group, the system drives the sub goal called artificial group of woody plant species and identifies the species (main goal) using woody plant species rule based on the user input facts. The complete rules in knowledge base of this prototype woody plant species identification KBS is attached as (appendix II).

In addition to rules discussed above, the KB contains the users query. These are used to collect facts from the user during woody plant identification. Some of these users query are the following.

Leaves-type(X):- menuask(leaves-type,X,[simple, compound]).

Arrangement(X):- menuask(arrangement,X,[opposite,opposite-  
decussate,alternate,ternateorinwhorlsof4,clustered]).

Leaves-margin(X):- menuask (leaves-margin, X,[entire, dentate, serrate, serrelute,  
toothed, undulate, crenulate]).

Exudate (X):- menuask (exudate,X,[presence, absence]).

Color-of-exudate (X):- menuask (color-of-exudate, X,[yellow, white]).

## 5.6 Inference Engine

There are two popular approaches for controlling inference in rule-based KBS which are forward chaining and backward chaining. The prototype KBS woody plant species identification applies backward inferencing mechanism since prolog has simple built in backward chaining and it fits to the problem at hand. Backward chaining is a goal-driven approach in which it starts from an expectation of what is to happen (hypothesis), then seek evidence that supports (or contradicts) the expectation. It is practical when there are a reasonable number of possible final answers (Chignell and Parsaye, 1998).

During woody plant species identification, the rules in the knowledge base are searched for conditions that can be satisfied by facts supplied by the user. This operation is performed by the inference engine. Once all conditions stated in the IF parts of a rule are matched, the appropriate conclusion is drawn. Based upon the conclusions drawn and the facts obtained during consultation, the inference mechanism determines which questions will be asked and in what order.

When the system is requested to identify the woody plant species, it automatically starts asking the user about the feature of the species. This is performed by the prolog menuask predicate. The menuask predicate in the prolog is coded as shown below.

```
Leavestype (X):- menuask (leavestype, X, 'What is the value for the leaf type?  
[simple, compound]').
```

The first question, the system asks, is the leaves type and then leaves arrangement of the woody plant to determine the sub goal of artificial group. After determining the sub goal

group, it continues asking the other features until it finds the woody plant species. In Figure 5-2 a simplified demonstration is given how the prolog infers in identifying the woody plant species by taking *Garcinia buchananii* species as an example.

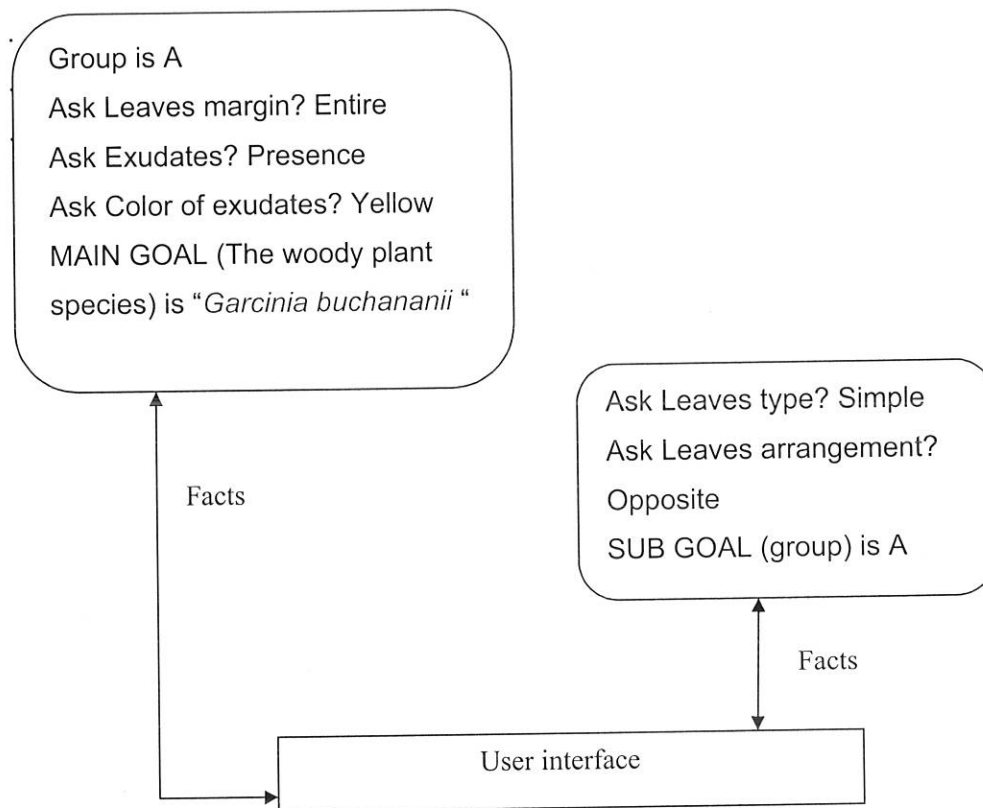


Figure 5.2 Backward chaining in woody plant species identification

The facts collected from the user are stored in the prolog database (working memory) during identification. It stores the known facts about attribute-values pairs.

### 5.7 Explanation Facilities

One attractive feature of this KBS is the program's ability to review an identification process. The explanation function is essentially a record of the reasoning process used by the expert to

resolve the problem. The 'how' explanation provides the user with an explanation for how its identification/ conclusion are derived. It provides for a better understanding of how the conclusion is reached and instills in the user a greater confidence in the conclusion and the KBS. In addition, KBS also provides 'whynot' a given conclusion is derived to the other woody plant species and why the KBS is asking a question during identification. Here is an example that explains or justifies 'why' system ask me this question, 'how' the sub goal of group A, and the main goal of the woody plant species *Acokanthera schimperi* is identified.

What is the value for leavestype?

1: simple

2: compound

Enter the number of choice> > **why.**

Menuask (leavestype, simple, [simple, compound])

leavestype (simple)

group (a)

Plant - species (*Garcinia buchananii*)

goal (*Garcinia buchananii*)

?- **how (group (a)).**

Group (a) because your inputs were:

leavestype (simple)

arrangement (opposite)

?-**how (plant-species (*Acokanthera schimperi*)).**

Plant – species (*Acokanthera schimperi*) because your inputs were:

group (a)

leavesmargin (entire)

exudates (presence)

colorofexudate (white)

## **5.8 User Interface**

The user interface is the part of the KBS through which users interact with the system. To use this system, user would require running the plant\_callback.exe file and identification page will be opened. The identify button on identification page is one that starts the identification process. The page will display a series of questions one after the other and await for user response. Depending on the answers provided by the user, the system will draw a conclusion (the woody plant species) for a conducted session. Finally the system provides short description of the known woody plant species from the database.

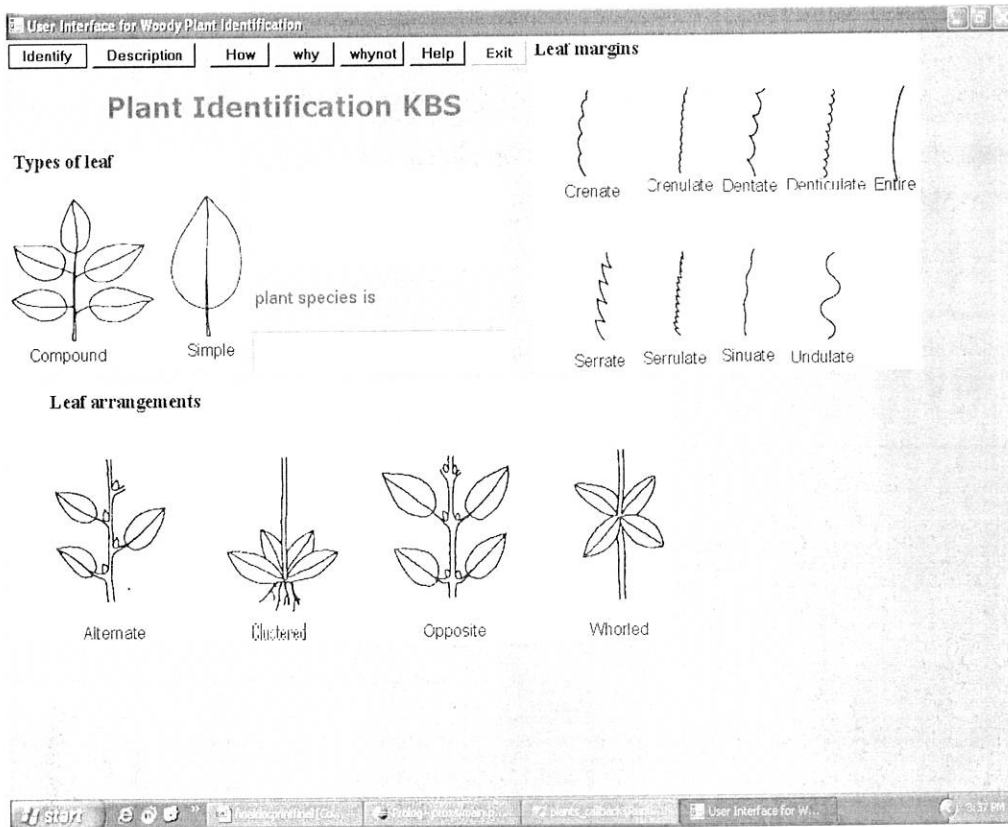


Figure 5.3 An overview of the user interface for woody plant identification.

When the user click on the identify button the system will start the identification process through asking a series of question until it draws woody plant species.

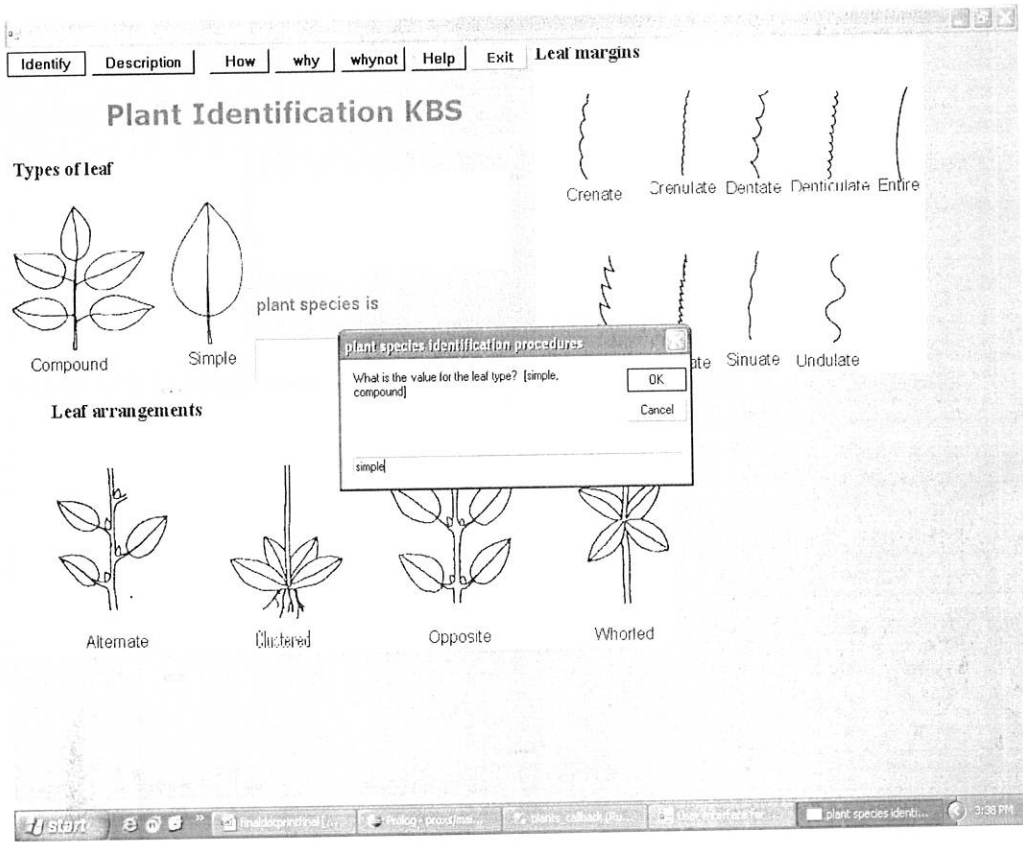


Figure 5.4 A scenario showing dialog session with users.

The system starts by asking the type of leaves and then arrangement to identify the artificial group. After identifying the artificial group, it asks again another questions to arrive at the woody plant species based on the answer given by the user and identified artificial group. The identified species is displayed as depicted in Figure 5.5.

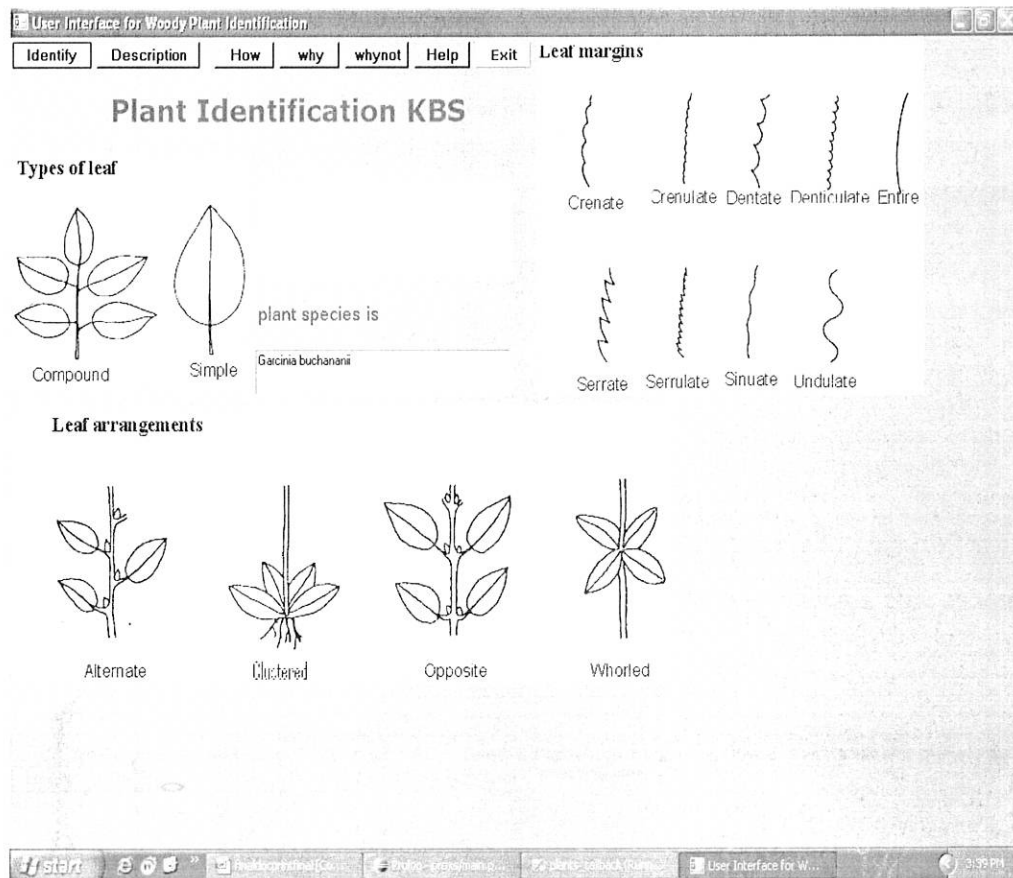


Figure 5.5 Page that displays the identified woody plant species.

Lastly, by clicking on the description button, users can get short description of the identified species concerning its leaves, habit, bark, family, flowers, fruits, wood, uses and images from the multimedia database as shown in Figure 5.6.

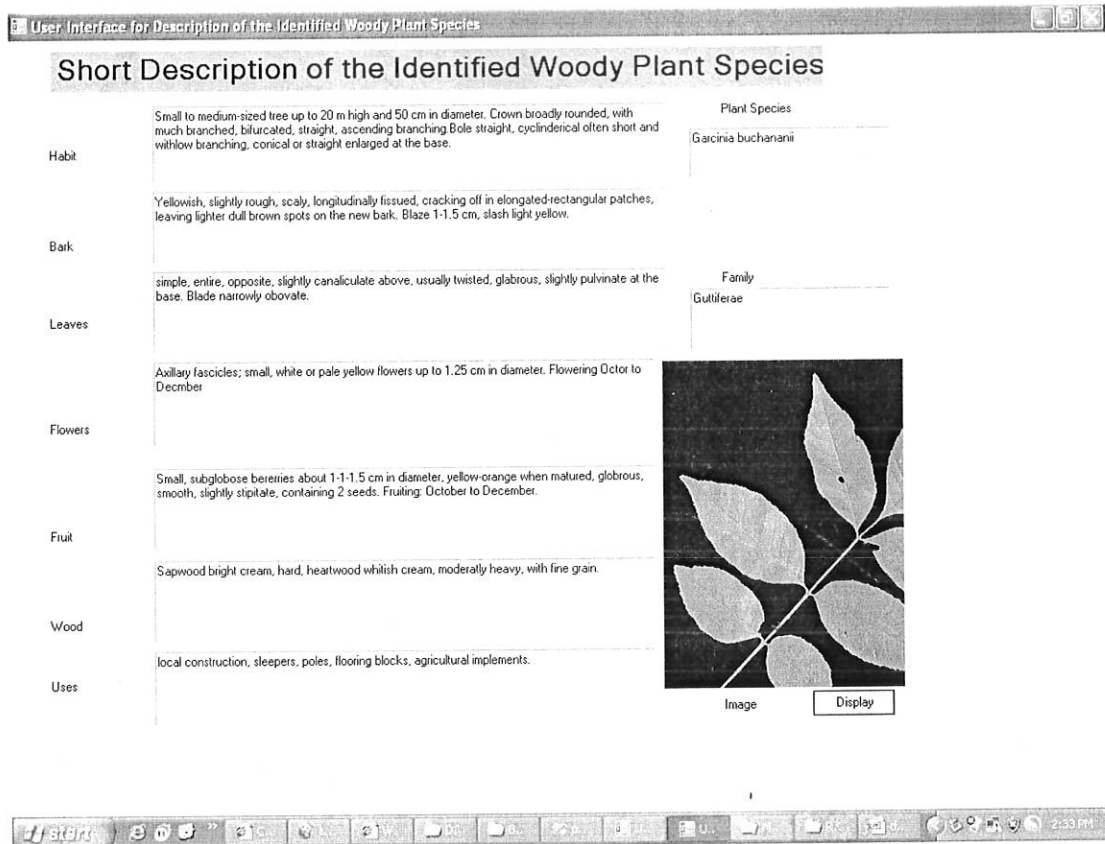


Figure 5.6 Short descriptions of the identified woody plant species.

## 5.9 Testing and Evaluation of the System

The developed knowledge based system is tested and evaluated by the potential users to ensure the system performance is converging towards established goals. The evaluation process is more focused on the system validation and user acceptance. Validation efforts verify if the system performs the intended task satisfactorily. While, user acceptance efforts are used to evaluate how well the system addresses the needs of the user. It also addresses the issue "is the system valuable?". This is reflected by the acceptance of the system by its end users and the performance of the system in its application (Aronson and Turban, 2004).

Following Aronson and Turban (2004) and Aladwani (1998), system evaluation is done in this study in step-wise manner. First, the systems internal consistency is verified. This test is to evaluate the complete knowledge base. The test applies all possible combinations of answers to the questions asked by the system. System-derived solutions are verified for each set of answers. The test provided the early verification of the system.

After the refinement and verification of the knowledge base, user acceptance testing is conducted. This evaluation is done by potential users in realistic situation. The objective of the test is to determine, if the system meets its original goals. This test also determines the validation of the system and assesses the user's acceptance.

Eight respondents: two technicians from the National Herbarium and four researchers and two technicians from the Forest Research Center are consulted to evaluate the system. All the evaluators have related work experience in woody plant species identification and none of the subjects is involved in any way with the development of this KBS.

Prior to the testing and evaluation, the researcher has given a brief introduction about the system: how it works and how they are going to interact to make the evaluation smooth. Each of these users is asked to identify five woody plant species that they want using the system. Since these users are familiar with the characteristic features used for plant identification, they interactively communicated with the system by selecting features of the woody plant species that they want the system to identify. Then, the users are requested to fill the evaluation

questionnaires designed for the purpose (Appendix IV). The questionnaires are designed to acquire information on the performance, usefulness and application of the system to the area. Users asked to provide a number of successful and unsuccessful trail for testing the performance and comprehensive value for the other evaluation questions (i.e. Comprehensive value, are converted into scale from one (worst) to four (best) to calculate and summarize the result of the evaluation).

The results of the testing and evaluation by the potential users is summarized and presented in Table 5.1 and 5.2 respectively. The testing and evaluation procedure indicates that 70 % of the 40 trials, 5 trials each by the potential users to identify woody plant species using this new system resulted in successful identification of the intended species. 30% of the trials are ended with a result 'unidentified woody plant species'. These unidentified species were not included in the KBS. Hence, completing the KBS with incorporation of all possible woody plant species could result in complete identification of the species.

Table 5.1 Testing result by the user

Trials	%
Successfully identified	70%
Unidentified	30%
No. of total trial	40

Table 5.2 Users' evaluation of the system

No.	Criteria of evaluation	Average score	%
1	Applicability of the system for woody plant identification	3.5	87.5%
2	Completeness of the knowledge base	3	75%
3	How well the inference simulate the taxonomist	3.38	84.5%
4	User interface friendliness	3.38	84.5%
5	Usefulness as a training tool	3.36	84.5%

The evaluation of the system by the potential end users indicated that the system is fairly applicable for woody plant species identification (Table 5.2), it works like taxonomist in identification, and the users found it ease to communicate with the system but the system will give an error message if the user makes a mistake in entering the required data or answering the question. Generally, the result is encouraging and leads to a direction to conduct further study to make it full-fledged and applicable system in the area.

Users have commented that the system incorporate some more key characteristics feature of woody plant species used in identification; leaves and bark features. In addition to the leave and bark characteristic features used in this system development, additional characteristic feature of woody plant species such as flower, fruit has to be included. Incorporation of such

features will enhance the accuracy of the identification process through the minimization of errors due to modification of leave and bark features due to environmental factors.

The taxonomist further commented that the system with its explanation facilities can have a great help to train new taxonomist. Training about taxonomy of plant is very complicated but this system with its explanation facilities make it easy to understand how plants are identified. Images of the basic characteristics feature of the plant species can support the non-expert in using it for identification. In addition, it can be used as teaching aid in dendrology courses that are offered in forestry and taxonomy fields.

According to their general comment, there is a problem to conduct research in different sub-disciplines of forestry since the plant species has to be identified first and this is done only in the National Herbarium. So developing such type of system has to be prioritized and can facilitate research conducted in the forestry area supplementing few taxonomists in Ethiopia.

Generally, the evaluation and test result stressed the importance of the system. Almost similar comments are forwarded by the potential users of the system. Though existing situation shows that there are infrequent introduction of new species, there is a need to undertake further as to how to make the system automatically updatable whenever new species are introduced.

## CHAPTER SIX

### 6. CONCLUSION AND RECOMMENDATION

#### 6.1 Conclusion

Knowledge Base Systems have wider applications in different disciplines. In this study, new knowledge/rule with minimum length and smallest set of features of the species is constructed through laddering modeling technique, based on which a KBS for woody plant species identification is developed. The research shows that KBS brings quicker identification and it is applicable and essential in forestry in general and in species identification in particular.

In the forestry sector, the KBS can offer a new advantage in the identification of tree species which will make it possible for forest technicians as well as research and development workers to identify woody plant species with comparable performance, minimized cost, time and acceptable accuracy with smallest set of the characteristics key. Taxonomists and technicians who are involved in plant species identification in the AAU National Herbarium and forest technicians and researchers from FRC have confirmed its applicability and comparable performance with some additional work incorporate the other woody plant species and additional identification morphological keys and create a better users friendly and interactive user interface.

The prototype can easily be full-fledged by incorporating identification characteristic keys for all tree species with minimum cost and can readily be available for the potential users with

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The prototype can easily be full-fledged by incorporating identification characteristic keys for all tree species with minimum cost and can readily be available for the potential users with

simple technology. The other advantage of the woody plant species KBS is that the users can check the accuracy of the identification procedure by making comparison between the characteristics of the plant species under investigation with the descriptions that will be displayed at the end of the identification.

The woody plant species identification KBS is the first of its kind in the country in the dendrology field identifying species with knowledge contains few numbers of key features. The system can also be adapted to other herbaceous species with simple modification and establishment of knowledge base for the respective plant species. The system needs to be updatable to incorporate the new woody plant species when it is infrequently introduced.

## **6.2 Recommendation**

To use the outputs of this research in designing a full-fledged knowledge based system for woody plant species identification, the following further studies are recommended.

- The system in this study has so far only addressed the identification of some of the most widely used woody plant species based on the characteristics features of leaves and bark in the country. For practical purpose, we need to enable the system identify all woody plant species found in Ethiopia. Hence, further study has to be conducted so as to investigate the need for inclusion of all available woody plant species in Ethiopia.

- In this study an attempt is made to develop prototype KBS for species identification using leaves and bark. However these fetures may be affected by weather condition. So further study has to be conducted so as to investigate the need for inclusion of the other key features such as flower and fruit.
- Further studies needs to be done to investigate the possibility of adding new knowledge automatically by the users whenever a new woody plant species are introduced.

The prototype system developed can also be taken as a stepping-stone for conducting research to further come up with other approaches than adopted in this work to design and implement knowledge based system for tree species identification in Ethiopian context. The KBS has to be designed, developed in frame based knowledge based and the result should be compared with this study. This enables to adopt the better approaches.

According to the researchers in FRC, there are also other potential areas to be performed by KBS in the Forestry sub fields. Some of these are: tree seed source identification, forest ecology, silviculture, entomology and plant pathology. For these, KBS needs to be developed and studied its application.

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## APPENDICES

### Appendix I: List of Tree and Shrub Species Considered for the Development of the KBS

No.	Plant species	Family
1.	<i>Lannea schimperi</i>	Anacardiaceae
2.	<i>Lannea microcarpa</i>	Anacardiaceae
3.	<i>Ozoroa insignis</i>	Anacardiaceae
4.	<i>Ozoroa pulcherrima</i>	Anacardiaceae
5.	<i>Acokanthera schimperi</i>	Apocynaceae
6.	<i>Cussonia holstii</i>	Araliaceae
7.	<i>Cussonia ostinii</i>	Araliaceae
8.	<i>Polyscias fulva</i>	Araliaceae
9.	<i>Schefflera abyssinica</i>	Araliaceae
10.	<i>Schefflera volkensii</i>	Araliaceae
11.	<i>Balanites aegyptiaca</i>	Balanitaceae
12.	<i>Barbeya oleoides</i>	Barbeyaceae
13.	<i>Kigelia aethiopum</i>	Bignoniaceae
14.	<i>Stereospermum kanthianum</i>	Bignoniaceae
15.	<i>Boswellia papyrifera</i>	Burseraceae
16.	<i>Commiphora confuse</i>	Burseraceae
17.	<i>Commiphora erythraea</i>	Burseraceae
18.	<i>Cassia arereh</i>	Caesalpinioideae
19.	<i>Cassia Singueana</i>	Caesalpinioideae
20.	<i>Tamarindus indica</i>	Caesalpinioideae
21.	<i>Crataeva adansonii</i>	Capparidaceae
22.	<i>Ritchiea albersii</i>	Capparidaceae

23.	<i>Elaeodendron buchananii</i>	Celastraceae
24.	<i>Combretum adenogonium</i>	Combretaceae
25.	<i>Combretum molle</i>	Combretaceae
26.	<i>combretum nigricans</i>	Combretaceae
27.	<i>Combretum ghasalense</i>	Combretaceae
28.	<i>Combretum gallabatense</i>	Combretaceae
29.	<i>Terminalia brownie</i>	Combretaceae
30.	<i>Terminalia macroptera</i>	Combretaceae
31.	<i>Terminalia schimperiana</i>	Combretaceae
32.	<i>Juniperus procera</i>	Cupressaceae
33.	<i>Diospyros abyssinica</i>	Ebenaceae
34.	<i>Diospyros mepiliformis</i>	Ebenaceae
35.	<i>Erica arborea</i>	Ericaceae
36.	<i>Croton macrostachys</i>	Euphorbiaceae
37.	<i>Arundinaria alpine</i>	Gramineae
38.	<i>Garciana buchananii</i>	Guttiferae
39.	<i>Hypericum lanceolatum</i>	Hypericaceae
40.	<i>Nuxia congesta</i>	Loganiaceae
41.	<i>Strychnos innocua</i>	Loganiaceae
42.	<i>Ekebergia capensis</i>	Meliaceae
43.	<i>Lepidotrichilia volkensii</i>	Meliaceae
44.	<i>Pseudocedrela kotschy</i>	Meliaceae
45.	<i>Trichilia dregeana</i>	Meliaceae
46.	<i>Trichilia emetic</i>	Meliaceae
47.	<i>Bersama abyssinica</i>	Melanthaceae
48.	<i>Acacia abyssinica</i>	Mimosoideae
49.	<i>Acacia albida</i>	Mimosoideae
50.	<i>Acacia horrid</i>	Mimosoideae
51.	<i>Acacia macrostachya</i>	Mimosoideae
52.	<i>Acacia polyacantha</i>	Mimosoideae

53.	Acacia Senegal	Mimosoideae
54.	Acacia seyal	Mimosoideae
55.	Acacia sieberiana	Mimosoideae
56.	Acacia tortilis	Mimosoideae
57.	Acacia hecatophylla	Mimosoideae
58.	Acacia laeta	Mimosoideae
59.	Albizzia grandibracteata	Mimosoideae
60.	Albizzia schimperiana	Mimosoideae
61.	Dichrostachys cinerea	Mimosoideae
62.	Ficus ovate	Moraceae
63.	Ficus sur	Moraceae
64.	Moringa oleifera	Moringaceae
65.	Rapanea simensis	Myrsinaceae
66.	Syzygium guineense	Myrtaceae
67.	Olea welwitschii	Oleaceae
68.	Olea hochstetteri	Oleaceae
69.	Schrebera alata	Oleaceae
70.	Erythrina abyssinica	Papilionoideae
71.	Millettia ferruginea	Papilionoideae
72.	Dalbergia boehmii	Papilionoideae
73.	Lonchocarpus laxiflorus	Papilionoideae
74.	Pterocarpus lucens	Papilionoideae
75.	Pittosporum abyssinicum	Pittosporaceae
76.	podocarpus falcate	Podocarpaceae
77.	Faurea saligna	Proteaceae
78.	protea guagedi	Proteaceae
79.	Cassipourea ruwensorensis	Rhizophoraceae
80.	Cassipourea malosana	Rhizophoraceae

81.	<i>Hagenia abyssinica</i>	Rosaceae
82.	<i>Canthium euryoides</i>	Rubiaceae
83.	<i>Canthium giordanii</i>	Rubiaceae
84.	<i>Crossopteryx febrifuga</i>	Rubiaceae
85.	<i>Morelia senegalensis</i>	Rubiaceae
86.	<i>Gardenia lutea</i>	Rubiaceae
87.	<i>Mitragyna inermis</i>	Rubiaceae
88.	<i>Galiniera coffeoides</i>	Rubiaceae
89.	<i>Hymenodictyon floribundum</i>	Rubiaceae
90.	<i>Hallea stipulosa</i>	Rubiaceae
91.	<i>Adina microcephala</i>	Rubiaceae
92.	<i>Fagaropsis angolensis</i>	Rutaceae
93.	<i>Teclea nobilis</i>	Rutaceae
94.	<i>Vepris dainellii</i>	Rutaceae
95.	<i>Dobera glabra</i>	Salvadoraceae
96.	<i>Filicium decipiens</i>	Sapindaceae
97.	<i>Blighia unijugata</i>	Sapindaceae
98.	<i>Zanha golungensis</i>	Sapindaceae
99.	<i>Allophylus abyssinica</i>	Sapindaceae
100.	<i>Manilkara butugi</i>	Sapotaceae
101.	<i>Malacantha alnifolia</i>	Sapotaceae
102.	<i>Aningeri adolfi-friderici</i>	Sapotaceae
103.	<i>Markhamia tomentosa</i>	Sapotaceae
104.	<i>Kirkia burger</i>	Simaroubaceae
105.	<i>Vitex doniana</i>	Verbenaceae

## Appendix II: KB for the Artificial Group and Woody Plant Species

KB for the Artificial Group of the woody plant species

group(a):-

leavestype(simple),

arrangement(opposite).

group(b):-

leavestype(simple),

arrangement(opposite-decussate).

group(c):-

leavestype(simple),

arrangement(alternate).

group(d):-

leavestype(simple),

arrangement(ternate or in whorls of 4).

group(e):-

leavestype(simple),

arrangement(clustered).

group(f):-

leavestype(compound),

arrangement( paripinnate or bifoliolate).

group(g):-

leavestype(compound),

arrangement( imparinnate or triimparipinnate).

group(h):-

leavestype(compound),

arrangement( biparipinnate).

group(i):-

leavestype(compound),

arrangement( compound-digitate or trifoliolate).

## **KB for Woody plant species**

%1

plant-species (*Garcinia-buchananii*):-

group( a),

leavesmargine ( entire),

exudate(presence),

colorofexudate (yellow).

%2

plant-species (*Acokanthera schimperi*):-

group( a),

leavesmargine (entire),

exudate(presence),

colorofexudate (white).

%3

plant-species (*Canthium euryoides*):-

group(a),

leavesmargine(entire),

exudate(absence),

interpetiolarstipules(presence),

formsofblade(ovate).

%4

plant-species (*Canthium giordanii*):-

group(a),

leavesmargine(entire),

exudate(absence),

interpetiolarstipules(presence),

formsofblade(ovate-lanceolate).

%5

plant-species (*Crossopteryx febrifuga*):-

group(a),

leavesmargine(entire),

exudate(absence),  
interpetiolarstipules(presence),  
colorofslashofbark(brown-orange).

%6

plant-species (*Morelia senegalensis*):-

group(a),  
leavesmargine(entire),  
exudate(absence),  
interpetiolarstipules(presence),  
colorofslashofbark(yellowish white).

%7

plant-species (*Arundinaria alpine*):-

group(a),  
leavesmargine(entire),  
exudate(absence),  
interpetiolarstipules(absence),  
surfaceofblade(glabrous),  
venation(parallelinerved).

%8

plant-species (*Olea hochstetteri*):-

group(a),  
leavesmargine(entire),  
exudate(absence),  
interpetiolarstipules(absence),  
surfaceofblade(glabrous),  
venation(penninerved),  
formsofblade(elliptic-lanceolate).

%9

plant-species (*Syzygium guineense*):-

group(a),  
leavesmargine(entire),

exudate(absence),  
interpetiolarstipules(absence),  
surfaceofblade(glabrous),  
venation(penninerved),  
formsofblade(elliptic-ovate).

%10

plant-species (Combretum nigricans):-

group(a),  
leavesmargine(entire),  
exudate(absence),  
interpetiolarstipules(absence),  
surfaceofblade(glabrous),  
venation(penninerved),  
formsofblade(elliptic-ovate),  
Secondarynerve(5-8 pairs).

%11

plant-species (Strychnos innocua):-

group(a),  
leavesmargine(entire),  
exudate(absence),  
interpetiolarstipules(absence),  
surfaceofblade(glabrous),  
venation(penninerved),  
formsofblade(elliptic-ovate),  
Secondarynerve(4-5 pairs).

%12

plant-species (Barbeya oleoides):-

group(a),  
leavesmargine(entire),  
exudate(absence),  
interpetiolarstipules(absence),

surfaceofblade(nonglabrous),  
formsofblade(elliptic-oblong).

%13

plant-species (*Combretum molle*):-

group(a),  
leavesmargine(entire),  
exudate(absence),  
interpetiolarstipules(absence),  
surfaceofblade(nonglabrous),  
formsofblade(elliptic).

%14

plant-species (*Cassipourea ruwensorensis*):-

group(a),  
leavesmargine(Serrelute),  
formsofblade(ovate-oblong).

%15

plant-species (*Elaeodendron buchananii*):-

group(a),  
leavesmargine(Serrelute),  
formsofblade(elliptic-ob lanceolate).

%16

plant-species (*Cassipourea malosana*):-

group(a),  
leavesmargine(dentate).

%17

plant-species (*Juniperus procera*):-

group(b),  
petiole(sessile).

%18

plant-species (*Hypericum lanceolatum*):-

group(b),

petiole(nonsessile),  
formsofblade(elliptic-lanceolate).

%19

plant-species (Dobera glabra):-

group(b),

petiole(nonsessile),

formsofblade(elliptic-ovate).

%20

plant-species (Galiniera coffeoides):-

group(b),

interpetiolarstipules(presence),

formsofblade(elliptic-oblong).

%21

plant-species (Mitragyna inermis):-

group(b),

interpetiolarstipules(presence),

formsofblade(elliptic-ovate).

%22

plant-species (Hallea stipulosa):-

group(b),

interpetiolarstipules(presence),

formsofblade(elliptic).

%23

plant-species (Olea welwitschii):-

group(b),

interpetiolarstipules(absence),

formsofblade(lanceolate).

%24

plant-species (Hymenodictyon floribundum):-

group(b),

interpetiolarstipules(absence),

formsofblade(obovate).

%25

plant-species (Malacantha alnifolia):-

group(c),

whitelatexonbark(presence),

surfaceofblade(glabrous).

%26

plant-species (Aningeri adolfi-friderici):-

group(c),

whitelatexonbark(presence),

surfaceofblade(nonglabrous).

%27

plant-species (Diospyros abyssinica):-

group(c),

whitelatexonbark(absence),

surfaceofblade(glabrous),

colorofslashofbark(yellowish).

%28

plant-species (Diospyros mepififormis):-

group(c),

whitelatexonbark(absence),

surfaceofblade(glabrous),

colorofslashofbark(pinkish).

%29

plant-species (Ficus sur):-

group(c),

leavesmargine(toothed),

whitelatexonbark(absence).

%30

plant-species (Erica arborea):-

group(d),

surfaceofblade(glabrous),

formsofblade(acicular).

%31

plant-species (*Gardenia lutea*):-

group(d),

surfaceofblade(glabrous),

formsofblade(obovate).

%32

plant-species (*Adina microcephala*):-

group(d),

surfaceofblade(glabrous),

formsofblade(lanceolate).

%33

plant-species (*Combretum adenogonium*):-

group(d),

surfaceofblade(glabrous).

leavesmargine(undulate),

%34

plant-species (*Combretum ghasalense*):-

group(d),

surfaceofblade(glabrous),

leavesmargine(entire),

formsofblade(oblanceolate).

%35

plant-species (*Nuxia congesta*):-

group(d),

surfaceofblade(glabrous),

leavesmargine(entire),

formsofblade(elliptic-obovate).

%36

plant-species (*Ozoroa pulcherrima*):-

group(d),  
surfaceofblade(nonglabrous),  
venation(brochidrome),  
formsofblade(elliptic-obovate).

%37

plant-species (Ororoa insignis):-

group(d),  
surfaceofblade(nonglabrous),  
venation(brochidrome),  
formsofblade(elliptic-lanceolate).

%38

plant-species (Combretum gallabatense):-

group(d),  
surfaceofblade(nonglabrous),  
venation(camtodrome).

%39

plant-species (Cussonia ostinii):-

group(e),  
leavesmargine(serrate).

%40

plant-species (Croton macrostachys):-

group(e),  
leavesmargine(crenulate).

%41

plant-species (Ficus ovate):-

group(e),  
leavesmargine(entire),  
whitelatexinbark(presence),  
formsofblade(lanceolate).

%42

plant-species (Manilkara butugi):-

group(e),

leavesmargine(entire),

whitelatexinbark(presence),

formsofblade(obovate).

%43

plant-species (*Pittosporum abyssinicum*):-

group(e),

leavesmargine(entire),

whitelatexinbark(presence),

formsofblade(oblongate).

%44

plant-species (*Faurea saligna*):-

group(e),

leavesmargine(entire),

whitelatexinbark(absence),

petiolelength(lessthan1cm),

slashofbark(fibrous),

secondarynerves(16-20 pairs).

%45

plant-species (*Protea guagedi*):-

group(e),

leavesmargine(entire),

whitelatexinbark(absence),

petiolelength(lessthan1cm),

slashofbark(fibrous),

secondarynerves(8-16 pairs).

%46

plant-species (*Podocarpus falcata*):-

group(e),

leavesmargine(entire),

whitelatexinbark(absence),

petiolelength(lessthan 1 cm),  
slashofbark(nonfibrous),  
petiole(sessile).

%47

plant-species (Rapanea Simensis):-

group(e),  
leavesmargine(entire),  
whitelatexinbark(absence),  
petiolelength(lessthan 1 cm),  
slashofbark(nonfibrous),  
petiole(nonsessile).

%48

plant-species (Terminalia schimperiana):-

group(e),  
leavesmargine(entire),  
whitelatexinbark(absence),  
petiolelength(morethan 1 cm),  
formsofblade(elliptic-ovate).

%49

plant-species (Terminalia macroptera):-

group(e),  
leavesmargine(entire),  
whitelatexinbark(absence),  
petiolelength(morethan 1 cm),  
formsofblade(oblanceolate).

%50

plant-species (Terminalia brownii):-

group(e),  
leavesmargine(entire),  
whitelatexinbark(absence),  
petiolelength(morethan 1 cm),

formsofblade(elliptic-obovate).

%51

plant-species (*Balanites aegyptiaca*):-

group(f),

twigsofleaves(armed).

%52

plant-species (*Filicium decipiens*):-

group(f),

twigsofleaves(unarmed),

rachisofleaves(winged).

%53

plant-species (*Pseudocedrela kotschy*):-

group(f),

twigsofleaves(unarmed),

rachisofleaves(nonwinged),

Leafletsarrangement(alternate).

%54

plant-species (*Blighia unijugata*):-

group(f),

twigsofleaves(unarmed),

rachisofleaves(nonwinged),

Leafletsarrangement(opposite),

Formsofblade(elliptic-obovate).

%55

plant-species (*Zanha golungensis*):-

group(f),

twigsofleaves(unarmed),

rachisofleaves(nonwinged),

Leafletsarrangement(opposite),

Formsofblade(ovate-oblong).

%56

plant-species (*Cassia Singueana*):-

group(f),

twigsofleaves(unarmed),

rachisofleaves(nonwinged),

Leafletsarrangement(opposite),

Formsofblade(elliptic-oblong).

%57

plant-species (*Cassia arereh*):-

group(f),

twigsofleaves(unarmed),

rachisofleaves(nonwinged),

Leafletsarrangement(opposite),

Formsofblade(elliptic-ovate).

%58

plant-species (*Tamarindus indica*):-

group(f),

twigsofleaves(unarmed),

rachisofleaves(nonwinged),

Leafletsarrangement(opposite),

Formsofblade(asymmetrical-oblong).

%59

plant-species (*Schrebera alata*):-

group(g),

Leafletsarrangement(opposite),

rachisofleaves(winged).

%60

plant-species (*Stereospermum Kanthianum*):-

group(g),

Leafletsarrangement(opposite),

rachisofleaves(nonwinged).

%61

plant-species (*Fagaropsis angolensis*):-  
group(g),  
Leafletsarrangement(opposite-decussate).

%62

plant-species (*Moringa oleifera*):-  
group(g),  
Leafletsarrangement(alternate or clustered),  
Compoundtype(triimparipinnate).

%63

plant-species (*Ekebergia capensis*):-  
group(g),  
Leafletsarrangement(alternate or clustered),  
Compoundtype(triimparipinnate),  
Leafletmargine(entire),  
Redexudate(presence),  
Blazeofbarkthickness(2-3cm).

%64

plant-species (*Pterocarpus lucens*):-  
group(g),  
Leafletsarrangement(alternate or clustered),  
Compoundtype(triimparipinnate),  
Leafletmargine(entire),  
Redexudate(presence),  
Blazeofbarkthickness(lessthan1.5cm),  
Formsofblade(elliptic-ovate).

%65

plant-species (*Lonchocarpus laxiflorus*):-  
group(g),  
Leafletsarrangement(alternate or clustered),  
Compoundtype(triimparipinnate),  
Leafletmargine(entire),

Redexudate(presence),  
Blazeofbarkthickness(lessthan1.5cm),  
formsofblade(elliptic-obovate).

%66

plant-species (Kirkia burgeri):-  
group(g),  
Leafletsarrangement(alternate or clustered),  
Compoundtype(triimparipinnate),  
Leafletmargine(entire),  
Redexudate(absence),  
Surfaceofblade(glabrous),  
colorofslashofbark(yellowish).

%67

plant-species (Dalbergia boehmii):-  
group(g),  
Leafletsarrangement(alternate or clustered),  
Compoundtype(triimparipinnate),  
Leafletmargine(entire),  
Redexudate(absence),  
Surfaceofblade(glabrous),  
colorofslashofbark(reddish).

%68

plant-species (Lannea microcarpa):-  
group(g),  
Leafletsarrangement(alternate or clustered),  
Compoundtype(triimparipinnate),  
Leafletmargine(entire),  
Redexudate(absence),  
Surfaceofblade(glabrous),  
Blazeofbarkthickness(2-3cm).

%69

plant-species (*Trichilia dregeana*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leafletmargine(entire),

Redexudate(absence),

Surfaceofblade(glabrous),

Blazeofbarkthickness(lessthan1.5 cm),

Whitelatexonbark(presence).

%70

plant-species (*Kigelia aethiopum*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leafletmargine(entire),

Redexudate(absence),

Surfaceofblade(glabrous),

Blazeofbarkthickness(lessthan1.5 cm),

Whitelatexonbark(presence),

Petiole(sessile).

%71

plant-species (*Lepidotrichilia volkensis*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leafletmargine(entire),

Redexudate(absence),

Surfaceofblade(glabrous),

Blazeofbarkthickness(lessthan1.5 cm),

Whitelatexonbark(presence),

Petiole(nonsessile).

%72

plant-species (*Lanea schimperii*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimpairipinnate),

Leafletmargine(entire),

Redexudate(absence),

Surfaceofblade(nonglabrous),

Leafletpairs(2-5 pairs),

Formsofleaflets(ovate).

%73

plant-species (*Trichilia emetica*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimpairipinnate),

Leafletmargine(entire),

Redexudate(absence),

Surfaceofblade(nonglabrous),

Leafletpairs(2-5 pairs),

Formsofleaflets(oblong).

%74

plant-species (*Polyscias fulva*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimpairipinnate),

Leafletmargine(entire),

Redexudate(absence),

Surfaceofblade(nonglabrous),

Leafletpairs(5-11 pairs),

petioletomainrachis(30-50cmlong).

%75

plant-species (*Millettia ferruginea*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leafletmargine(entire),

Redexudate(absence),

Surfaceofblade(nonglabrous),

Leafletpairs(5-11 pairs),

petioletomainrachis(20-30cmlong).

%76

plant-species (*Boswellia papyrifera*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leavesmargine(toothed),

Whitefragrantrasinonbark(presence).

%77

plant-species (*Hagenia abyssinica*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leavesmargine(toothed),

Whitefragrantrasinonbark(absence),

Foliaceousreddishstipules(presence).

%78

plant-species (*Markhamia tomentosa*):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leavesmargine(toothed),

Whitefragrantrasinonbark(absence),

Foliaceousreddishstipules(absence),  
Surfaceofblade(nonglabrous).

%79

plant-species (Bersama abyssinica):-

group(g),

Leafletsarrangement(alternate or clustered),

Compoundtype(triimparipinnate),

Leavesmargine(toothed),

Whitefragrantrasinonbark(absence),

Foliaceousreddishstipules(absence),

Surfaceofblade(glabrous).

%80

plant-species(Acacia sieberiana):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(15-30cmlong),

prickleype(straight).

%81

plant-species(Acacia polyacantha):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(15-30cmlong),

prickleype(recurved),

tipsofpricklescolor(black).

%82

plant-species(Acacia hecatophylla):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(lessthan15cmlong),

prickleype(recurved),

tipsofpricklescolor(dark brown).

%83

plant-species(*Acacia tortilis*):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(lessthan15cmlong),

prickleinpair(yes),

prickleintype(two).

%84

plant-species(*Acacia laeta*):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(lessthan15cmlong),

prickleinpair(yes),

prickleintype(single),

prickletype(recurved),

tipsofpricklescolor(brown).

%85

plant-species(*Acacia horrida*):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(lessthan15cmlong),

prickleinpair(yes),

prickleintype(single),

prickletype(recurved),

tipsofpricklescolor(reddish).

%86

plant-species(*Acacia seyal*):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(lessthan15cmlong),

prickleinpair(yes),

prickleintype(single),  
prickletype(straight),  
prickleatthebase(swollen).

%87

plant-species(*Acacia albida*):-  
group(h),  
Twigsofleaves(armed),  
petioletomainrachis(lessthan15cmlong),  
prickleinpair(yes),  
prickleintype(single),  
prickletype(straight),  
prickleatthebase(nonswollen),  
pricklelength(2cm).

%88

plant-species(*Dichrostachys cinerea*):-  
group(h),  
Twigsofleaves(armed),  
petioletomainrachis(lessthan15cmlong),  
prickleinpair(yes),  
prickleintype(single),  
prickletype(straight),  
prickleatthebase(nonswollen),  
pricklelength(0.5cm).

%89

plant-species(*Acacia abyssinica*):-  
group(h),  
Twigsofleaves(armed),  
petioletomainrachis(lessthan15cmlong),  
prickleinpair(yes),  
prickleintype(single),  
prickletype(straight),

prickleatthebase(nonswollen),

pricklelength(4cm).

%90

plant-species(*Acacia senegal*):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(lessthan15cmlong),

prickleinpair(no),

prickleintype(three).

%91

plant-species(*Acacia macrostachya*):-

group(h),

Twigsofleaves(armed),

petioletomainrachis(lessthan15cmlong),

prickleinpair(no),

prickleintype(single).

%92

plant-species(*Albizzia grandibracteata*):-

group(h),

Twigsofleaves(unarmed),

conspicuousfoliaceousbracts(presence).

%93

plant-species(*Albizzia schimperiana*):-

group(h),

Twigsofleaves(unarmed),

conspicuousfoliaceousbracts(absence).

%94

plant-species(*schefflera-volkensii*):-

group(i),

leafletpairi(three-six),

leafletsarrangement(alternateorclustered),

petiolelength(four-tencm),  
formsofblade(elliptic-obovate).

%95

plant-species(ritchiea-albersii):-  
group(i),  
leafletpairi(three-six),  
leafletsarrangement(alternateorclustered),  
petiolelength(four-tencm),  
formsofblade(obovate).

%96

plant-species(cussonia-holstii):-  
group(i),  
leafletpairi(three-six),  
leafletsarrangement(alternateorclustered),  
petiolelength(ten-thirtycm),  
formsofblade(ovate).

%97

plant-species(schefflera-abyssinica):-  
group(i),  
leafletpairi(three-six),  
leafletsarrangement(alternateorclustered),  
petiolelength(ten-thirtycm),  
formsofblade(elliptic-ovate).

%98

plant-species(vitex-doniana):-  
group(i),  
leafletpairi(three-six),  
leafletsarrangement(opposite-decussate).

%99

plant-species(commiphora-confusa):-  
group(i),

leafletpairi(onlythree),  
leafletsarrangement(alternateorclustered),  
fragrantresinousodouronbark(presence),  
formsofblade(obovate).

%100

plant-species(commiphora-erythrae):-

group(i),

leafletpairi(onlythree),  
leafletsarrangement(alternateorclustered),  
fragrantresinousodouronbark(presence),  
formsofblade(ovate).

%101

plant-species(erythrina-abyssinica):-

group(i),

leafletpairi(onlythree),  
leafletsarrangement(alternateorclustered),  
fragrantresinousodouronbark(absence),  
twigsoftheleaves(armed).

%102

plant-species(teclea-nobilis):-

group(i),

leafletpairi(onlythree),  
leafletsarrangement(alternateorclustered),  
fragrantresinousodouronbark(absence),  
twigsoftheleaves(unarmed),  
leafletmargine(entire),  
secondarynerve(twentyfive-thirtypairs).

%103

plant-species(crataeva-adansonii):-

group(i),

leafletpairi(onlythree),

leafletsarrangement(alternateorclustered),  
fragrantresinousodouronbark(absence),  
twigsoftheleaves(unarmed),  
leafletmargin(entire),  
secondarynerve(six-ninepairs).

%104

plant-species(allophylus-abyssinica):-

group(i),

leafletpairi(onlythree),

leafletsarrangement(alternateorclustered),

fragrantresinousodouronbark(absence),

twigsoftheleaves(unarmed),

leafletmargin(serrate).

%105

plant-species(vepris-dainellii):-

group(i),

leafletpairi(onlythree),

leafletsarrangement(opposite).

### **Appendix III: Check List for the Elicitation of Knowledge from the Experts**

1. How do you identify the plant species and woody plant species in particular?
2. What are the key characteristics of the woody plant species used in an identification of woody plant species?
3. Are all the characteristics features of the woody species equally important for all the woody plant species identification?
4. How each of the characteristics features of woody plant species used for the identification used for different woody plant species?

## Appendix IV: Questionnaire for the Testing and Evaluation of KBS with the Researchers and Technicians

Name.....

Organization.....

Job title.....

Please try to identify 5 woody plant species using the developed system for identification of tree species and tick on identified if system successfully identifies and tick on unidentified if it is not successful:

Trials	Identified	unidentified
1		
2		
3		
4		
5		

1. Is the system applicable/acceptable in woody plant species identification?
  - a. Unacceptable
  - b. less acceptable
  - c. Fairly acceptable
  - d. highly acceptable
2. Is the questions (characteristic features of the species) asked by the system complete to identify all the woody plant species found in Ethiopia?
  - a. Not complete
  - b. Less complete
  - c. fairly complete
  - d. very complete
3. Do the inference/ identification process of the system similar to the way taxonomist identifies the woody plant species?

- a. Not similar    b. Less similar    c. Fairly Similar    d. very similar
4. Can you easily interact/ communicate with the system during woody plant identification?
- a. Very difficult    b. Difficult    c. simple    d. very simple
5. How useful do you find this system as a tool for the identification of woody plant species in your study area?
- a. Not useful    b. less useful    c. Fairly useful    d. very useful
6. How useful do you find this system as a training tool to supplement the identification of woody plant species?
- a. Not useful    b. less useful    c. fairly useful    d. Very useful
7. Is such kind of system applicable to other disciplines of forestry?
- a. Inapplicable    b. less applicable    c. Fairly applicable    d. highly applicable

Please state the disciplines that the system could potentially be applied?.....

8. What do you suggest to make system complete?.....
- .....

## DECLARATION

I declare that this thesis entitled '**APPLICATION OF KNOWLEDGE BASED SYSTEM FOR WOODY PLANT SPECIES IDENTIFICATION**' is my original work, has not been presented for a master degree in any other university and that all sources of material used for the thesis have been duly acknowledged.



Dejen Alemu

April, 2009

The thesis has been submitted for examination with my approval as university advisor.



Dr. Million Meshesha

April, 2009