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CEREAL CROP LAND IDENTIFICATION USING KNOWLEDGE BASED SYSTEM

By

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DECLARATION

I declare that this thesis is my original work and it has not been presented for a Degree in any other universities. All the material sources used in this work are duly acknowledged.

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This thesis has been submitted to the department for examination with our Approval as university advisors:

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DEDICATION

This work is dedicated to my mother Emebet Bekele.

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This work has been in its present shape with considerable professional, financial and material inputs from various sources. it is an excitement to me to come to this final point and to express deepest gratitude to all individuals and organizations who contributed directly or indirectly to this study. First of all, I would like to acknowledge my principal advisor Mr.Amanuel Ayde (Assist. Prof and PhD candidate) and co-advisor Mr. Berhanu Megerssa for their professional support for the completion of this study. It is also my pleasure to thank Jimma agricultural and research center (Department of water and natural resource conservation and Department of soil inspection) for their willingness during data collection.

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List of Abbreviations and Acronyms

AI	Artificial Intelligence
ANN	Artificial Neural Network
ATVET	Agricultural Technical Vocational Education and Training
ATA	Agricultural Transformation Agency
BFS	Breadth First Search
CBR	Case Based Reasoning
CEC	Cation Exchange Capacity
DAS	Demonstration and Training Extension System
DFS	Depth First Search
ES	Expert System
EIAR	Ethiopian Institute of Agricultural Research
GDP	Gross Domestic Product
GIS	Geographical Information System
IDS	Iterative Deepening Search
ISSS	International society of soil science
JARC	Jimma Agricultural and Research Center
KBES	Knowledge Based Expert Shell
KBS	Knowledge Based System
MIS	Management Information System
PAS	peasant Associations
PH	Potential Hydrogen
RBR	Rule Based Reasoning
TPS	Transaction Processing System

Abstract

Advanced information technologies in modern decision support system enables to improve the decision-making process in agricultural management for land identification. Agriculture is the key pillar of the economy and ensures food security. Managing soil fertility for improved production is significantly important. In this regard knowledge based approach to land evaluation for selecting suitable agricultural cereal crops for a land unit is necessary. This thesis presents the design and development of a prototype knowledge based cereal crop land identification (KBCCLI) for evaluating land resources and choosing suitable agricultural crops for a farm unit. The study was conducted using empirical research design. The developed prototype system is powered primarily by human and laboratory experimented data collected from Jimma agricultural and research center (JARC). Domain knowledge was acquired using interview and questionnaire. Purposive and stratified sampling technique was employed to get right expert respondents. The total sample taken was 17 experts and 87 farmers. Decision tree was used as a knowledge modeling tool and forward chaining method to infer the rule and provide appropriate direction. The knowledge base consists of representative rules to reflect the inherent physical and chemical property of soil that affect the choice of land use. Soil texture is the relative proportions of sand, silt and clay in a soil and is a feature used to classify land for cereal crop cultivation. The system is developed using SWI Prolog programming language. The knowledge-based approach to land evaluation is built on the land evaluation framework designed by the united nation food and agricultural organization (FAO). The KBCCLI model of land evaluation suggests a strategic land use plan considering soil physiochemical property which eliminates non-feasible land use or crop choice. According to the system evaluator the prototype system achieved 87.76% of overall performance in identifying suitable land for cereal crop cultivation. It is believed that the prototype system achieved good performance and has potential to use as a decision tool for land identification for cereal crop.

CHAPTER ONE

INTRODUCTION

Agriculture is the basis for the economy of Ethiopia. It accounts for the employment of 90% of its population, over 50% of the country's gross domestic product (GDP) and over 90% of foreign exchange earnings. In Ethiopia it can generally be characterized by limited technological inputs. Farming is largely small-scale and is still being carried out using undeveloped technologies (Ayalew & Selassie, 2017).

The yield of agricultural product is dependent on how well the land has been evaluated and understood by the farmers and stakeholder. Land evaluation is the procedure of assessing the capability of land for specific land use purpose (FAO, 2003). The process of land evaluation is a vital part of land management and helps in preparing a successful land use plan. The purpose of land use planning is to utilize available resources in a land unit to maximize economic returns without degrading environmental values.

Multidisciplinary knowledge is required for comprehensive evaluation of farm unit resources and to identify its true potentials of a farm unit and limitation. In case of agricultural land use, the result of land evaluation can help in choosing the most suitable land use and a profitable plant for a farm unit. Land evaluators and plantation experts help farmers to choose the most profitable plant that is best suited for a farm unit by assessing the farm units' performance by observing its land characteristics (Ponnusamy, 2007). To date, the FAO guidelines on the land evaluation system are widely accepted for the evaluation. The value of land quality is the function of the assessment and grouping of land types into orders and classes in the framework of their fitness (FAO, 2010).

In spite of proper land use, sound soil management and decision for cultivation relies on a good knowledge of soil properties and functions. Soils are one of the most important components which help to grow plants. It provides nutrients for plants for successful growth and better agricultural productivities. As basic resources for food production they should be well understood and in a way to maximize crop product. Soil physical and chemical properties play a key role in soil sustainability and crop production(Chekol, 2014). They determine how easily plant roots can grow to access soil nutrients and how easily water can flow through the soil to deliver nutrients to plants.

The soil that is best for plant growth is directly related to the type of plants being grown. This means that each plot of land will have its own blend of minerals, organic matter and inorganic matter which largely determines the crops or plants that can grow successfully. Therefore, knowing soil type (texture) and its composition is beneficial because it provides a tool for choosing the right plants for land and the best opportunity for knowing how to maintain the plants for better yield (Patzek and Pimentel, 2005).

Soil organic matter varies considerably depending on soil physical property (texture) (sandy, silt, and clay).The relative proportion of sand, silt, and clay in the soil is known as soil texture (Production et al., 2014). Soil texture is the relative proportions of sand, silt and clay in a soil. Seed of a wide range of plant species has its own particular characteristics, making it more or less suitable for a particular soil texture. Texture is one of the most important properties of a soil and it greatly affects plant production. The texture of a soil in the field is not readily subject to change, so it is considered a permanent soil attribute (Production, 2014).

On top of this, Information is scarce on the effects of soil physical and chemical properties (texture) on crop yield for farmers and stakeholders. Historically, farmers relied on their own experience with regard to adopting "good farming practices". But, Agricultural extension worker will continue to be the main strategy to reach out valid information for farmers to improve agriculture and their livelihoods.

Technical advice and information from agricultural extension worker and coordinator towards farmers is increasingly significant. According to Ethiopian development research (2012) the Ethiopian agricultural extension system consists of four major components: the Participatory Demonstration and Training Extension System, Farmer Training Centers, Agricultural Technical Vocational Education and Training (ATVET) and Institutional Coordination. Among the four division of extension worker for farmer, the Participatory Demonstration and Training Extension System (DAS) are responsible to provide information related to soils which deal with soil properties, soil fertility and agriculture, soil and water conservation, and soil-water-plant relationship. Thus, a system approach is important for land type identification with respect to associated soil attribute for cereal crop cultivation to meet increased productivity and ensuring food security.

The principal cereal crops grown in Ethiopia are teff, wheat, maize, barley and sorghum which are primarily cool and warm weather grain crops. The increasing demand for crop in Ethiopia and throughout the world continues in alarming rate **(**Annette, 2015). Today agricultural knowledge has a wide meaning to different players and sectors; farmers refer to it as experience; indigenous and tacit facts, extension and research organizations recognise it as proven good practices that maximises the crop yield, conserves environment etc (Francom & Counselor, 2015).

Currently the most common form of knowledge exchange in agriculture is knowledge bases and knowledge management tools for document creation and sharing, support/expert systems and information systems (Rafea, 2009). The term knowledge based system(expert system) specifically in agriculture might refer to a document repository system or centre for reports, scientific papers white papers, a forum or a social networking system for knowledge dissemination and publication through e-media, world wide web, books and so on. For instance E-agriculture, e-agriculture.org, is a global community for exchange of information about agricultural activity. My Agriculture Information Bank, agriinfo. In, is also a web-based KBS that provide tool to the user search query and generate advice as required created by experts in agriculture(Joy, 2014). However, in Ethiopia Information for farmer and agricultural stakeholder about soil fertility management and perceptions on production constraints of cereal crop is limited. Therefore, in this study an attempt is made to develop cereal crop land identification using knowledge based system.

1.1 Background

The results of exploiting land-use without consideration of the consequences on soil quality have been environmental degradation (Ponnusamy, 2007). Agricultural use and management systems have been generally adopted without recognizing consequences on soil conservation and therefore significant decline in agricultural soil quality has occurred worldwide (brady, 2010). The concept of soil quality is useful to assess the condition and sustainability of soil and to guide soil research, planning and conservation policy. The importance of soil quality lies in achieving sustainable land use and management systems to balance productivity and environmental protection. Unlike water and air quality, simple standards for individual soil-quality indicators do not appear to be sufficient. For assessing soil quality a complex integration of static and dynamic chemical, physical, and biological factors need to be defined in order to identify different management and environmental scenarios (Imeson, 2006).

The soil system does not necessarily change as a result of changing external conditions or use because soil has the capacity of resistance (or resilience) to the effects of potentially damaging conditions. In part, this capacity of the soil in buffering the consequences of inputs and changes in external conditions arises because the soil is an exceedingly complex and varied material with many diverse properties and interactions between soil properties. It is this complex dynamic nature which often makes it difficult to distinguish between changes as a result of natural development and changes due to non-natural external influences. Soil-quality assessment based on inherent soil factors and focusing on dynamic aspects of soil system is an effective method for evaluating the sustainability of land use and management activities (Nortcliff, 2002).

However, the process of evaluating soil is not new and agro-ecological land evaluation has much to offer. Land suitability is defined in land evaluation as "the fitness of a given land unit for a specified type of land use" (FAO, 2015). In a more operational sense, suitability expresses how well the biophysical potentialities and limitations of the land unit match the requirements of the land-use type. Therefore, new investigations must obviously be based on a solid understanding of past studies. Agro-ecological land evaluation predicts land behavior for each particular use and soil-quality evaluation predicts the natural ability of each soil to function.

Land evaluation is not the same as soil-quality assessment because biological parameters of the soil are not considered in land evaluation. Soil surveys are the building blocks of the dataset needed to drive land evaluation. Soil surveys and soil classification systems are used to define with precision to a specific soil types. Emerging technologies in data and knowledge engineering are providing excellent possibilities for the development and application processes of Soil Quality and method for its assessment (De la Rosa, 2005).

1.2. Statement of the Problem

Currently Ethiopian receives more food aid than almost any other country in the world. Since 1985, well over half a million tons of food has been delivered to Ethiopia every year (Levinsohn and McMillan, 2007). As the basis for most Ethiopian food consumption, low cereal crop product and lack of significant attention for product development technique could be improved significantly. The highest market value of the cereals grown in Ethiopia and income to the Ethiopian small farm households' crop cultivation requires special attention on how to moderate the production process and increase the yield (Demeke, 2013).

According to Bimerew and Beyene (2014), "food security is a multidisciplinary concept which includes economic, political, demographic, social, cultural, and technical aspects". Ethiopia faces food and nutrition security issues for long period of time. Food production in Ethiopia is vastly less than the country's known potential. Farmers and extension coordinator still use very old farming techniques. Most of the country's cropped area is not planted with improved seeds and proper soil type identified suitable for the plant growth through scientific method.

Agricultural activity at many levels focuses on product. Cereal crop production in Ethiopia plays a vital role in generating surplus capital to speed up the overall socio-economic conditions of the country. The major cereal crops cultivated in Ethiopia are teff, maize, sorghum, wheat and Barley (Haileselassie, 2018). Increasing agricultural productivity is absolutely necessary to feed the ever growing demography by enhancing land productivity. The national average yield of cereal crop is currently below 1 ton per hectare and the present production system cannot satisfy the consumer's demand as the current farming system adopts traditional and subsistence level which is not supported by modern technologies (Haileselassie, 2018).

The principal factors for declining yields of cereal crop are attributed mainly by absence of knowledge to farmers and their stakeholders on improved production methods such as matching types of land used in terms of suitable soil type with types of plant cultivated for better yield (CTA, 2001). On top of this, there is increasing realization that Ethiopia need new source of growth to drive their economy and those contemporary challenges in improved agricultural production systems. Within this context, Strategic shift in favour of knowledge-based transformation of agricultural cereal crop production system is equally vital in dynamic demographic and ecological conditions. There are many works in the literature that explains about knowledge based systems in the agriculture domain specifically on crop production and improvement advisory system for both farmers and their stakeholders locally and internationally.

To conclude, several studies have been developed in Artificial Intelligence (AI) using knowledge based systems to reason out the solution of a particular problem. But, according to the researcher's knowledge, there is no indication for research conducted on cereal crop land identification using knowledge based system by taking soil texture class as a feature for land evaluation. Thus, in this study an attempt is made to develop cereal crop land identification using knowledge based system. To identify land suitable for cereal production, soil texture physical and chemical property was used as a test parameter**.** Further on, the aim of this study is to better inform agriculture stakeholders a number of attributes that leading to reduced cereal crop production through the developed knowledge based system, as consequence to better empower them to take action when required.

1.3 Research Question

1. What are factors leading to reduced yield for cereal crop production?
2. To what extent the existing technology provide advice for agricultural sector in identifying land for cereal crop production?
3. What are the most preferred soil types used to maximize cereal crop production?
4. What are the performances of the prototype knowledge based system?

1.4 Objective of the Study

1.4.1 General Objective

General objective of this study is to develop knowledge based agricultural land use decision support system for suitable cereal crop land identification.

1.4.2. Specific objective

- To acquire knowledge from human (domain) experts, farmers and documents.
- To model and represent the acquired knowledge into prototype system to assist stakeholders in choosing suitable agricultural land for crop cultivation.
- To identify the most preferred soil type used to maximize cereal crop production?
- To test the performance of the developed prototype knowledge based system with experts in the field.

1.5 Scope of the Study

At large the scope of the study is to build knowledge based systems that better help agricultural stakeholders to improve the decision making process for cereal crop cultivation by providing information through knowledge based system. It is to be clarified that by using the developed system, it is not possible to solve all the problems faced by the farming community. However, it is believed that by providing expert advice about suitable cereal crop land to agriculture extension worker, it can resolve situations that reduce the cereal crop production process and improve productivity.

1.6 Significance of the Study

Technological change has been the major driving force for increasing agricultural productivity and promoting development throughout the world. The trend towards better education and training of agricultural stakeholders, the shift in the focus of advice, quicker and cheaper means of disseminating and sharing information are contributing towards facilitating the adoption of sustainable farm technologies. The result of this study enables agricultural stakeholder to identify and select types of land suitable for crop production by accessing information with the help of the developed KBS.

The information provided in the developed KBS expected mainly to assist the knowledge gap observed in agriculture for identification of suitable land for farmers and their stakeholders. It can also assist the work of Demonstration and Training Extension System professionals to match the land (in terms of soil texture) with proper crop type for improved productivity. Moreover, it will support the government strategy and plan for development through improved agricultural practise and sustainable food security.

1.7 organization of the thesis

The thesis has been organized into seven chapters. Following the introductory and background part, chapter two discuss about related works followed with evolution of Computers in decision support system, Computers in land use planning, Concepts on Knowledge-based Systems, Methods in KBS Development, Methods in KBS Reasoning, Technique in rule based reasoning, Knowledge Based System Implementation Tools, Application of search in AI problem solving, State of Agricultural Practise in Ethiopia, Need of Knowledge Based systems in Agriculture, Application of KBS in Agriculture, Issue of Soil in Ethiopian Agriculture, Soil Formation Factor, Classification of soils, Soil quality perception, Soil-quality Indicators, Method of Determining Soil Texture, Plant soil nutrient requirement, Major Ethiopian cereal crop production constraints and Existing gap in land evaluation and decision support.

Chapter three, outlined with the rationale methodology, Knowledge Acquisition, Knowledge Modeling, Knowledge Representation, Implementation Tool, Method of System Evaluation, Study site description, Sample size and sample size determination, Data gathering tool. Chapter four, this chapter leads to on how, what and from where knowledge is acquired, the model used and the technique followed to represent the acquired knowledge. Chapter five lets, the prototype system development, the architecture used for prototype system development, the snapshooted user interface during identification of lands. Chapter six, performance evaluation of the developed prototype knowledge based system including system performance testing and user acceptance testing. The last chapter, chapter seven shows conclusion, recommendation and future research direction.

CHAPTER TWO

LITERATURE AND RELATED WORKS

Expert systems (ES) were developed in the middle of 1960s.The basic idea behind the expert system is simply the transformation from a human expert to computer program. An expert system is a computer program that attempts to emulate the reasoning processes of a human expert can make decisions and perform required tasks based on user input. The expert`s knowledge is available even in the absence of human expert, so the knowledge will be available at all times at anywhere as necessary. ES provides a powerful and flexible approach for getting solutions for a variety of problems that can’t often dealt with traditional system of regarding application.

The expert system is designed to behave like a human expert to solve the problems and make decisions with the help of a collection of domain knowledge and a set of rules as a software program. Many methods can be used to design the skill of the expert; it includes the creation of knowledge base which uses some knowledge representation format to capture the domain knowledge, and codified it according to the special format, which is called knowledge engineering. And make the reasoning process with the aid of inference engine. Expert systems have been used in agriculture since 1980s; several systems have been designed for diagnosis, management and production aspects (Joy,2014).

Agricultural production has changed as a complex business requiring the accumulation and integration of knowledge and information from many diverse sources. To improve the quality of production management expert system can be an effective tool. The application of expert system on agricultural domain has spread into the crop production management, pest management, diagnostic systems, overall planning systems as well as economical decision making. According to (Joy,2014) the most successful application of Artificial Intelligence (AI) is decision making and problem solving so the expert system can act as a decision makers and problem solvers.

2.0 Related research work

There are many works in the literature that explains about knowledge based systems in the agriculture domain. Local research work shows that Desalegn (2015) has developed a knowledge based system for wheat crop disease diagnosis and treatment. The study was focused on the development of KBS for wheat disease and pest control where it is intended for the diagnosis of common diseases and pests occurring in the wheat crop. A knowledge based system for cereal crop disease diagnosis and treatment is explored by Ejigu [10]. The focus of the study was to address problems of common diseases occurring in cereal crop.

Moreover internationally, Sudeep (2012) has developed an online expert system known as AGRIDAKSH for maize diseases diagnosis, variety selection and insect identification. The system is developed to detect and identify crop diseases related to maize variety. Ontology was used as a tool to acquire the required data. Expert system on wheat crop management- EXOWHEM (2012) was developed by Division of Computer Applications specialist to provide the users with all kinds of suggestions and advices regarding the wheat crop production selection as well as the economic benefits. Bandung Regency Agriculture Department (2014) developed Application of Pineapple Diseases Expert System with forward chaining and fuzzy logic (FC-FL**)** Method.

Krishna P. & Reddy, (2004) was developed a framework of a cost-effective agricultural information dissemination system (AgrIDS) to disseminate expert agriculture knowledge to the Indian farming community to improve the crop productivity by using weather condition and rain fall patterns to predict the type of crop to be raised. In this study, the system predicts condition information for six crop type including rice, wheat, pulses, food grain, potato and sugarcane by integrating the required information through internet infrastructure to be accessed by farmer and stakeholders. Sanjay (2013), design the system using service Oriented Architecture (SOA) to process spatial data and knowledge base. Spatial data is stored into Postgres SQL database and is retrieved through Restful web services for specific query. The knowledge base is of maintained in the form of ontologies. A farmer can provide and the system receives input in the form of geographical data regarding climate parameters such as temperature, humidity, rainfall, administrative boundary data etc and such spatial data is passed to the GIS based spatial analysis module for further processing to generate results. The output generated is given to a JSON parser at the user end which parses the data and displays the output on android based mobile devices.

Felino (2007) also developed a knowledge based crop forecasting system (KCFS) to generate accurate and timely crop forecasts by using objective systems analysis-based procedures and methodologies that rely on information systems tools like crop simulation models, geographic information system communication technologies (GIS), geographic positioning system (GPS) and remote sensing. A knowledge based crop forecasting system (KCFS) was used to predict crop production given advanced seasonal climate information. The KCFS involves four activities, namely: (1) analysis and downscaling of seasonal climate outlook (2) crop yield given the climate information (3) determination of cropped area and (4) estimation of dissemination of information on crop forecasts.

To conclude, several studies have been developed in AI using knowledge based systems to reason out the solution of a particular problem. But, according to the researcher's knowledge, there are no research conducted cereal crop land identification using knowledge based system to identify suitable land for maximum crop production. Thus, in this study an attempt is made to develop a rule based knowledge system for cereal crop land identification and evaluate its performance with the help of professional experts in the field.

2.1 Evolution of Computers in decision support system

The use of computer in decision making dates back to 1960s (lucas, 2009). The earliest computer system were transaction processing system (TPS) that were used to do repetitive ,labour-intensive processes that could be streamlined to reduce costs (stair,2005). Later, information systems were developed for digitizing, storing data and retrieving information. Management information system (MIS) made use of these information systems to assist management functions including report preparation, scheduling and planning. The evolution of various technologies adopted in decision support systems is presented below.

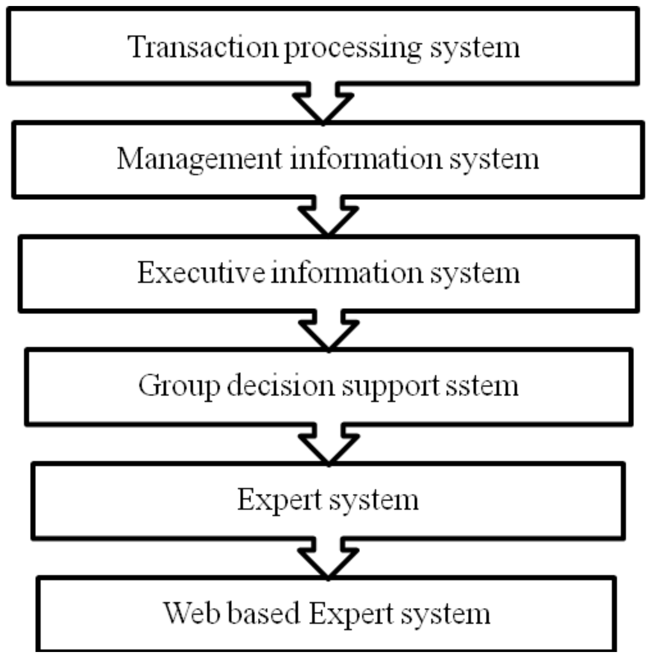

Figure 2.1 Evolution of decision support system

Mintzberg, et al. 2010 indicates that decision making involves three stages (1) defining a problem, (2) developing alternate solution and (3) choosing the best solution from those alternatives. An ideal decision support system should help users in these three steps of decision making to solve a specific problem. Decisions support systems have been applied in almost in every conceivable field, have embraced every kind of technology and have grown stronger over the years (Beynon, Rasmequan& Russ, 2002). With other complementary technologies, decision support systems have been applied in planning and management of resources. Land use planning is one such area in which they have been found a successful application.

2.2 Computers in land use planning

The process of land use planning has become simpler and more refined with the advent of computers. Many organizations developed information system to store, analyze and retrieve stored information for helping in day to day decision making. These information system helped decision makers to solve resource allocation problem better and faster. However, these systems simply stored the data and facts which supported decision maker. Decision makers were supplied with critical information and patterns that exist in the data for simplifying the decision making process. Also, each information system was a standalone computer system which made the interaction process difficult in case of a problem high could benefit from integration of information from multiple scientific disciplines (lucas, 2009).

Later, semi-automated decision support systems were introduced which used specific algorithm for solving problems. Semi-automated decision support system presented decision makers with various alternate choices and recommending the best among them. Numerous decision supports have been developed for land evaluation and land use planning and they have been reported in the literature. The more significant are the field level GIS, the spatial decision support system (SDSS), the technique for order preference by similarity to ideal solution (TOPSIS) and the multiple criteria decision making model (MCDM) DSS. These consider multiple factors to support problem solving in land use decision making (Mathew,s & craw,2012).

A notable recent development is the spatial decision support system(SDSS) (ochola & kerkides, 2004) which carries out land quality assessment based on a number of factors such as land holding, farm labour availability and access to agricultural extension services as well as selected socioeconomic factors. However, such decision support systems could not match the decision making process of a human expert and had some inherent limitations. These decision support systems required a set of predefined input datasets to begin their analysis. Without providing such inputs in a proper required, the system could not begin their analysis. After getting input from users with a step by step approach as dictated by algorithms, the decision system proceeded to analyze the input data to reach conclusions. Often the knowledge about solving the problem was represented in the DSSs algorithm based on a multiple criteria decision making model (Laaribi,chevalier& martel,2011).

The system analyzed the input information and produced a better land use plan after evaluating the land capabilities and eliminating unfeasible crops choices for a farm unit. The quality of the results of land evaluation and land use decisions depended on the efficiency of algorithms. The algorithms were embedded within the decision support systems and hence a change in algorithm needed redevelopment of the decision support systems. New algorithms and hence new decisions support systems were developed in order to improve the quality of land use decisions. The following section lists the drawback of such traditional decision support systems that depend on algorithms that are difficult to change without modifying the entire software application.

2.3 Concepts on Knowledge-based Systems

Knowledge bases over the internet are becoming increasingly popular. A Knowledge Based System‟ (KBS) aims to provide query results on the information‟ or verified knowledge‟ from structured information based on database design or semantic annotations (e.g. meta-data, ontologies) (Adelman and Riedel, S., 2012). KBS provides knowledge processing and representation tools that can be used effectively for problem solving (Nalepa G, 2010). The beginning of KBS was development of expert systems and artificial intelligence. These systems however could not provide the type of functionality that is expected from a biological system like human brain that uses complex pattern recognition and information recovery/linkage to derive knowledge and make decisions (Knowledge Based Systems, 2014).

Despite these drawbacks, rule-based systems that can perform "if-then" questions can be widely used in many areas like medicine to aid specialists that deal with complex symptoms. In farming, some of these techniques are embed into the decision support. Appearance of knowledge mining and other automated knowledge extraction tools however opens new possibilities to build knowledge systems that extend beyond rule-based decision aiding systems; perform query on stored knowledge in any form (natural language or formal database with predetermined queries) and relates knowledge concepts to the areas that the researcher is not aware. A KBS can logically consist of a database and a query mechanism. They can be built using variety of techniques from object oriented programming to hierarchical structures. It can be used in conjunction with an inference engine to provide new knowledge, knowledge gaps and knowledge-data analyses (Moore A, 2014).

Research on KBS has recently accelerated due to availability of classification and analysis techniques for information extraction and decision techniques (Akerkar R. and Sajja P., 2009). For the agriculture domain, there have been formal attempts to define standard KBS vocabularies by Food and Agriculture Organization of the United Nations (FAO). AGROVOC, aims.fao.org/agrovoc, is a multilingual standard vocabulary that covers all of the areas related to agriculture that are of interest to FAO. It currently covers 32,000 concepts in 20 languages in RDF/SKOS-XL as well as linked-data formats and can be used in variety of ontology related products like building standard databases and semantic products. The current version of AGROVOC contains standard concepts however these tables should be expanded to encompass sub-domain specific vocabularies that might be related to different sets of knowledge e.g. crops that are underutilised in a geographic area. Expansion of this database is done automatically using context driven ontology extraction techniques from available documents (Hazman M., 2009).

2.4 Expert system component

In the early 1980s, the science of artificial intelligence began to develop knowledge based expert decision support systems which could use not only scientific knowledge but, also cognitive knowledge to solve some simple medical diagnostic problem (kent & William, 2000). With acquired in depth knowledge and expertise in a narrow domain, expert system can be engineered to deliver decisions and recommendations (suggestions) as easily as human can. Like a human expert, these systems rely on extensive knowledge base to solve domain specific problem. A typical knowledge base stores information and knowledge in the form of rules and it is independent from other program modules (Jackson, 2004).

Expert system keeps the rules used in decision making (called as knowledge base) separate from the program which controls the flow (the inference engine). Expert system utilizes the derived human intelligence (knowledge) to imitate human experts in solving problem. Expert system is usually suited for land identification and land use planning problems, as this field requires comprehensive, up-to-date knowledge from various domains involving a variety of information sources. Since expert systems work on a continuously growing knowledge base, they can behave similarly to a human expert in solving multiple problems in a domain.

2.4.1 Knowledge Base

Knowledge base is the core of a knowledge based system (KBS). It records the factual and fundamental knowledge from human experience and scientific studies in more than one way. According to Adelman et al. (2012) KBS aims to provide query results on the ’information’ or ‘verified knowledge’ from structured information based on the designed database or semantic annotations. KBS provides knowledge processing and representation tools that can be used effectively for problem solving. The beginning of KBS was development of expert systems and artificial intelligence(Ponnusamy, 2007).

These systems however could not provide the type of functionality that is expected from biological system like human brain that uses complex pattern recognition and information linkage to derive knowledge and make decisions. In this study, the knowledge base contains a collection of rules and declaration on soil texture evaluation for crop suitability. The knowledge rules used will be supplied by the Jimma agricultural and research center (JARC) department of land, water and biodiversity conservation in addition with farmers in the field.

2.4.2 Inference Engine

Inference Engine is a set of program which represents as a problem solving models. It firstly decides which rule to fire, depending upon situation specific knowledge in working memory to solve problem. In this case, when the user input a set of land qualities or land characteristic in terms of soil texture, the inference engine matches these with the existing rules in the knowledge base and suggests a crop most suited to that particular land unit. It acts as an interpreter between the knowledge base and the user interface. The inference engine receives each incoming query (problem) and matches it with similar pattern in the existing knowledge base to prepare a solution (answer) for that query. In other words, the inference engine does the reasoning and then provides explanation for arriving at a particular solution.

2.4.3 Working Memory (context)

Working memory is storage medium in rule based knowledge based system. It represents set of facts known about domain. The information about particular problem is stored into working memory. In this system, working memory could contain details of particular crop type with respect to suitable soil texture category.

2.5 Methods in KBS Reasoning

2.5.1 Rule Based Reasoning (RBR)

The knowledge base is a collection of rules or other information provided by the human expert. These rules consist of a condition or premise followed by an action or conclusion (IF condition...THEN action). The rule can then be used to perform operations on data given as input in order to reach appropriate conclusion(Joy, 2014).

The rules in the knowledge base are representing what should be done and what should not be done while some conditions are fulfilled. In the same way, the knowledge acquired from domain experts stored in the knowledge base as rules (Ligeza, 2006). Generally, the rules are presented as follows.

IF

First premise, and

Second premise, and

Third premise, and

...

THEN

Conclusion will be drawn

For this study, forward chaining method was employed by providing pieces of information through prolog user interface in order to reach the goal state.

2.5.2 Case Based Reasoning (CBR)

In this approach, knowledge base contains the solutions that have been already achieved uses to get a solution to the new problem. Here the, descriptions of past experience of human experts, represented as cases, are stored in a database for later retrieval when the user encounters a new case with similar parameters.

2.6 Technique in Rule based reasoning

In an expert system one starts with an initial state and tries to reach the goal state for the particular problem. The process of shifting through alternate solutions to proceed from the initial state to goal state is called search and the realm of all possible avenues of exploration is the search space. Two of the search techniques widely used in rule based systems are forward chaining and backward chaining.

2.6.1 Forward chaining

In forward chaining, the search proceeds in the forward direction. The forward chaining is a data driven search. The forward chaining is useful when goal states are smaller in number when compared to the initial state. Antecedent part is checked first and then goes to consequent part.

2.6.2 Backward chaining

A system is said to exhibit backward chaining if it tries to support a goal state or hypothesis by checking known facts in the context. It is search in the state space going from goal state to the initial state by the application of inverse operators. When there are few goal states and many initial states, it may be better to start from the goal to work back towards the control state. Backward chaining is a Goal driven search.

2.7 Knowledge Based System Implementation Tools

A KBS tool is a set of software instructions and utilities taken to be a software package designed to assist the development of knowledge-based systems. Mary (2009), indicated that languages and tools available for building KBES into three categories These tools are general purpose programming languages, general purpose representation languages and Domain Independent Expert System Frameworks. LISP and PROLOG seem very popular among AI researchers for general purpose programming languages.

On the other hand, SRL, RLL, KEE, OPS5, ROSIE, LOOPS, and AGE is general purpose representation languages which is not restricted to implementing any particular control strategy, but facilitate the implementation of a wide range of problems such as facilities for experimentation with large chunks of knowledge, tentative modifications, planning and reasoning strategies.

Systems under Domain Independent Expert System Frameworks category include: EMYCIN KAS, HEARSAY-III, EXPERT, and KMS (currently marketed as KES). Provides framework for builder with an inference mechanism, from which a number of applications can be built by adding domain specific knowledge. Such systems provide knowledge-acquisition and explanation modules to simplify the construction of the expert systems (Mary, 2009).

2.8 Application of search in AI problem solving

In computer science, AI researchers have created many tools to solve the most difficult problems. Many problems can be solved in theory by intelligently searching through many possible solutions. A search algorithm takes a problem as input and returns a solution in the form of action sequence. Before an AI problem can be solved it must be represented as a state space. The state space is then searched to find a solution to the problem (Luger G, 2004).

A state space essentially consists of a set of nodes representing each state of the problem, arcs between nodes representing the legal moves from one state to another, an initial state and a goal state. Factors that determine which search algorithm or technique will be used include the type of the problem and the how the problem can be represented. Each state space takes the form of a tree or a graph (Engr V, 2012).

2.8.1 Depth-first Search (DFS)

Depth-first search (DFS) is an algorithm for traversing or searching tree or graph data structures. The algorithm starts at the root node (selecting some arbitrary node as the root node in the case of a graph) and explores as far as possible along each branch before backtracking. In depth-first search, we start with the root node and completely explore the descendants of a node before exploring its sibling (and siblings are explored in a left-to-right fashion). This is one of the most basic and fundamental exhaustive search algorithms in prolog program. DFS is a good idea when that all partial paths either reach dead ends or become complete paths after a reasonable number of steps. It facilitates questioning deeply down a potential solution path in the hope that solutions don’t lie too deeply down the tree.

2.8.2 Breadth-first Search (BFS)

Breadth-first search (BFS) is an algorithm for searching tree or graph data structures. It starts at the tree root (or some arbitrary node of a graph, sometimes referred to as a 'search key) and explores all of the neighbor nodes at the present depth prior to moving on to the nodes at the next depth level (Coppin B, 2004).

2.8.3 Iterative Deepening Search (IDS)

Iterative deepening search or more specifically iterative deepening depth-first search (IDS or IDDFS) is a state space/graph search strategy in which a depth-limited version of depth-first search is run repeatedly with increasing depth limits until the goal is found.

2.8.4 Decision Tree

A decision tree is predictive modeling technique used in classification, clustering, and prediction tasks. It uses a divide and conquers technique to split the problem search space into subsets" (Dunham, 2000). A decision tree is a classifier expressed as a recursive partition of the instance space.

According to Fekadu (2004), there are two main types of decision trees. These are classification trees and regression trees. Classification trees are decision trees used to predict categorical variables, because they place instances in categories or classes. And, the second one is regression trees, which is a decision tree used to predict continues variables (variable which are not nominal). Classification trees can provide the confidence to correctly classify the data. In this case, the classification tree reports the class probability, which is the confidence that a record is in a given class.

On the other hand, regression trees estimate the value of a target variable that takes on numeric value. The structure of decision tree is a tree like structure, where each internal node represents a test on an attribute, each branch characterizes an outcome of the test, and leaf nodes at the end represent classes in which the data is assigned. The top most nodes in a tree are the root node. The basic algorithm for decision tree induction is greedy algorithm that constructs decision trees in a top-down recursive divide-and conquer manner (Thair, 2009).

The algorithm is summarized as follows:-

Create a node N;

If samples are all of the same class, C then

Return N as a leaf node labelled with the

Class C; If attribute-list is empty then

Return N as a leaf node labelled with the most common class in samples;

Select test-attribute, the attribute among attribute-list with the highest

Information gain;

Label node N with test-attribute;

For each known value ai of test-attribute

Grow a branch from node N for the

Condition test-attribute= ai;

Let si be the set of samples for which test-attribute= ai;

If si

Is empty then

attach a leaf labelled with the most common class

In samples; else attach the node returned by

Generate_decision_tree(si,attribute-list_test-attribute)

2.9 State of Agriculture in Ethiopia

Agriculture is becoming more integrated in the food chain and the global market. Global demand for agricultural crops is increasing and may continue to do so for decades propel by a 2.3 billion person increase in global population. Understanding the future demand of global crop production and how to achieve greater yields with lower impacts requires quantitative assessments of future crop demand and how different production practices implemented (Laurie W, 2010).

Technological change has been the major driving force for increasing agricultural productivity and promoting agriculture development. In the past, the choice of technologies and their adoption was to increase production, productivity and farm incomes. But, now policies for agriculture, trade, research and development, education, training and advice have been strong influences on the choice of technology, the level of agricultural production and farm practices.

Ethiopian agriculture is for the most part animal and human powered and traditional technology mostly employed. The most widespread innovation for crop production is artificial fertilizer which in 1976/77 was used on 9 percent of all holdings but often at very low levels(“Farming Systems research in Ethiopia,” n.d.).

2.10 Need of Knowledge Based systems in Agriculture

The need of expert systems for technical information transfer in agriculture can be identified by recognizing the problems in using the traditional system for technical information transfer, and by proving that expert systems can help to overcome the problems addressed, and are feasible to be developed (Rafea, 2015). An increased application of information technology is used throughout the agricultural industry to manage resources, increase yields, reduce input costs, predict outcomes, improve business practices, and more.

The capability of technology to visualize agricultural environments and workflows has proved to be very beneficial to those involved in farming. The powerful analytical capabilities of technology is used to examine farm conditions and measure and monitor the effects of farm management practices including crop yield estimates, soil amendment analyses, and erosion identification and remediation. It can also be used to reduce farm input costs such as fertilizer application, seed, and labour intensification. In addition, farm managers and stakeholders uses improved technology to submit government program applications, simplifying what used to be time-consuming multistep processes production.

Agricultural research has long history and most of these researches are available online in the form of human-readable documents. One challenge regarding the agricultural knowledge is that it is scattered and is not systematically organised in a knowledge database or an ontology/semantic related system. This slows the process of knowledge acquisition by growers and managers that often need direct answers to direct questions. Currently the most common form of knowledge exchange in agriculture is knowledge bases and knowledge management tools for document creation and sharing, support/expert systems and information systems(Jahanshiri & Walker, 2015).

The term knowledge base specifically in agriculture might refer to a document repository system or centre for reports, scientific papers white papers, forum or a social networking system for knowledge dissemination and publication through print, World Wide Web, books and so on. For instance E-agriculture, e-agriculture.org, is a global community for exchange of agricultural information, My Agriculture Information Bank, agriinfo. In, is a web-based information dissemination created by experts in agriculture and AGRIS database, agris.fao.org, is a document management system that contains augmented bibliographically indexed information in the form of documents. Information is often augmented by addition of datasets and statistics and maps related to the user search query.

The need of knowledge based systems for technical information transfer in agriculture domain can be identified by recognizing the problems in using the traditional system for technical information transfer and by proving that expert systems can help to overcome the problems addressed and are feasible to be developed.

Information Transfer Problems: Examining the information stored and available in the agriculture domain revealed that this information is static and may not respond to the growers need as when required.

Information unavailability: most of the time agricultural Information may not be available in different form of media. It is only available from human experts, extension professional or experienced growers. In addition, the information transfer from specialists & scientists to extension and farmers represents a restricted access for the development of agriculture on the national level. The current era is witnessing a vast development in all fields of agriculture. Therefore there is a need to transfer the information of expert knowledge in certain domain to the general public of farmers and their stakeholder.

2.11 Application of KBS in Agriculture

Due to tremendous advances, one can observe that information technology today affecting all the spheres of human life. We can exploit these advances to design a cost effective system to provide expert advice to the farmers. The field of agriculture is a vast domain and has many specializations including, agronomy, horticulture, soil science, plant pathology, entomology, agricultural economy, plant breeding and genetics, and agricultural extension. Among these specializations, agricultural engineering, agriculture extension deals with the dissemination of advanced agricultural information to the farmers(Reddy, 2004).

The agricultural experts (AEs) are required to provide the advice, as factors that affect the crop and their effect on crop productivity are understood much better by them. An AE is a person who possesses an advanced nontrivial knowledge about the management of crops. They also possess an expertise to recommend the possible steps based on the current production situation.

As a result of intensive research on advanced seeds, technologies and agricultural practices, a large amount of agricultural knowledge has been produced at agricultural research labs and educational institutes. Also, given a crop situation, there is a large pool of qualified agricultural scientists to provide appropriate advice to the farmers. In spite of this, the majority of farming community is practicing old methods due to the fact that research and scientific advice is not reaching the needy farmers in a timely manner. Also, as most of the farmers are illiterate or with little education, there is a large gap between agricultural research and its application, resulting in continuous suffering in the farming community due to low crop yield. So, there is room to improve education and method of dissemination of advanced scientific advice to the needy farmers in a timely manner(Reddy, 2004).

There are many works in the literature that explains about knowledge based systems application in various discipline such that agriculture, medicine, Production planning, Decision making, Knowledge learning etc. specifically in agriculture domain there are many works in the production and improvement advisory system for both farmers and their stakeholders locally and internationally.

Internationally, SudeepMarwaha (2012) has developed an online expert system known as AGRIDAKSH for maize diseases diagnosis, variety selection and insect identification. It uses ontology based methodology. This expert system can be accessed from the site http://expert.iasri.res.in/ agridaskh. Expert system on wheat crop management-EXOWHEM (2012) has developed by Division of Computer Applications specialist to provide the users with all kinds of suggestions and advices regarding the wheat crop productionselection as well as the economic benefits. Ravindran,s(2013) was also developed an expert system on barley crop management to help barley growers for production and management.

Bandung Regency Agriculture Department (2014) developed Application of Pineapple Diseases Expert System with forward chaining and fuzzy logic (FC-FL**)** Method. This expert system was used to facilitate pineapple farmers to acquire knowledge and information about pineapple diseases management. Ginanjar WiroSasmito(2011) developed Simulation Diagnose Pest and Disease for Red Onion and Chilli Plant. This study was completed using forward chaining and rule based reasoning(Joy, 2014)**.**

2.12 Issue of Soil in Ethiopian Agriculture

Soil fertility is one of the major blockages to agricultural productivity in the world particularly in Africa and Ethiopia. Agricultural production must increase to meet the challenge of food security (Giday et.al, 2014). In Ethiopia low and declining soil fertility due to net nutrient extraction by crops is responsible for low agricultural productivity and food insecurity (Nakhumwa, 2012). Moreover, the widespread soil degradation and the consequent decline of its productivity due to loss of essential plant nutrients is among the underlying reasons for poor crop yield and food insecurity. Over 50% of cropped areas of Ethiopia are in an advanced stage of land degradation. Erosion on fields planted with small seed cereals such as teff was found to be high due to high tillage frequency insecurity (Gebeyaw, 2007).

The problem of soil poverty is well recognized by the Ethiopian government since several decades ago. A number of policies and strategies have been devised which directly and indirectly contribute to deal with the soil degradation challenge. Extensive land rehabilitation programs have been underway to restore degraded cultivated fields. Apart from decades of land conservation activities, a new initiative which focuses on soil health and fertility has emerged recently by the Ethiopian Agricultural Transformation Agency (ATA). National level data on soil fertility in the country has remained largely old-fashioned and fragmented with limited detail. The country had no a centralized source of soil information with adequate coverage and level of detail to guide policy formulation and agricultural decision-making. Early efforts through the Ethiopian Institute of

Agricultural Research (EIAR) and the National Soil Laboratory had been very limited (ATA, 2014).

(ATA, 2014) has developed a Soil Sector Development Strategy and it is authorized by the Minister of Agriculture. The strategy includes the identification of a vision on soil level and systemic obstacle and intervention frameworks. The recommended interventions identified in the Soil Sector Development Strategy 2014 include: the promotion of agronomic practices designed to rehabilitate degraded soils while preventing further erosion; increasing the availability and access to improved soil nutrients needed to help smallholders maximize their growing potential; and the establishment of a comprehensive sustainable land management program.

2.13 Soil Formation Factor

Soil origin refers to the developmental processes that the soil as a natural entity has undertaken over long time periods as the result of the complex interactions of physical, chemical and biological processes. Soil forming processes usually refer to the results of the interaction of different nature such as the accumulation of soil components, transport within the soil profile or changes in the aggregation state of soil particles (e.g. formation of a structure). These processes will define the soil type and can strongly affect soil quality (Foth, 1984; Brady and Weil, 2002).

The kind of soil that develops depends on five major factors. These factors are the type of parent material, the climate under which soil material has existed, organisms, topography; and the length of time the forces of soil formation have acted on the soil material. Knowing some basics of soil formation helps us to understand the soil resources that farmers use when they engage in food production.

A proper understanding of soil characteristics and adequate interpretation of the magnitudes of its properties combined under the broader term of soil quality is required for proper management of agricultural soils. In places, a variation in any of the five factors results in a formation different kind of soil.

2.13.1 Climate

The climate affects soil formation by temperature and moisture. Temperature and moisture influence the speed of chemical reactions which in turn help control how fast rocks weather and dead organisms decompose. When the climate is temperate (milder and usually wetter) conditions for soil development are more favourable. Soils develop faster in warm, moist climates and slowest in cold or dry ones. Extremely cold temperatures will freeze the soil, stopping it from developing, whereas very hot temperatures slow down soil formation.

2.13.2 Organisms

Soil is an amazing ecosystem for a wide variety of plants, microorganism and microbes to live. Large organisms such as earthworms consume organic material near the surface of the soil and then burrow down, excreting organic material as they move. This releases nutrients from organic matter such as nitrogen (N) and carbon (C) into the soil. Micro-organisms (bacteria/fungi) are responsible for decomposing organic material that enters the soil. Vegetation also plays a part in shaping our soils. For example, acidic waste from decay plant leads to the formation of an acid soil whereas waste from deciduous trees increases the pH helping to make a more fertile soil.

2.13.3 Topography

According to weil, (2000), topography is the study of the shape of the Earth. The shape of the land and the direction it faces make a difference in the soil formation. This includes elevation, slope and aspect. On steep slopes soil can move down the slope with gravity whilst in shallow, water-logged hollows in the landscape.

2.13.4 Parent material

Parent material refers to material from which the soil has been derived and in most cases is of geological origin. The nature of the parent material can have a profound influence on the characteristics of the soil. Every soil “inherits” traits from the parent material from which it’s formed. Every soil formed from parent material deposited at the Earth’s surface. The material could have been bedrock that weathered in place carried by flooding rivers, moving glaciers or blowing winds. Parent material is changed through biological, chemical and environmental processes such as weathering and erosion.

2.13.5 Time

Soils take time to form. Parent material weathers as the seasons change and the temperature fluctuates. The topography of the Earth changes as mountains are built and erosion occurs. Erosion can take millions of years or happen suddenly during a storm. It takes time for micro-organisms and plants to colonise the soil and start mixing it.

2.14 Classification of soil

Soil scientists classify soils by different classification or taxonomic systems. Formerly, the classifications at national level were based on easily recognizable features and relevant soil properties for cropping. Soil-type names were generally well understood by farmers. Even on a higher classification level, the division into zonal soils (mainly formed by climate), intra-zonal soils (mainly formed by parent material or water) and azonal soils was easy to understand. Modern and global-scale classification systems are based on developmental (pedogenic) aspects and resulting special soil properties. A common one is the system of soil types developed by FAO and the United Nations Educational and Scientific Cooperation Organization (UNESCO) used for the World soil map or the international classification. The major soil units depicted are contains the modern FAO/ UNESCO classification and USDA equivalents(FAO, 2010).

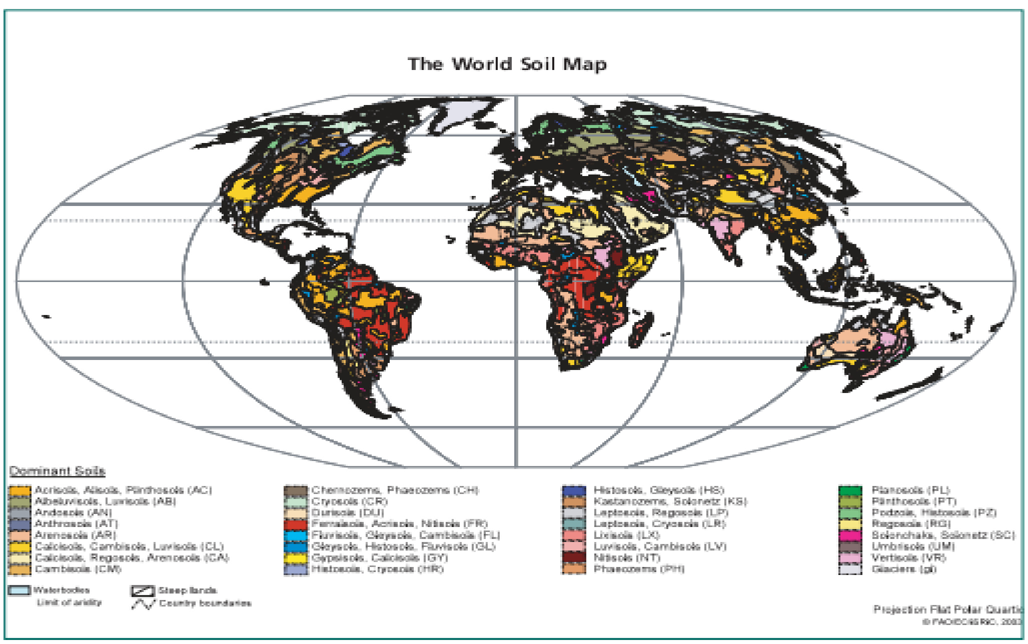

Figure 2.2 world soil Map

Source, FAO,2010

2.15 Soil quality perception

Varying perceptions of soil quality in agriculture have emerged since in the early 1990s, but unlike air and water quality, legislative standards for soil quality have not been and perhaps should not be defined (Mausbach & Cline, 2010). Soil provides the media for root anchoring and healthy plant growth. In addition, soil health affects availability and transport of water, air and nutrients, the resistance to degradation and erosion and water and air pollution. To some, the concept of soil quality seems unnecessary and redundant. After all, everyone must know what constitutes good soil and where good soils are found. To other, quantifying soil quality is impossible because of "natural differences"(Wingeyer et al., 2015).

The importance of soil quality lies in achieving sustainable land use and management systems to balance productivity. For assessing soil quality a complex integration of static and dynamic chemical, physical, and biological factors need to be defined in order to identify different management and environmental scenarios. Also, the consequences of any decline in soil quality may not be immediately experienced. The soil system does not necessarily change as a result of changing external conditions because soil has the capacity of resistance (or resilience) to the effects of potentially damaging conditions or misuse or to filter out harmful materials added to it.

In part, this capacity of the soil in buffering the consequences of inputs and changes in external conditions arises because the soil is an exceedingly complex and varied material with many diverse properties and interactions between soil properties. It is this complex dynamic nature which often makes it difficult to distinguish between changes as a result of natural development and changes due to non-natural external influences.

Society is demanding solutions from science. Simply measuring and reporting the response of an individual soil parameter to a given land or management practice is no longer sufficient. The soil resource must be recognized as a dynamic living system that emerges through a unique balance and interaction of its biological, chemical, and physical components(Mausbach & Cline, 2010). According to the soil factors considered, the soil quality can be physical, chemical, or biological. Most of the physicochemical factors are related to inherent soil quality. Although soil quality often focuses on biological aspects, this must not diminish the importance of physical and chemical factors. Soil-quality assessment, based on inherent soil factors is an effective method for evaluating the environmental sustainability of land use and management activities (Ball & Rosa, 2006).

2.16 Framework for land evaluation

As illustrated in the work of Rossiter, 1996, land evaluation is considered as a complex, multi-faceted problem. Since 1950s attempts have been made to develop a satisfactory, universal land evaluation model. A comparative evaluation and a detailed review of different land evaluation frameworks were presented by Rossiter (1996). Prior to the land evaluation frameworks released by food and agricultural organization (FAO, 2000), land evaluation program had some common shortfalls. They gave much importance to physical land evaluation and ignored socio-economic aspect of land use. They tried to classify land for a generic land use which is an inappropriate method of evaluation as opposed to a detailed, local evaluation of land attribute for specific land use purpose (Diepen. 1991).

To alleviate these shortcomings, scientists at the United Nations food and agricultural organization (FAO) worked together to prepare a common framework. Frameworks developed for land evaluation released by FAO in 1976, is considered to be a milestone in the discipline of land evaluation (FAO, 1976). This framework provided a general overview of land evaluation methodology outlining important consideration.

In designing a methodology for land evaluation suited in local conditions. It provides definitions, a description of land quality and guidelines for physical and economic land evaluation. The radical change reflected in the FAO framework are the inclusion of socioeconomic factors in the land evaluation process, assessment of land with respect to specific land use types, a multi-disciplinary approach to land evaluation, setting priority for environmentally sustainable land uses and providing alternative land use option for users.

Moreover, the FAO framework is easily modifiable to adapt different implementation methods to different local condition. The framework developed by FAO comprises key terms and their definition such as land characteristics, land quality, land utilization type and land use requirement (FAO, 1976). Land characteristics are a direct measure of simple attribute of the land that can be directly observed in a routine survey. For instance soil texture or PH of the soil. Land quality is a complex attribute that can be derived by combining one or more land characteristics. For example a land quality named soil acidity is derived from PH, calcium, aluminum measurements in the surface and deep soil. Land utilization type is a type of broad land use category. Combination of certain land qualities forms the ability of the land to fulfill specific land use requirements. Further, the FAO (FAO, 1994) framework outlines the steps involved in executing a land evaluation which is briefly presented below:

- ✓ Identification of decision makers, their objectives and means of implementation
- ✓ Definition of the spatial entities that need to be evaluated
- ✓ Definition of the land utilization types to be evaluated
- ✓ Definition of the land utilization types in term of land use requirement
- ✓ Translation of the land use requirements in terms of land qualities and land characteristics
- ✓ Building computer model for evaluation
- ✓ Computing and calibrating the result
- ✓ Presentation and implementation of the results

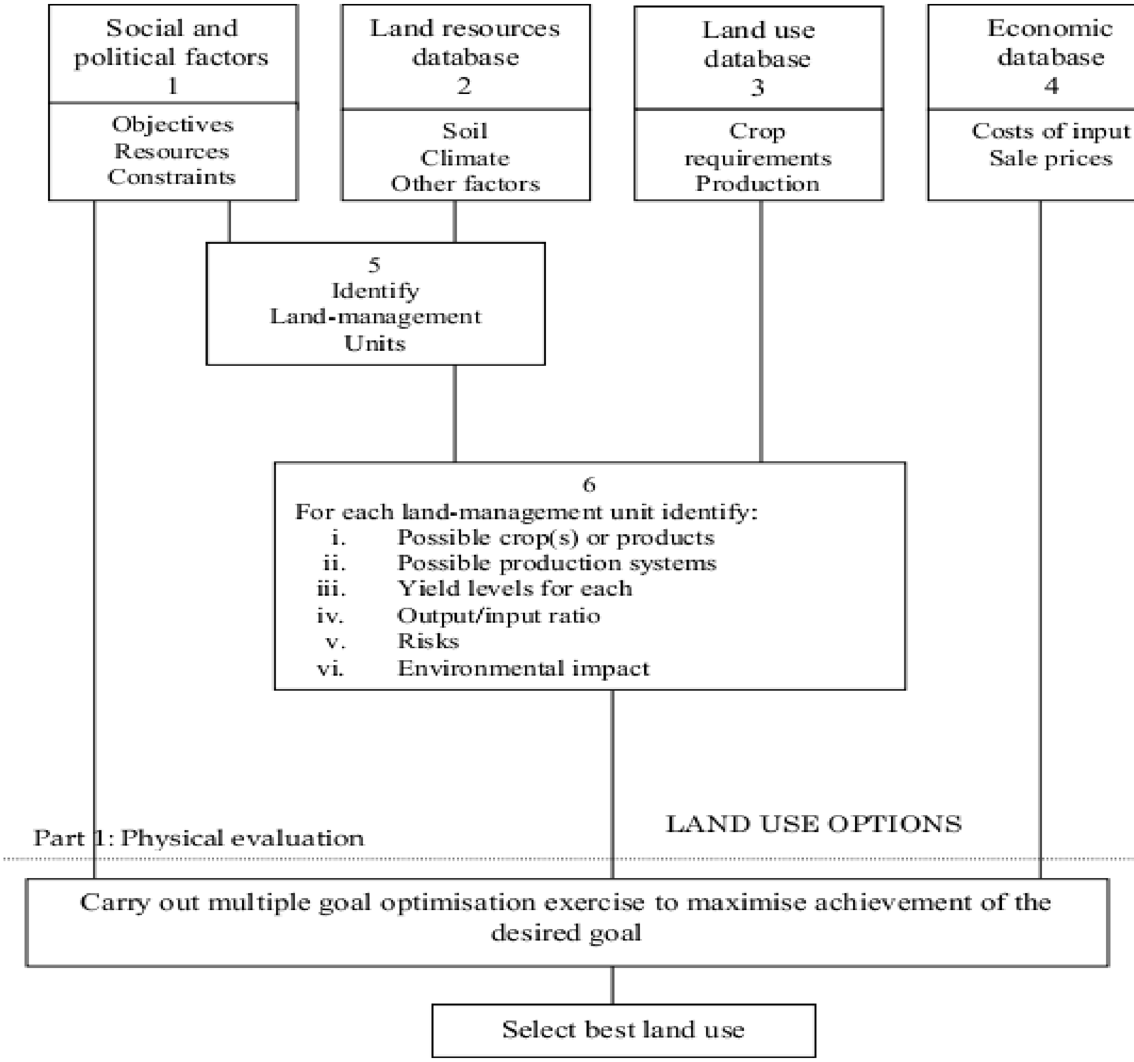

Figure 2.3 FAO Model about the best use of land

2.17 Soil-quality Indicators

A soil-quality indicator is an attribute of the soil which may be measured to assess quality with respect to a given function. It is important to be able to select attributes that are appropriate for the task given the complex nature of the soil and the exceptionally large number of soil parameters. The selection of soil quality indicators will vary depending upon the nature of the soil function under consideration. These soil attributes can be classified in three broad groupings: physical, chemical, or biological indicators. Many of the physical and chemical soil attributes are permanent in time (inherent parameters). In contrast, biological and some physical attributes are dynamic and exceptionally sensitive to changes in soil conditions and in management practices (dynamic parameter). They appear to be very responsive to different agricultural soil conservation and management practices (Ewing S, 2012).

2.17.1 Dynamic soil quality indicator

Dynamic soil quality states how soil changes depending on how it is managed. Apart from the inherent property of soil, the quality and performance of soil for agricultural practice is directly affected by the management and utilization process. According to the soil factors considered, the soil quality can be physical, chemical or biological. Most of the physicochemical factors are related to inherent soil quality and biological and some physical factors with the dynamic soil quality (Ball & Rosa, 2006).

2.17.2 Inherent (Natural) soil quality indicators

It is a soils natural ability to function. These characteristics are permanent and do not change easily. The inherent quality of soils is often used to compare the abilities of one soil against another and to evaluate the value or suitability of soils for specific uses. The physical and chemical attribute of soil is conventional used as a preferable parameter used to identify specific land from one to the other.

Physical indicators are related to the arrangement of solid particles and pores. Examples include topsoil depth, porosity, aggregate stability, color, texture, and compaction. Physical indicators primarily reflect limitations to root growth, seedling emergence, infiltration, or movement of water within the soil profile.

Chemical indicators include measurements of pH, organic matter, cation-exchange capacity, nutrient cycling and concentrations of elements that may be potential contaminants (heavy metals, radioactive compounds) or those that are needed for plant growth and development. The soil’s chemical condition affects soil-plant relations, water quality, buffering capacities, availability of nutrients and water to plants and other organisms (National Soil Survey Center, 2004).

As shown in Table 2.1, USDA (2006) selects five physical, three chemical and two biological indicators which represent a minimal dataset to characterize soil quality.

Table 2.1 Soil property used as indicators of soil quality

Grouping type	Soil quality indicators
Physical property	Soil color
	Soil texture(sandy, silt and clay soil)
	Soil structure
	Permeability/ Infiltration
	Drainage
Chemical property	Nutrient and water reaction (pH)
	Acidity
	Plant nutrients
Biological property	Populations of organisms(organic matter)
	Respiration rate

Source: Key indicators selected by the USDA (2006)

2.18 Soil physical property

As reported by the soil quality management (USDA, 2006), soil physical attribute (quality) concept are commonly used to evaluate sustainable land management in agricultural ecosystem. The purpose of assessing soil physical property (quality) is to protect and improve long-term agricultural productivity, water quality and habitats of all organisms including people.

The simplest definition for soil physical attribute is “the capacity of a specific kind of soil to function within natural ecosystem boundaries to sustain plant productivity, maintain or enhance water and nutrient and support plant, human health and habitation." An agricultural soil with "good physical quality" is one that is "strong" enough to maintain good structure, hold crops upright, and resist erosion and compaction; but also "weak" enough to allow unrestricted root growth and production of soil flora and fauna. Soil with good physical quality also has fluid transmission and storage that permit the correct proportions of water, dissolved nutrients and air for both maximum crop performance and minimum environmental degradation (Karlen, 2011).

Soil Physical characteristics include soil texture, colour, depth; structure and porosity largely control the composition of soil physical property. Among the attribute identified, texture is an important soil property closely related to many aspects of soil behavior.

Texture affects the amount of air and water a soil will hold and the rate of water movement through the soil. Plant nutrient supplies are also related to soil texture.

2.18.1 Soil texture

Soil texture is one of the inherent soil physical properties less affected by management. They determine a number of physical and chemical properties of soils. It affects the Infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Gupta, 2004). It is also an indicator of soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil. Soil texture can have a profound effect on many agricultural practises and is considered among the most important soil physical properties. It is the proportion of three mineral particles, sand, silt and clay in a soil. These particles are distinguished by size and make up the fine mineral fraction (Lilienfein et al., 2000).

Texture is the result of 'weathering', the physical and chemical breakdown of rocks and minerals. Because of differences in composition and structure, materials will weather at different rate resulting a soil's texture. Since weathering is a relatively slow process, texture remains fairly constant and is not altered by management practices. A soil's ability to provide plants with adequate water is based primarily on its texture. Over a very long period of time, pathogenic processes such as erosion, deposition, eluviations and weathering can change the textures of various soil horizons. Soil texture class can be categorized as sand soil, silt soil and clay soil (Brady and Weil, 2002).

2.18.1.1 Sandy soil

Ken (2014) sandy soils are well aerated, light and easy to work they allow viable seeds to germinate easily and easy penetration of roots but they have the disadvantages of being hungry soils because nutrients are easily leached away by drainage. Water drains easily through sandy soils very rapidly. Sandy soils are also referred to as coarse-textured and have the tendency to drain quickly after rainfall or irrigation. Because they drain faster than other soil textures, they are subject to nutrient losses through leaching and they also warm faster in the spring. Sandy soils tend to have a low pH and very little buffering capacity hence is often acidic.

2.18.1.2 Silt soil

Silt -soil particles are smaller than sand separates but larger than clay soil. Because they are intermediate-size, they might be fairly well-drained, but they usually retain more water than sandy soils. Soils with a greater percentage of silt have a floury appearance when dry and a smooth feel when moist and they occasionally form some ribbons when pressed between fingers. These soils have the tendency to compact easily when moist and form crusts when wet. As compare with both sand and clay soil, it has a moderate chemical nutrient concentration necessary for plant growth (Danny H. Rogers, 2015).

2.18.1.3 Clay soil

Clay type of soil refers to a group of clay-sized fraction of soils. The mineral within the soil is similar in chemical and structural composition to the primary minerals that originate from the Earth's crust. Transformations in the geometric arrangement of atoms and ions within their Structures occur due to weathering. Primary minerals form at elevated temperatures and pressures and are usually derived from igneous or metamorphic rocks. Inside the Earth these minerals are relatively stable, but transformations may occur once exposed to the ambient conditions of the Earth's surface.

Clay soil also known as vertisol is sticky, plastic and easily mouldable in to shapes when wet. Air and water do not move easily within them. Clay particles tend to aggregate in to piece which gets very hard as they dry out. Thus clay soils are heavy to work, drain highly, very hard for root to penetrate and seed to germinate. Clay soil is potentially rich in plant nutrients. However, because of poor drainage these nutrients are often withheld from the plants. The vertisol are known by a variety of names such as gray soils, cracking clays or swelling clays and it has a high cationic exchange capacity (~70 meq/100 g) (Sabburg et al., 2009).

Table 2.2 Properties of sand, silt and clay soil particles

Particle	**Property**
Sand	Visible to naked eye, generally spherical or cubical in shape, feel gritty, low water and Nutrients holding capacity, loose when dry, very low plasticity and stickiness when wet.
Silt	Not visible to naked eye, seen through an ordinary microscope, generally spherical or cubical in shape, low to medium in capacity to hold water and nutrients, feel smooth, some plasticity and stickiness when wet.
Clay	Visible only through an electron microscope, platy in shape, low water and nutrients holding capacity, hard when dry, high degree of plasticity and stickiness when wet, exhibit swelling and shrinkage behaviour. It well drains during low rainfall or irrigation.

Source: International Society of Soil Science (ISSS), March, 2016

Table 2.3 Classification of soil texture particles according to their sizes

Particle	**Diameter (mm)**	Approximate size
sand	0.2-0.02	
Silt	0.02-0.002	
Clay	<0.002	Invisible to naked eye

Source: International Society of Soil Science (ISSS), March, 2016.

2.19 Soil chemical property

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microorganisms. The chemical reactions that occur in the soil affect processes leading to plant development and soil fertility. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil. Soils inherit the chemical trace of their parent rocks. This is true of macronutrients such as (K, P, Ca and Mg), micronutrients (Fe, Cu, Zn and Mn) and exchangeable insoluble acidic nutrient (Al).

2.20 Method of Determining Soil Texture

There are several ways to determine the texture of soil. Methods that can be used for textural determination include the laboratory method, texture by feel.

2.20.1 Laboratory Method

Analysis by a soil testing laboratory is an accurate way to determine soil texture. Organic matter is removed before the analysis can be performed. Soil testing laboratories use several methods for analyzing soil texture and can require the help of an extension educator (Klute, 2010).

2.20.2 Soil Texture by Feel

Soil texture by feel is usually more of an estimation of the percentages of the separates based on feeling a moist soil with the fingers. There are three types of soil-texture-by-feel tests (Berry and Whiting, 2016):

1. **General feel tests** - Rub some moist soil between fingers.
2. **Ball squeeze tests** - Squeeze a moistened ball of soil in the hand.
3. **Ribbon tests** - Squeeze a moistened ball of soil out between thumb and fingers.

Following are guidelines for judging soil texture by feel.

Sand

- ✓ Feels rough when rubbed between fingers.
- ✓ Falls apart easily if formed into a ball and dropped from hand to hand.
- ✓ Forms a ribbon that is less than 1 inch long when a moistened ball is squeezed between the thumb and fingers.
- ✓ High organic matter indicated by very dark soil colors, could make a longer ribbon and feels less rough than light colored soils.

Silt

- ✓ Feels smooth when moist and has a floury appearance when dry.
- ✓ Changes shape easily and break apart with slight pressure.
- ✓ Occasionally forms a ribbon when squeezed between fingers and thumb.
- ✓ The length of the ribbon depends on the clay content.

Clay

- ❖ Feels sticky and is bendable when moist.
- ❖ Forms a ball easily and resists breaking even when pressed.
- ❖ Form a ribbon that could get up to 2 inch in length before breaking, a longer ribbon formed before it breaks indicates a greater percentage of clay.

Figure 2. 4 Picture showing determining soil texture by feel

Source: Journal of Agronomic Education, 2016. A Flow Diagram for Teaching Texture by-Feel Analysis, Virginia Tech.

2.21 Plant soil nutrient requirement

Elemental distribution is different in different plants and is variable within the plant itself. Basically one can consider the roots, the stems and woody parts and the leaves of plants. One of the functions of plant roots is to gather the necessary mineral elements needed for proper growth and development. Nutrient in soils are present in different chemical forms which can remain in solution or bound to soil particles. Exchange of nutrients between different forms or "soil pools" is governed by physical, chemical, or biological processes.

All these processes are included in the concept of "nutrient cycle" in soils. Since the soil is not a "closed system", gains or losses of nutrients from the soils occur to/from the atmosphere or water courses. In agricultural soils, application of fertilization clearly alters the cycle introducing nutrients in the system. Without this supply, the natural input of nutrients in soils would be much lower than typical crop extractions, thus inducing a "negative balance" which would cause a progressive depletion of nutrients and thus a progressive loss of soil fertility and agricultural productivity. Thus analysis of plant with their nutrient requirement from soil for matching proper land for a specific crop would become a new paradigm in agricultural activity to maximize productivity.

2.22 Analysis of Macro, Micro and Exchangeable Acid in soil

A better understanding of the mechanisms involved in plant nutrient acquisition and distribution in edible products with increased micronutrient concentrations could pave the way to the development of improved plant varieties and participate in management of human malnutrition. Soil mineral nutrient deficiency may be the consequence of different constraints including intrinsic low soil mineral contents, sub-optimal biotic conditions like extreme temperatures, pH, low soil water content or anaerobic conditions that will alter mineralization and hence phyto-availability. Sixteen elements are essential for plant nutrition and they are classified as major and micro nutrients (Philippe E, 2018).

2.22.1 Macronutrient

A macronutrient also known as immobile nutrient is used to promote fertility in soil while helping plant to grow as productive as possible. They are less susceptible of loss through leaching. Macronutrient mixes commonly include the most important element such as potassium (k), phosphorus (p) and calcium (ca) and magnesium (Mg). Each macronutrient plays a unique and essential role in promoting plant growth (David P, 2016).

2.22.2 Micronutrients

Micronutrient plays a vital role in maintaining soil health and also productivity of crops. These are needed in very small amounts. The soil must supply micronutrients for desired growth of plants and synthesis of human food. Studies related to the micronutrients status of Ethiopian soils on the other hand are scarce, although the role of micronutrients play in agriculture may be equally important (Yifru A and Mesfin K, 2013). However, exploitive nature of modern agriculture involving use of organic manures and less recycling of crop residues are important factors contributing towards accelerated exhaustion of micronutrients from the soil. The deficiencies of micronutrients have become major constraints to productivity, stability and sustainability of soils. Soils with finer particles and with higher organic matter can generally provide a greater reserve of necessary element.

According to Yifru, 2013 the four essential micronutrients that exist as cation in soils are zinc (Zn), copper (Cu), and iron (Fe) and manganese (Mn). Factors affecting the availability of micronutrients are parent material, soil reaction, soil texture, soil organic matter (SOM) and from which the soil is formed (Brady and Weil, 2002).

2.22.3 Exchangeable Acidity

Exchangeable hydrogen (H) together with exchangeable aluminum (Al) is known as soil exchangeable acidity. Soil acidity occurs when acidic H ion occurs in the soil solution to a greater extent and when an acid soluble Al^{+3} reacts with water (hydrolysis) and results in the release of H^{+} and hydroxyl Al ions in to the soil solution (Weil, 2002).

As soils become strongly acidic, they may develop sufficient insoluble Al in the root zone and the amount of exchangeable basic cation decrease, solubility and availability of some toxic plant nutrient increase and the activities of many soil microorganisms are reduced resulting in reduced mineralization and lower availability of some macronutrients like Ca, k and P and limitation of growth of most crop plants and ultimately decline in crop yields and productivity (Brady and Weil, 2002).

2.23 Major Ethiopian cereal crop and production constraints

In Ethiopia, crop production and marketing are the means of livelihood for millions of small holder households and it constitutes the single largest sub-sector in economy. Cereal accounts for roughly 60% of rural employment, 80% of total cultivated land, more than 40% of a typical household's food expenditure and more than 60% of total caloric intake. The contribution of cereals to national income is also large. According to available estimate, cereal production represents about 30% of gross domestic product (GDP) (World Bank, 2007). This follows from the fact that agriculture is 48% of the nation's GDP and that cereals' contribute to agricultural GDP is 65% (Diao et al, 2007). However, the Ethiopian agriculture has been suffering from various external and internal problems. It has been stagnant due to poor performances as a result of factors such as:

- ✓ Low resource utilisation (e.g. the proportion of cultivated land compared to the total amount of land suitable for agriculture related with the amount of water and nutrient availability)
- ✓ Low-tech farming techniques
- ✓ Over-reliance on fertilizers and underutilised techniques for soil and water conservation
- ✓ Inappropriate agrarian policy
- ✓ Ecological degradation of potential arable lands
- ✓ Increase in unemployment rate due to increase in the population
- ✓ Neglect and lack of agricultural investment etc

These constraints, coupled with the rapid population growth, have significantly contributed to the problem of food insecurity.

2.23.1 Teff

Teff is believed to have been first domesticated by pre-Semitic inhabitants in Ethiopia between 4,000 B.C and 1,000 B.C. it is an annual grass which is widely cultivated throughout Ethiopia as a staple cereal crop. Among cereals, teff accounts for the largest share of the cultivated area (28.5 percent in 2011) followed by maize (with 20.3 %) in Ethiopia. It is second (to maize) in terms of quantity of production. It accounts for the largest share of the total value of cereal production. Since teff farm operations such as land preparation, weeding and harvesting are highly labour intensive with limited availability of suitable mechanical technology, there are no large scale teff farmers in the country. Many farmers grow teff as cash crop because of its higher and more stable market price (CSA, 2007).

More recently demands for teff grain by African Diasporas communities is increasing in alarming rate. In the United States due to increasing demands for teff, the land devoted to teff production has exploded and teff is currently grown in at least 25 states across the nation (Davidson and Laca, 2010). In spite of the significant growth in terms of demand and area cultivated under teff production, yield is still very low (Occasional Report, 2010). This implies the quantity of yield currently produced in the country is below the expected potential of the crop. Some of the major causes of low yield are inability of farmers to use the required quantities of mineral nutrition and unbalanced chemical fertilizer application (CSA, 2007). Besides, decline in soil organic matter and insufficient attention to crop nutrient studies greatly contributed to the loss of soil fertility resulting in severe nutrient reduction of soils. Fertilizer usage is one instrument implemented as a means of raising production and income of farm households (AESE, 2005).

Teff is well adapted in well-drained, clay (vertisol) and silt soil areas of the Ethiopian where most other cereal crops cannot be easily grown. Teff has a short growing season with rainfall needs of 450–550 mm, and temperature range of 10–27°C (Roseberg, et al., 2005). Teff can grown from sea level to as high as 3000 meters altitude, with maximum production occurring at about 1800-2100 meters (Ketema, 2001; Stallknecht, 2007).

Information on farmers' soil fertility management and their perceptions on production constraints of teff are limited. Nitrogen (N) and phosphorus (P) fertilizers are the major soil fertility management practices applied by Ethiopian smallholder farmers growing teff for long period of time.

2.23.2 Maize

Maize is the second most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socio-economic conditions typically under rain-fed production. Smallholder farms account for more than 95 % of the total maize area and production in Ethiopia with low soil fertility as a constraint to maximize production.

Soil type has a major effect on maize production. The ideal maize soil is medium texture, fertile, well drained and well aerated. Good-structured heavy soils and sandy soils, provided they are well drained, can also grow excellent crops of maize. Tightly-textured soils, such as some black and grey clays soils will not grow good crops. These soils are poorly aerated and maize roots cannot penetrate the clods, resulting in an inadequate root system. Severely compacted soils, especially those worked with a plough or disk pan, will not give adequate yields. A root zone of 750 mm or more is ideal, but not always achievable. To reach full development, maize requires 400 to 450 mm of rain or irrigation to penetrate the root zone. Ideal growth takes place between 24°C and 30°C. Growth is restricted below 14°C, at temperatures over 42°C, maize pollen can be damaged, resulting in poor pollination.

The ideal soil pH for maize is between 6.0 and 8.0. Yields decrease when soil is too alkaline (pH 7.5 and above) and when it is too acid (pH lower than 5.5). PH correction should be addressed well in advance of field preparation. The pH of the soil is determined through a soil analysis (Doug M, 2017).

2.23.3 Wheat

Wheat is grown extensively over a broad range of climatic and soil conditions and consequently has a wide geographical distribution. It is the national food in over 40 countries and the main staple for over one third of the world's population. In Ethiopia current wheat production is insufficient to meet domestic needs forcing the country to import 30 to50% to fill the gap. The low yield is primarily related with the depletion of soil fertility due to continuous nutrient uptake of crops followed with low fertilizer use and insufficient organic matter application Research outputs revealed that macronutrient such that nitrogen (N) and phosphorus (P) in the order are the two major plant nutrients that limit wheat productivity (Kidane Giorgis, 2015).

Wheat can grow on almost any soil, but for good growth it needs a fertile soil with good structure and porous subsoil for deep roots. The optimal soil reaction is slightly neutral (pH 6.6-7.3) although it can be grown successfully in alkaline (pH 7.4-7.8) calcareous soils under irrigation. The water supply should not be restrictive and rains should be well distributed. Teklu et al. (2007) indicated that the deficiency of Zn and Cu as micronutrient from soil causes minimum wheat yield.

2.23.4 Barely

Barley is one of the most important cereal crops in the world. It is believed to have been cultivated in Ethiopia as early as 300 BC. This long history of cultivation and large agro-ecological and cultural diversity in the country has resulted in large number of landraces and rich traditional practices (Martin et al., 2006). In Ethiopia, among cereals, barley is the fourth most important cereal crop next to teff, maize, sorghum and wheat (Central Statistical Authority, 2008/2009). It is the staple food grain for Ethiopian who manages the crop with indigenous technologies and utilizes different parts of the plant for preparing various types of traditional food. However, barley yield in Ethiopia is low due to several constraints of both biotic and abiotic natures. Soil acidity and excessive aluminum (Al) accumulation in soil leading to major challenge across the barley growing regions of Ethiopia (Ofosu and Leitch, 2009).

2.23.5 Sorghum

Sorghum is a crop dominated by resource-poor smallholders and typically produced under adverse conditions in most parts of Ethiopia where there is low rainfall. The primary demand for sorghum is for food in Africa and Ethiopia, especially in the dry land regions where these are the principal crops. Sorghum is mainly grown on low potential shallow soils with high clay content which usually are not suitable for the production of maize, wheat or barely.

Sorghum usually grows poorly on sandy soils, except where heavy textured subsoil is present. Sorghum is more tolerant of acidic and alkaline salty soils than other grain crops and can therefore be successfully cultivated on soils with a pH between >5.0 and 9.0. Sorghum can better tolerate short periods of water logging compared to maize and other crop. Nitrogen deficiency is recognized as a major yield constraint (Jéan du Plessis, 2008).

2.24 Existing gap in land evaluation and decision support

The rapid population growth has caused increased demands for food and in parallel requires improved production method. Under the present situation where land is a limiting factor, it is difficult to satisfy the ever growing food demand unless the production and cultivation method improves in parallel with science and technology (Fischer et al., 2002).

According to Godfray (2010), global demand for cereal crop is increasing and may continue to do so for decades propelled by a 2.3 billion person increase in global population and greater per capita incomes anticipated through midcentury. Current yield differences among nations are large. Precision agriculture, the study of management practices to maximize food production is one of many modern farming practices that make production more efficient. With precision agriculture, farmers and soils work better. One example of a precision agriculture practice is to understand how soils differ within a field and manage the different areas differently (Godfray, 2010).

As a result in countries like Ethiopia the traditional practise of agricultural activity is continuing for century with its most of the production was consumed in home. The need and application of large scale mechanized farming was practised by different regime for sustaining development and ensuring food security with its long term vision of providing export goods and service to the rest of the world. But, no longer is achieved all the needed development and vision due to low involvement of technology-oriented input for the farming sector. It’s evidenced from the developed countries that the integration of information technology in the farming community brings better agricultural management and increase overall production. The Ethiopian demonstration and training extension system (DAS) responsible for the dissemination of improved agricultural practise to the needy rural farmer should be supported with advanced to increase the productivity level of farmer and their stakeholder.

Assessment of agro-ecological information for agricultural practise such that evaluation of soil type assessment, weather condition, distribution of rainfall pattern, etc was one of well known tool to develop a framework for developing expert decision support system in agricultural sector.

CHAPTER THREE

Methodology

In this study, different procedures are followed for developing knowledge based system for cereal crop land identification. These are knowledge engineering tools (knowledge acquisition, knowledge modeling, knowledge Representation, and Knowledge based system development for teff land identification).

3.1.1 Research design

This study follows empirical research design. Empirical research is research using empirical evidence. It is a way of gaining knowledge by means of direct and indirect experience. As a result, in this study the researcher used experimental method for model building, analysis and prototype development, whereas non-experimental method was also used for knowledge elicitation through discussion with experts, farmers and document review.

3.1.2 Knowledge Acquisition

In order to design and develop the knowledge based system both qualitative and quantitative data was used from different sources. The primary data was collected from experts and farmer. In addition, secondary data is used in support of primary data like documented source of knowledge on the area of cereal crop cultivation, protection and treatment from sources such as agricultural books, journals, publications, internet sources, crop protection guidelines and training manuals was analyzed. Questionnaire and interview were used as an instrument for data collection from the intended respondent and purposive sampling was employed to get the right expert respondents. The reason of taking purposive sampling to get respondent was the knowledge of expert on the issue and involvement in the relevant department for the researchers work.

3.1.3 Knowledge Representation

After modeling the acquired knowledge by using decision tree, it is represented in a format that is both understandable by humans and executable on computers. Production rules are the most popular form of knowledge representation which is an easy way to understand and reasonably efficient in problems identification. Knowledge is represented in the form of condition-action pairs: IF this condition or premise or antecedent occurs, THEN some action (or result or conclusion or consequence) will occur.

3.1.4 Knowledge Modeling

The acquired knowledge is modeled by using decision tree. Decision tree shows the relationships of the problem graphically and can handle complex situations in a compact form. Knowledge diagramming is often more natural to experts than formal representation methods and decision trees can easily be converted to system. In land identification, decision trees give a clear expression of the comparison between land-use requirements and land characteristics. Decision tree is drawn using flow chart symbols as it is easier for many to read and understand. It helps to identify a strategy most likely to reach a goal and allow the addition of new scenarios.

3.1.5 Model development

Cereal crop land identification is designed based on rule based techniques. The knowledge was acquired from experts, farmers and documented knowledge sources. Potential sources of knowledge include domain experts, farmer, books, journal articles, proceedings, electronic sources and information available on the web. Then, the acquired knowledge is effectively modeled and represented as a prototype system in the knowledge base. Knowledge base contains rule base from which the system draws conclusion through inference engine. The inference engine accepts query from the user via user interface and quick the action in user understandable form until the goal is satisfied. A forward chaining technique is used as inference mechanism to search and extract the rules for Teff land identification and use.

3.1.6 Inference Engine and Working Memory

In the development of the knowledge base, working memory and inference engine was built to provide the expert system and then built rules with classification of decision tree concluded with IF-THEN rules by apply techniques of forward chaining, i.e. data driven, where the system began with delivers early initialization element.

3.1.7 Implementation Tool

Prolog logic programming language was used to develop a rule based knowledge based system for cereal crop land identification. The reasons for selecting Prolog are the features and abilities of the language that integrate features. Prolog is a declarative language and has the capacity to describe the real world. Because of its declarative semantics, built-in search and pattern matching, Prolog provides an important tool for programs that process natural language. To achieve the established objective of the study, the prototype system is extensively tested and evaluated to ensure that whether the performance of the system is accurate and the system is usable by research centers and development agents.

3.2 Method of System Evaluation

Once the proposed knowledge based system is developed, it was tested and evaluated to measure its performance in identifying suitable land for cereal crop cultivation in terms of soil texture class composition and determined whether the system satisfies the requirements of its users and applicable in the domain area. Testing and evaluation of the prototype system is the final step that can assist the knowledge engineer to measure, if the objective of the proposed system is met or not. To check if the system fits its purpose, system testing and user acceptance testing was conducted.

3.2.1 System Performance testing

Performance testing is the process of determining the accuracy of the developed system. The performance of the system was tested and validated using test case. A test case is a set of test inputs, execution conditions, and expected results developed for a particular objective such as to exercise a particular program path or to verify compliance with a specific requirement (Wako, 2017). The testing procedure is carried out by system evaluators to classify the test cases as correctly identifying case or incorrectly identified case and compares the decisions made by the system with that of the experts' decision on those cases. Then system evaluators validate the numbers of correct decisions made by the system.

3.2.2 User acceptance testing

User acceptance testing was conducted to assess the performance of the system from domain experts' perspective and measure how well the system accomplished its tasks in the domain area. Researchers' prepared checklists for domain experts to make evaluations and comments while interacting with the system. For user acceptance testing, questionnaires was prepared and customized from (Adane, 2010). Finally, all experts are requested to evaluate the system based on a given questionnaire. The evaluators was give questionnaires which are answered as excellent, very good, good, fair and poor.

3.3 Study site description

Jimma agricultural and research center (JARC) is a forefront institution in the region that brings improved and scientific agricultural practise for their surrounding farmer community and stakeholders. It is composed of different section and department. Among the division, experts found in the department of water, land and natural resource conservation and agricultural soil inspection and calibration department is selected as the main department for data collection. The selection of the specified departments was done based on the concerning department for the researcher work.

In addition, based on the agronomic information taken from jimma agricultural and research center as the most cereal crop cultivator zones in jimma locality, eight jimma zone farmers were found to be the highest producer of a variety of cereal crop by utilizing different soil type. Among eight of nominated zone, three of them were selected as the main investigation site for this study. It includes, Omo-Nada wereda farmers, Serbo wereda farmers and dedo wereda farmers, three of the specified zones were selected based on the average crop yield scored over the years as evidenced from jimma agricultural and research center. But, the data requested for the average crop yield scored over the year in the woreda do not obtained.

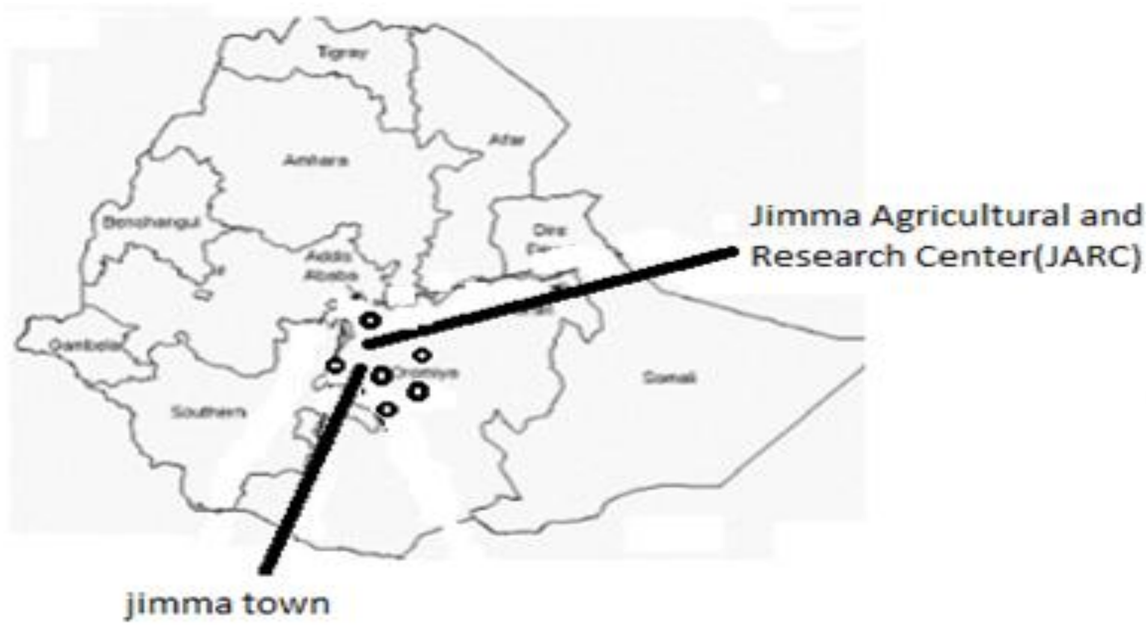

Figure 3.1 Maps of Ethiopia showing study site

3.4 Sample size and sampling technique

There are totally 17 domains experts in the specified department composed of different educational status, experience and position. Three (3) of them are Assistant professor, six (6) of them are doctor and the rest are Msc and Bsc level employee in agricultural science stream. Thus, in order to get the expert respondent, the researcher employed purposive sampling technique. From the given experts, eight of them are used for knowledge elicitation and the rest are used as a system evaluator for the developed prototype cereal crop land identification system. The selection of the informant's domain expert mainly considers their knowledge of the issue and involvement in the relevant departments for the researchers work.

Farmers in all three woredas were also grouped into peasant association (PAs) based on the relative closeness in to particular Kebele. There were totally 20 PAs in those three woreda. 9 PAs in Omo-nada, 6 PAs in Serbo and 5 PAs in dedo woreda respectively. Totally there were 286 house-holds grouped into twenty peasant association (PAs). PAs were stratified depending on closeness and farness from the center (town). Then a total of six PAs were selected, two PAs from each woreda (one from far and one from closer to town from each study site). Finally respondents were randomly selected using stratified sampling. A random number of respondents are then selected from each PAs. Sample size is determined based on research time and resource available. Accordingly the total size of farmer respondents considered for this study was 87 farmers.

CHAPTER FOUR

KNOWLEDGE ACQUISITION, REPRESENTATION AND MODELING

4.1 Knowledge Acquisition

Knowledge acquisition is a task in Artificial intelligence (AI) concerned with eliciting and representing knowledge of human experts. Knowledge acquisition is the transfer and transformation of potential problem solving expertise from some knowledge source to a program. It is phase of expert system development that progress together with knowledge representation, knowledge modeling and prototype system development. These are basic for the development of an integrated rule base of the expert system to be built. The acquisition of knowledge is a major and critical phase in the development of expert systems. The knowledge acquisition process incorporates typical fact finding using interviews, questionnaire and record reviews to acquire factual and explicit knowledge.

4.1.1 Results for Soil physical property from farmers point of view

Farmers were asked with common criteria questions to evaluate and identify their soils. They used soil color, water holding capacity, workability, limitations and possible measures taken to increase fertility status. Based on these criteria farmers categorized their soils into: Koticha/Guracha (sand soil), Ambocha/dalacha (clay soil) and Daro (Silt soil).

Table 4.1 Distribution of sampled farmer respondents in the study area

S. No	Name of PAs	No. of PAs	Total number of HH	selected PA	No. of respondents
1	Omo-Nada woreda	9	104	PA-1 and PA-9	21
2	Serbo woreda	6	94	PA-1 and PA-6	32
3	Dedo woreda	5	88	PA-1 and PA-5	34
Total		20	286	6	87

Where PAs =Peasant Association HH= House Hold

Table 4.2 Indicators for soil physical property identified by farmers

	Indicators for quality of soil texture physical property						
Soil texture	**color**	**Local name**	**WHC**	**Fertility status**	**workability**	**limitation**	**Possible measures taken**
Sand	Black	Guracha/Koticha	low	poor	easy to work	drain quickly after rainfall	Fertilizer application/irrigation
Silt	White	Daro	high	High	Good	poorly drained	-
Clay	gray	Ambocha/dalacha	low	very hard as they dry but good in rainy season	heavy to work	well drain	-

Where, WHC= Water Holding Capacity

Table 4.2 shows critical analysis how farmers in different settings classify and manage soils.-Talawar and Rhoades (2010) found that farmers see soil productivity as a versatile concept. According to Corbeelset al. (2000), soil color is an important criterion for farmers as it often reflects the soil's hidden parent material which determines specific soil characteristics.

Farmers ranked 'Koticha or Guracha (meaning black soil or sand) to be the best soil in terms of productivity in the years of moderate rainfall. According to farmers in the area, due to its high water holding capacity, sandy soil (black soil) gives better yield than other soils at times of even low rainfall. On the other hand clay (gray) is the best soil in seasons of high rainfall. Its main limitation is low water holding capacity making it less productive in low rainfall years (seasons). In addition, this soil is sticky when wet and hard when dry making it difficult to dig. Daro (Silt) soil is the intermediate soil between 'sandy' and 'clay soil' in terms of water holding capacity and fertility. The main criterion they classify ‘Daro/silt’ soil is its white color.

4.1.2 Laboratory Analysis for soil chemical property

The major part of the soil chemical analysis was carried out at the Soil Research Laboratory at jimma agricultural and research center (JARC). Standard laboratory procedures were followed in the analysis of the selected soil texture physicochemical properties for the study.

4.1.2.1 Soil chemical property

According to Delgado A, (2016), soil chemical property is the most important among factors that determine the nutrient supplying power of the soil to the plants and microorganisms. The chemical reactions that occur in the soil affect processes leading to plant development and soil fertility. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil. Soils inherit the chemical trace of their parent rocks. This is true of macronutrients such as (K, P, Ca and Mg), micronutrients (Fe, Cu, Zn and Mn) and exchangeable insoluble acidic nutrient (Al). The concentration of abundant minerals and substances in the soil can vary from one soil type to the other and determined by soil pH value ranging from strongly acidic to strongly alkaline.

4.2 Parameters used to identify soil chemical property

4.2.1 Soil PH

Soil pH is a measure of the soil chemical solution's (soil water together with its dissolved substances) acidity and alkalinity determined by the concentration of hydrogen ions (H+) on a scale ranges from 0 to 14 with pH 1 being extremely acidic ($1x10^{-1}$ or 0.1 moles of hydrogen ions per litter) and pH 14 being extremely basic ($1x10^{-14}$ moles of hydrogen ions per litter or 0.00000000000001 moles/L). PH 7 is considered to be "neutral" (neither acidic nor basic). When soil contains a high concentration of hydrogen ions, it is considered to be acidic and when it has a low number of hydrogen ions, it is considered to be basic. Acidity or alkalinity of soil can be measured in the laboratory using a soil sample taken from the field or directly in the field using a soil test kit. The natural pH of a soil depends on the nature of the material from which it was formed (Ann**,** 2017).

Soil ph has a profound influence on plant growth. It affects the quantity, activity and types of nutrient in soil which in turn influences decomposition of crop residues, manures, mud and other organics. It also affects other nutrient transformations and the solubility or plant availability of many plant essential nutrients. Soil pH is measured to assess potential nutrient deficiencies, crop suitability, pH amendment needs and to determine proper testing methods for soil nutrients. The optimum availability of most plant nutrients in soil occurs over a small range of soil pH values. Unfortunately the range for each nutrient is not the same but there is sufficient overlap in the ranges to decide the best possible compromise for each cropping system and soil type.

4.2.1.1 Conventional soil Ph ranges

Soil pH has a profound effect on nutrient availability to crops with most essential plant nutrients being most available to most crop plant species within the pH range of 6.0 to 6.5. The ideal soil PH and range will also vary with soil type and crop. Crop quality and yield can be severely affected where soil pH not maintained close to target for the soil and crops soil pH level. Maintaining optimum soil pH values in all parts of the field is essential in order to maintain soil quality and health, crop quality and yield. Soil pH also affects uptake of potentially toxic elements such as aluminum made more available for crop uptake at lower pH values as acidic feature. Soil pH also affects the numbers, diversity and functions of beneficial and pathogenic micro-organisms. According to (Foth and Ellis, 2010) descriptive terms commonly associated with certain ranges in pH are:-

-Extremely Acidic (pH < 4.5): Extremely Acidic stage of soil status requires additional fertilizer program to add extra macro and micronutrients.

-Very strongly Acidic (pH 4.5-5.0): As soils become strongly acidic they may develop sufficient aluminum(Al) in the root zone and the amount of exchangeable basic cation decrease, solubility and availability of some toxic plant nutrient increase and the activities of many soil microorganisms are reduced resulting in reduced mineralization and lower availability of macronutrients like Cu, Fe and Zn and limitation of growth of most crop plants and ultimately decline in crop yields and productivity (Brady and Weil, 2002).

-Strongly Acidic (pH 5.1-5.5): Low pH has many adverse effects, including toxicities as well as low amounts of Ca and Mg. Soil P levels are inadequate when ph value goes to strongly acidic. Also, soil K becomes too low for most plant.

-Moderately Acidic (pH 5.6-6.0): it has toxicity feature for plant growth with low amount of macro and micro nutrient.

-Slightly Acid (pH 6.1-6.5): sometimes preferable for special type of plants in desert area and semi-humid altitude.

-Neutral (pH 6.6-7.3): No need for additional fertilization or compost application.

-Slightly Alkaline (pH 7.4-7.8): has high concentration of basic soil nutrient comfortable for optimal growth of plant.

-Moderately Alkaline (pH 7.9-8.4):

-Strongly Alkaline (pH 8.5-9.0): Levels are higher than desired, but not likely to be a problem.

-Very strongly Alkaline (pH > 9.1): Soil pH is too high and could result in micronutrient deficiencies. The macronutrient content such as P, K, Mg and Ca becomes too high which could lead to micronutrient deficiencies (Cu, Fe, Zn and Mn) environmental contamination could result. Problems such as nutrient imbalances particularly micronutrient problems could develop.

Table 4.3 Range of soil PH interpretation

Category	**PH range**
Extremely Acidic	pH < 4.5
Very strongly Acidic	pH 4.5-5.0
Strongly Acidic	pH 5.1-5.5
Moderately Acidic	pH 5.6-6.0
Slightly Acid	pH 6.1-6.5
Neutral	pH 6.6-7.3
Slightly Alkaline	pH 7.4-7.8
Moderately Alkaline	pH 7.9-8.4
Strongly Alkaline	pH 8.5-9.0
Very strongly Alkaline	pH > 9.1

4.2.2 Water holding capacity/Field capacity

Water holding capacity of soil also known as ‘Field capacity’ (FC) is the amount of water remaining in the soil texture after all gravitational water has drained. Remaining water is held in micro pores via ‘capillary’ forces or surface tension between water and solids. Unlike gravitational water, capillary water is retained in the soil and can only be removed by plant uptake. The amount of capillary water that is available to plants is the soil's 'water holding capacity' (WHC) or 'plant available water' (PAW) (Weil, 2002). According to weil, the amount of water in a soil can be measured directly using the gravimetric method, which is simply the weight of the water in a soil sample in proportion to the dry soil sample weight. The gravimetric water content is related to the volumetric content by the following relationship shown.

$$\textbf{Gravimetric water \%} = \frac{\textbf{wet sample weight} - \textbf{dry sample weight}}{\textbf{Dry sample weight}} \times 100$$

4.2.3 Cation exchange

Cations can simply be defined as the fraction of nutrient and mineral elements available for normal plant growth. Cation can be bound in soil in varying degrees. The cation exchange capacity helps characterise the soil type under consideration. Typical cation exchange value will range starting from: **very low, slightly low, normal range and high.**

Table 4.4 Soil cation Exchange (CEC) value

Rating	CEC/(meq/100g)	Comment
Very low	0-10	Very low nutrient holding capacity. Nutrient will be easily leached and foliar applied nutrient is highly recommended.
Slightly low	11-15	Slightly low nutrient holding capacity. Soil leaching may still be a problem and therefore application is considered.
Normal range	16-40	Adequate to high nutrient holding capacity indicating well for plant growth.
High	>40	Nutrient can be bound very tightly to the soil particle and availability can be restricted.

Source: American soil science society, 2015

4.2.4 Exchangeable acidity

Exchangeable hydrogen (H) together with exchangeable aluminum (Al) is known as soil exchangeable acidity. Soil acidity occurs when acidic H ion occurs in the soil solution to a greater extent and when an acid soluble Al^{+3} reacts with water (hydrolysis) and results in the release of H^+ and hydroxyl Al ions in to the soil solution (Weil, 2002).

As soils become strongly acidic, they may develop sufficient insoluble Al in the root zone and the amount of exchangeable basic cation decrease, solubility and availability of some toxic plant nutrient increase and the activities of many soil microorganisms are reduced resulting in reduced mineralization and lower availability of some macronutrients like Ca, k and P and limitation of growth of most crop plants and ultimately decline in crop yields and productivity (Brady and Weil, 2002).

4.2.5 Laboratory Results for soil texture chemical property

Soil samples were collected from lands based on high potentials for agricultural production in the study site. Samples were collected from three soil depths 0-10 cm, 10-20 cm and 20-30 cm based on expert instruction. Soil sampling was based on the identified soil texture class as sandy soil, silt soil and clay soil. In each soil type, a composite soil type of 9 samples was taken from each soil depth from the study site. From the composite soil samples, parameters analyzed include soil pH-level, field capacity (water holding capacity), cation exchange capacity and exchangeable acidity was tested in the laboratory.

Table 4.5 showing soil ph, field capacity, Concentration of nutrient

Soil texture	**Place**	**Sample-code**	**PH**	**FC/ WHC**	**Exchangeable cation**									
					Macronutrient				Micronutrient				Exchangeable acid	
					K	Ca	Mg	P	Zn	Cu	Fe	Mn	Al	Total CEC
Sand	Omo-Nada	O_100	5.5	8.0	-	-	-	-	-	-	-	-	High	13.93 (Slightly low)
	Dedo	D_200	5.5	8.0	-	-	-	-	-	-	-	-	High	
	Serbo	S_300	5.5	8.0	-	-	-	-	-	-	-	-	High	
Silt	Omo-Nada	O_100	7.5	13.9	-	-	-	-	-	-	-	-	Low	29.65 (normal range)
	Dedo	D_200	7.5	13.9	-	-	-	-	-	-	-	-	Low	
	Serbo	S_300	7.5	13.9	-	-	-	-	-	-	-	-	Low	
Clay	Omo-Nada	O_100	8.7	4.0	-	-	-	-	-	-	-	-	Low	11.05 (Slightly low)
	Dedo	D_200	8.7	4.0	-	-	-	-	-	-	-	-	Low	
	Serbo	S_300	8.7	4.0	-	-	-	-	-	-	-	-	Low	

The results of the chemical properties of the three soil textures used in the study are presented in Table 4.5. The soil ph value from laboratory investigation was found to be strongly acidic (5.5); slightly alkaline (7.5) and strongly alkaline (8.7) for sand, Silt and

Clay soil respectively. silt soil had normal or good range of cation exchange capacity (29.65) followed with sand(13.93) and Clay Slightly low (11.05) cation exchange capacity. Conversely, Silt soil exhibited the highest (13.9) water holding capacity following with sand (8.0) and Clay soil (4.0).

Although, the soil pH values were higher and the total acidity concentrations (H + Al) were lower in the clay soil. Lower soil pH values and greater acidity (H+A1) were found in the sandy soil and slightly alkaline soil ph with low acidic concentration found in silt soil.

According to the laboratory technician at JARC, the pH of the soils was measured in water and potassium chloride (KCl) suspension using a glass-calomel combination electrode.

- ✓ Exchangeable acidity (Al) was determined by saturate the soil samples with potassium chloride solution as evidenced from lab technician.

4.3 Analysis for soil physical property

The simplest definition for soil physical attribute is “the capacity of a specific kind of soil to function within natural ecosystem boundaries to sustain plant productivity, maintain or enhance water and nutrient and support plant-human health and habitation." An agricultural soil with "good physical quality" is one that is “strong” enough to maintain good structure, hold crops upright and resist erosion and compaction. But also "weak" enough to allow unrestricted root growth and production of soil flora and fauna. Soil with good physical quality also has fluid transmission and storage that permit the correct proportions of water, dissolved nutrients and air for both maximum crop performance and minimum environmental degradation (Karlen, 2011).

4.4 Parameters used to identify soil physical property

4.4.1 Soil color

According to Corbeelset, (2000), soil color is an important physical property for farmers and agriculture professional as it often reflects the soil's hidden parent material which determines specific soil characteristics. Farmers view soil color in relative terms and they often relate it with the water holding capacity and fertility level for a given seedling. The soil color variation for the soil textural classes are defined based on document survey and experts explanation.

4.4.2 Soil structure

Structure of soil is the leading parameter mainly used for the determination of soil textural class fertility level. It is defined as the arrangement of soil particles in a certain structural pattern. This arrangement results in formation of different sized soil type. It is a composite soil quality that exerts significant control over most physical, chemical, and biological processes that occur in both natural and anthropogenic altered soils, including transport and storage of liquids, gases, and heat; penetration and abundance of roots; microbial life; and decomposition and storage of soil organic matter. It is an inherently complex soil property because the constituent particles are heterogeneous in size, shape, and chemical nature as well as because the mechanisms that bond the particles are diverse. It is also a dynamic soil property, continuously changing in response to various internal and external drivers including moisture and temperature variation, biological activity and human intervention (Teamrat, A, 2016).

On the other hand, soil structure describes the arrangement of mineral particles and organic matter in the soil and particularly the arrangement of pores among particles and also the stability of this arrangement under external forces such as rainfall drops. Structure of soil influences almost all the plant growth factors such that water supply, aeration (air movement), availability of plant nutrients, root penetration, microbial activity etc. It is also useful for classification of soils. The sand, silt and clay particles in a soil texture class are classified based on its structure and aggregate space between them.

4.4.2.1 Grades of Soil Structure

Grade is used to describe the distinctness of individual structural units and the proportion of units that hold together when the soil is handheld. Grade of soil structure is a qualitative means of classification of soil structure. It is identified on the basis of stability of aggregates. Stability of aggregates refers to their resistance to distraction by impact of raindrops or under flooded condition. It is influenced by moisture content, amount and type of soil nature or forming factor of the adsorbed cations. Teamrat, A, (2016), identified three structural soil grades as: weakly aggregate, moderately aggregate and strongly aggregate.

Weak: It refers to barely observable structural units that disintegrate upon moderate handling.

Moderate: It refers to well-formed and readily recognizable structural units. Most of the units retain their integrity upon moderate handling/disturbance.

Strong: It refers to soil structural units that are distinctly observable and that separate cleanly when the soil is disturbed.

Table 4.6 grade of soil structure by soil science society

Grade	**Characteristics**
Weak aggregate	Poorly formed, indistinct peds which are not stable
Moderate aggregate	Moderately developed peds which are fairly stable and distinct
Strong aggregate	Very well developed peds which are quite stable

Source: American soil science society, 2015

4.4.3 Permeability and Infiltration

Soil permeability is another parameter used to define the ability of the soil for transmitting water. It is important to understand the water dynamics and the water balance of the soil and it must be known for accurate management. It is determined partly by texture, with sandy soils having high permeability as compared to clay soils. Other parameters that reflect the water transmission properties of the soil are the infiltration rate i.e. the ability of a soil to conduct water, a parameter extremely sensitive to soil water content.

A soil with low infiltration is one into which water does not enter very quickly. The permeability and the infiltration rate are influenced by the size (structure) and distribution of pores in the soil. The more pores in the soil, the higher its permeability and infiltration. Soils with low permeability are not suited to plant growing since the movement of water through the soil profile is low. This is because water entry is restricted, resulting in low water storage at each point. According to Ass, 2016 soil permeability is grouped into classes ranging from: very slow to very rapid as shown in Table 4.7.

Table 4.7: soil permeability classes

Classification	Infiltration Rate (in/hr)
Very Slow	< 0.06
Slow	0.06 – 0.2
Moderately Slow	0.2 – 0.6
Moderate	0.6 – 2.0
Moderately Rapid	2.0 – 6.0
Rapid	6.0 – 20.0
Very Rapid	> 20.0

Source: American soil science society (Asss), 2016.

4.4.4 Drainage

According to the U.S department agricultural hand book manual of 2008, the first and foremost factor to be taken into account when selecting land for agriculture is the feature of soil resilience for drought. A specific type of soil has the following drainage class:-

4.4.4.1 Soil -drainage classes

1. **Very poorly drained (VPD)** - Water is removed from the soil so slowly that the water table remains wet at or on the Surface the greater part of the time.
2. **Poorly drained (PD) -**Water is removed so slowly that the soil remains wet for a large part of the time.
3. **Somewhat poorly drained (SPD):** Water is removed from the soil slowly enough to keep it wet for significant Periods but not all of the time.
4. **Moderately well drained (MWD) -**Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time**.**
5. **Well-drained (WD):** Water is removed from the soil readily but not rapidly. A well-drained soil has "good" drainage**.**
6. **Somewhat excessively drained (SED) -**Water is removed from the soil rapidly.
7. **Excessively drained(ED)** - Water is removed from the soil very rapidly.

Source: Soil Survey Manual. U.S. Dept. Agriculture Handbook No. 18, 2008.

4.4.5 Interview result from domain Experts about soil physical property

Primary source of knowledge were acquired from human experts in the domain area at jimma agricultural and research center office. Eight (8) domain experts were selected using purposive sampling technique. They were selected based on their knowledge of the issue and involvement in the relevant sector offices and departments.

Table 4.8 list of experts interviewed and their profile

No	Educational background	Specialization	position
1	Doctor	Plant nutrition	Research & publication affairs for improved practise
2	Doctor	Plant nutrition	Head Coordinator-1
3	Doctor	Agro forestry &soil conservation	Coordinator
4	Doctor	Animal breeding	Quality control and assurance
5	Doctor	Animal breeding	coordinator
6	PHD candidate	Horticultural science	Endemic flowering supervisor
7	PHD candidate	Horticultural science	Foreign flowering supervisor
8	Msc	Plant science	Soil & plant laboratory calibrator

Table 4.9 domain expert soil texture physical property assessment

Soil texture physical property assessment																		
texture	Soil Structure			permeability/infiltration					Drainage							Soil color		
	Ws	Ms	Ss	VL	L	M	H	VH	VPD	PD	SPD	MWD	WD	SED	ED	W	G	B
Sand		√			√								√					√
Silt			√				√			√						√		
Clay	√				√										√		√	

(Where, Ws: weak structure; **Ms:** moderate structure; **Ss:** strong structure**; Permeability/infiltration Level:** Very Low (**VL**), Low (**L**), Medium (**M**), High, and Very High (**VH**). **Drainage class**: very poorly drained (V**PD**), poorly drained (**PD**), somewhat Poorly drained (**SPD**), moderately well drained (**MWD**), well drained (**WD**), somewhat excessively drained (**SED**), excessively drained(**ED**).

As we see in table 4.9, the data collected from eight domain experts about the soil texture described as sand, silt and clay and associated physical property indicated that most respondent be of the same opinion that the specified soil type have their own natural property and have impact in agricultural practice and crop cultivation beginning with typical observable color variation as sand soil has black colored soil following with silt soil white colored soil and clay soil gray colored soil type. In addition, for the question related with structure of soil, expert respondent evidenced that sand, silt and clay soil has weakly, moderately and strongly aggregated soil structure respectively. On the other hand for the question presented related with permeability and infiltration rate, sand and clay soil has low water permeability and infiltration rate as compare with silt soil having high permeability and infiltration rate. Lastly, for the question presented related with the drainage feature of the soil texture class, experts witnessed that sand soil is a well drained soil type if the season is a low rainfall season and silt and clay soil is poorly and excessively drained soil type respectively in case of low rainfall season.

4.5 Standard soil_ph requirement for crop cultivation

Different crops have different optimum ranges of nutrient requirements from soil. A soil pH provides optimum conditions for most agricultural plants for their nutrient requirements. All plants are affected by the extremes of pH but there is wide variation in their tolerance of acidity and alkalinity. Some plants grow well over a wide pH range, while others are very sensitive to small variations in acidity or alkalinity (Ann**,** 2017). Table 4.10 provides a guide to the preferred soil pH level for some common cereal crops.

Table 4.10 Range and recommended soil_ph for optimal growth of cereal crops

Cereal Crop type	Soil ph requirement	Soil yield limiting factor crop nutrient response	
	Soil pH range for Normal growth	Macronutrient	Micronutrient
Teff	6.0 to 7.5	p	zinc
Maize	6.3 to 8.0	Shortage in N and P	--
Wheat	6.3 to 8.0	Shortage in N and P	Fe and Cu
Barely	5.5 to 7.5	-	Mn
Sorghum	5.5 to 8.7	Ca	-

Source: document survey and expert interview in the study area

As shown in Table 4.10, the recommended soil PH range information for optimal production of the crop type listed was collected from both agricultural expert and document survey. based on the collected data, the soil PH required for most favourable production of Teff crop is 6.0 to 7.5, maize 6.3 to 8.0, for wheat 6.3 to 8.0, barely 5.5 to 7.5 and sorghum 5.5 to 8.7 ranges. Thus in order to build the proposed system, the researcher match the collected soil Ph range of each crop with the conventional soil PH class in order to decide which crop type is on which conventional soil PH class and further to decide which land type is suitable for which crop type.

As a result, based on the conventional soil PH class, the soil PH range described for teff crop is grouped and can grow under the conventional soil type such that slightly acidic(pH 6.1-6.5), Neutral (pH 6.6-7.3) and Slightly Alkaline (pH 7.4-7.8). Maize and wheat requires the same soil PH range for maximum growth and can grow under slightly acidic (pH 6.1-6.5), Neutral (pH 6.6-7.3), Slightly Alkaline (pH 7.4-7.8) and Moderately Alkaline (pH 7.9-8.4) soil. Barely is grouped under the soil PH class, Strongly Acidic (pH 5.1-5.5), Moderately Acidic (pH 5.6-6.0), Slightly Acid (pH 6.1-6.5), Neutral (pH 6.6-7.3) and Slightly Alkaline (pH 7.4-7.8). Sorghum is also grouped and can grow under the soil type; Strongly Acidic (pH 5.1-5.5), Moderately Acidic (pH 5.6-6.0), Slightly Acid (pH 6.1-6.5), Neutral (pH 6.6-7.3), Slightly Alkaline (pH 7.4-7.8), Moderately Alkaline (pH 7.9-8.4)and Strongly Alkaline (pH 8.5-9.0).

On the other hand, one of the determinant factors for agricultural product variation between crop species is the demand and intake of specific nutrient by different plant from soil. They can be called as macronutrient and micronutrient. Shortage of macronutrient or micronutrient in plant can be a yield limiting factor as evidenced from documents and expert. In table 4.9, shortage of macronutrient such that nitrogen and phosphorus in the soil for the production of maize and wheat can cause reduced maize and wheat product. Shortage of micronutrient such that zinc (Z), iron (Fe), copper (Cu) and aluminium can also be a yield limiting factor for most crop required from soil.

4.6 Knowledge Representation

Knowledge representation is set of actual conditions required to give output. Documented knowledge, questions and interview conducted were leading the researcher to better understand the data and provide guidelines to proceed further. Rules are the typical examples of knowledge representation scheme. It is responsibility of the knowledge engineer to select appropriate knowledge representation scheme that is efficient, transparent and developer friendly.

In Rule Based KBS, knowledge about domain is stored into knowledge base in the form of "if – then "rules, also called as inference rule. Inference engine selects the particular rule depending upon related facts from working memory. If "IF" condition satisfies then and then only action within "THEN" part takes place. The reasoning and inference aspect of land identification stops after assigning comparative importance to each primary node. The primary nodes of domain space are soil-color. Each primary node splits into different secondary nodes. By considering the value assigned to the nodes, it decide the land identification process for particular crop type.

The knowledge representation table contains Rule number, Rule Code, Rule description and findings. Under rule description all the property or characteristics (chemical & physical quality) of particular soil texture class are identified and depending upon its result findings is drawn in the form of soil textural class. As a result, based on the described rule and the findings made the proposed system goes to the inference engine to match the land type suitable for a specific crop by checking the standard soil ph range required for normal growth of the crop.

4.6.1 Building the Rule base

During rule base development for cereal crop land identification using soil texture class identified as sand soil, silt soil and clay soil, rules are constructed using different parameter. The parameter used to identify one soil type from the other in the given farm land includes soil color, soil structure, water holding capacity, drainage feature, permeability/infiltration and soil ph level. The system starts the identification process by providing three different soil colors (black colored soil, white colored and gray colored soil) types associated with the soil texture class. Then, once users choose the type of soil found on their farmland based on the observed color type, the system continues to bring additional unique property related with the selected soil color type. Lastly, it recommends user to choose types of crop mainly teff crop and decides whether the selected crop is productive or not on the selected soil type.

4.6.2 Sample Rule

Rule#1

If soil has black color

AND if it has weakly aggregated structure

AND if it has low permeability and infiltration

AND if it has low water holding capacity

AND if it is well drained soil during low rainfall season

It is in a conventional soil ph class strongly acidic type soil (ph level (5.5))

Recommend user to choose crop type need to be cultivated on their farmland

What do you want to cultivate on your farmland?

1. Teff
2. Maize
3. Wheat
4. Barley
5. sorghum

1.

THEN MESSAGE: The land is sand type soil and is more suitable for cultivating barely and sorghum because the soil ph because the soil ph found in the soil is matches with the range of soil ph required for barely (5.5-7.5) and sorghum (5.5-8.7) production.

Rule#2

If soil has white color

AND if it is moderately aggregated structure

AND if it has high permeability and infiltration

AND if it has high water holding capacity

AND if it is poorly drained during low rainfall season

It is in a conventional soil ph class Slightly Alkaline type soil (ph level (7.5))

Recommend user to choose crop type need to be cultivated on their farmland

What do you want to cultivate on your farmland?

1. Teff
2. Maize
3. Wheat
4. Barely
5. Sorghum
   1.

THEN MESSAGE: The land is silt type soil and is more suitable for cultivating teff, maize, wheat and sorghum because the soil ph because the soil ph found in the soil is matches with the range of soil ph required for teff (6.0-7.5), maize(6.3-8.0), wheat(6.3-8.0)and sorghum(5.5-8.7) production.

Rule#3

If soil has gray color

AND if it has strongly aggregated structure

AND if it has low permeability and infiltration

AND if it has low water holding capacity

AND if it is excessively drained during low rainfall season

It is in a conventional soil ph class Strongly Alkaline type soil (ph level (8.7))

Recommend user to choose crop type need to cultivated on their farmland

What do you want to cultivate on your farmland?

1. Teff
2. Maize
3. Wheat
4. Barely
5. Sorghum
   1.

THEN MESSAGE: The land is clay type soil and is more suitable for cultivating sorghum because the soil ph found is matched with the range of soil ph required for sorghum (5.5-8.7) production.

Table 4.11 Rule detail for soil texture physical and chemical property

R.No	Code	Rule description	Finding
1	A	If soil has black color	Sand soil
2	B	If it is weakly aggregated soil structure	Sand soil
3	C	If it has low permeability and infiltration rate	Sand soil
4	D	If it has low water holding capacity	Sand soil
5	E	If it is well drained during low rainfall season	Sand soil
6	F	It is in a conventional soil ph class strongly acidic type soil (ph level (5.5))	Sand soil
1	G	If soil has white color	Silt soil
2	H	If it is moderately aggregated soil structure	Silt soil
3	I	If it has high permeability and infiltration rate	Silt soil
4	J	If it has high water holding capacity	Silt soil
5	K	If it is poorly drained during low rainfall season	Silt soil
6	L	It is in a conventional soil ph class Slightly Alkaline type soil (ph level (7.5))	Silt soil
1	M	If soil has gray color	Clay soil
2	N	If it is strongly aggregated soil structure	Clay soil
3	O	If it has low permeability and infiltration rate	Clay soil
4	P	If it has low water holding capacity	Clay soil
5	Q	If it is excessively drained during low rainfall season	Clay soil
6	R	It is in a conventional soil ph class Strongly Alkaline type soil (ph level (8.7))	Clay soil

Table 4.12 Decision detail for cereal crop type

No	Code	Description
1	AA	Suitable for Teff
2	BB	Suitable for Maize
3	CC	Suitable for Wheat
4	DD	Suitable for Barely
5	EE	Suitable for sorghum
6	FF	Suitable for Teff and Maize
7	GG	Suitable for Teff and Wheat
8	HH	Suitable for Teff and Barely
9	II	Suitable for Teff and sorghum
10	JJ	Suitable for maize and wheat
11	KK	Suitable for maize and barely
12	LL	Suitable for maize and sorghum
13	MM	Suitable for wheat and barely
14	NN	Suitable for wheat and sorghum
15	OO	Suitable for barley and sorghum
16	Pp	Suitable for teff, maize and wheat
17	QQ	Suitable for maize, wheat and barely
18	RR	Suitable for maize, barely and sorghum
19	SS	Suitable for maize, wheat and sorghum
20	TT	Suitable for wheat, barley and sorghum

As shown in table 4.11 and 4.12, the acquired knowledge from different sources are represented in a way to be easily understandable and to be programmed in computer system as knowledge base-inference of the developed system. therefore, the physical and chemical property of soil texture class determined as sandy soil (black soil) has 5.5 Strongly acidic type standard soil PH value and weak structured soil having low permeability (the ability to transmit water) and infiltration (ability to conduct water) with well drained behaviour during low rainfall season and low water holding capacity.

On the other hand, silt soil (white colored soil) has 7.5 standard soil PH values which is mostly preferred type soil ph for optimal plant growth and has moderately aggregated structure as compare with sand and clay type soil. In addition, silt soil has high permeability and infiltration rate to transfer and conduct water from soil to plant root and also has high water holding capacity with poorly drained behaviour.

Lastly, on contrary, clay (gray colored) soil has 8.7 standard PH which is strongly alkaline soil with strongly aggregated structure which is not more suitable for most of plant species as evidenced from experts and documents. In addition, it has low permeability and infiltration rate for transmitting and conducting water as compared with silt soil. Clay soil is excessively drained soil during low rainfall season

4.7 Knowledge modeling

Knowledge modeling addresses languages tools, techniques and methods to develop abstract models of target domain or problem solving behavior. Some examples for tools and methods that are serving to structure and represent knowledge are decision tree, semantic nets, topic maps or ontology's. It is a symmetric representation of knowledge with mechanism of inheritance to generate a certain type of communication.

4.7.1 Decision Tree

A decision tree is a flow-chart-like tree structure where each internal node denotes a test on an attribute value each branch represents an outcome of the test and tree leaves represent classes or class distributions. The topmost node in a tree is the root node. A decision tree is created by a process known as splitting on the value of attributes. The aim is to develop classification rules from the data in the training set and descriptions of objects are held in tabular form in a training set. It can easily be converted to classification rules.

Decision trees are constructed in a top-down recursive divide and conquer manner. Most algorithms for decision tree induction also follow such a top-down approach. Each ovals of the figure shown below comprises an instance attribute values and the classification corresponding to one object. This is often done in the implicit form of a decision tree. Decision trees have two different functions: Classification and prediction are two forms of data analysis that can be used to extract models describing important data classes or to predict future data trends. Classification predicts categorical (discrete, unordered) labels whereas prediction is the task of predicting continuous (or ordered) values for given input.

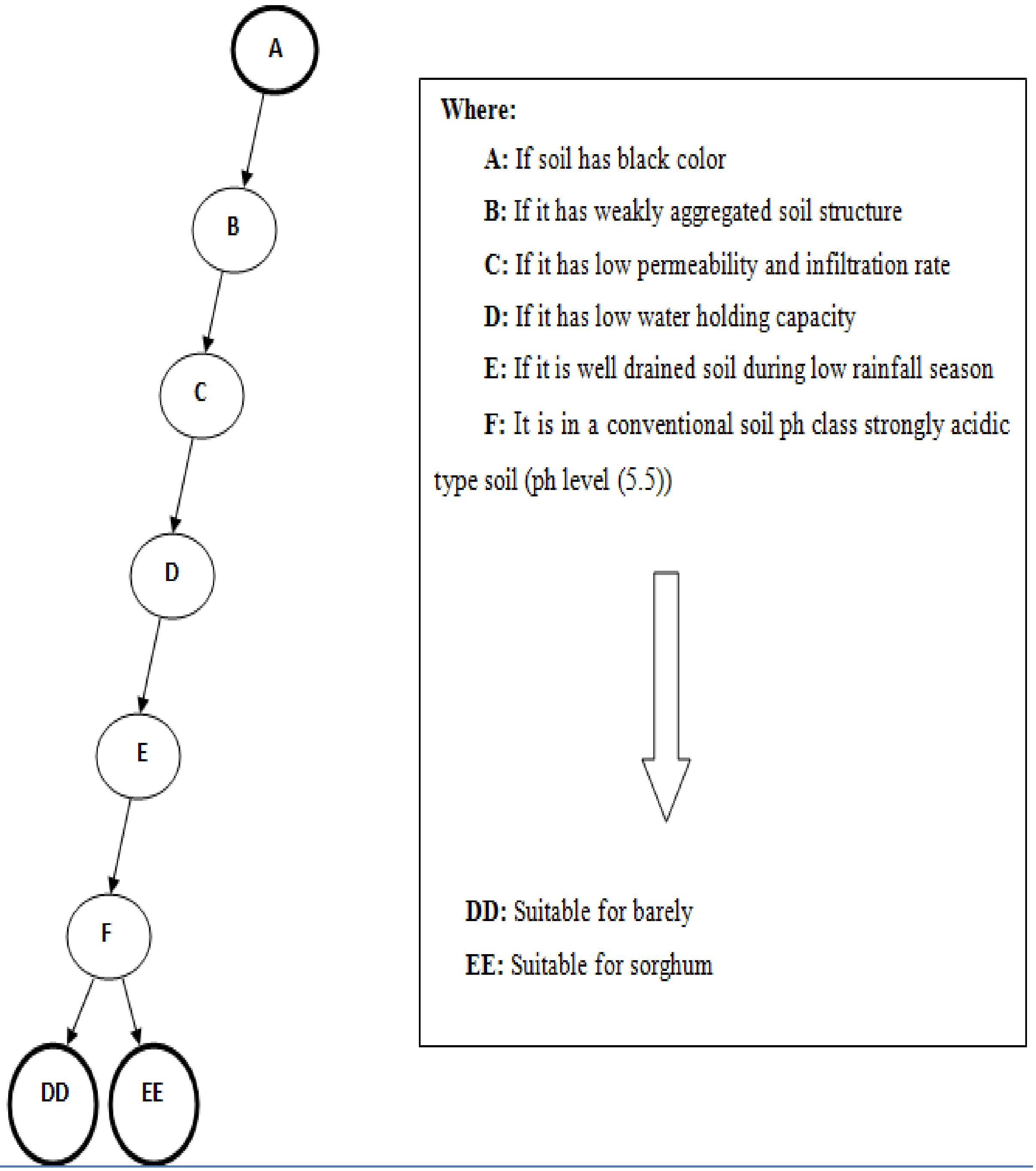

Figure 4. 1 black color soil and recommended type of crop to be cultivated

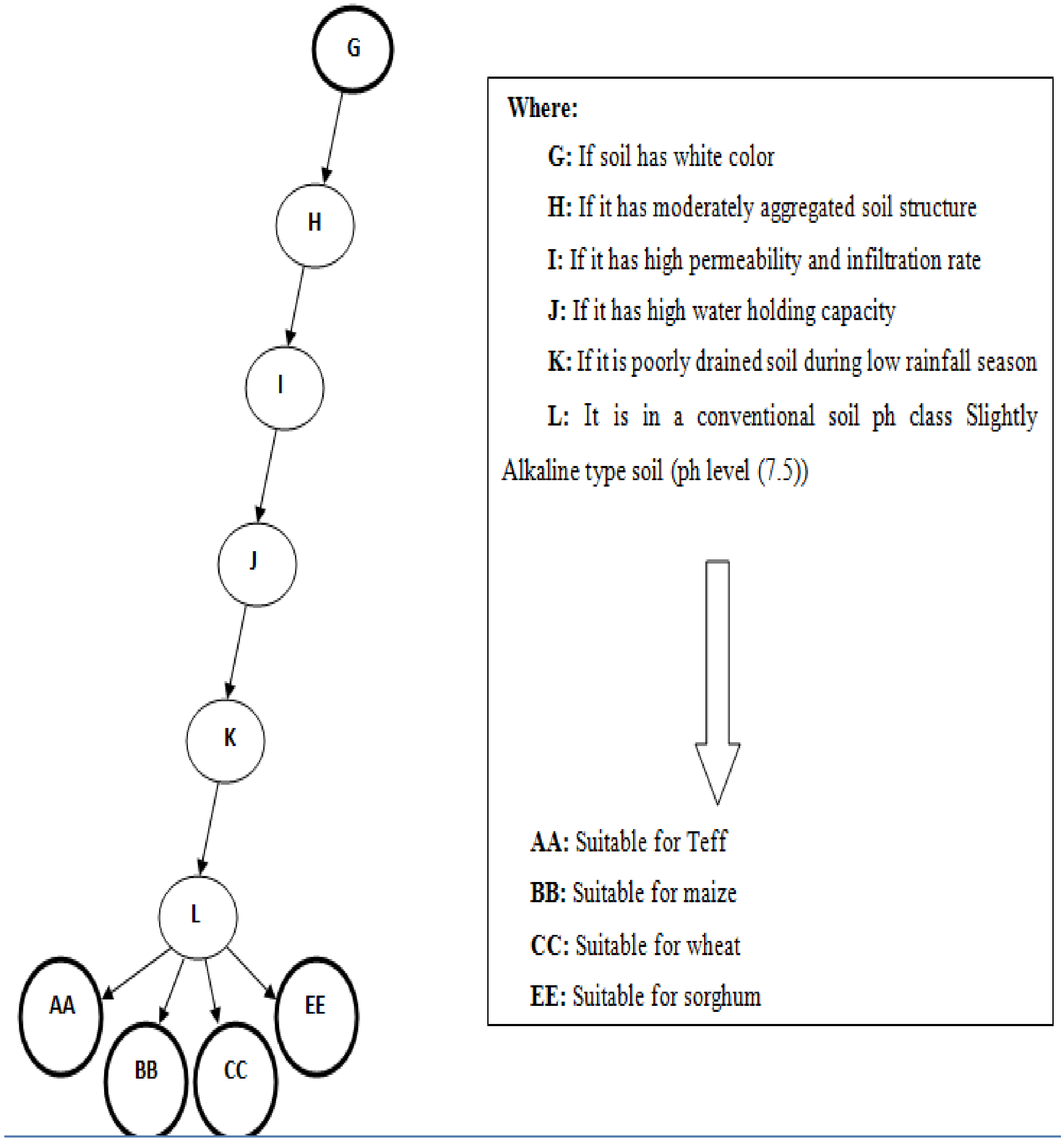

Figure 4. 2 white color soil and recommended type of crop to be cultivated

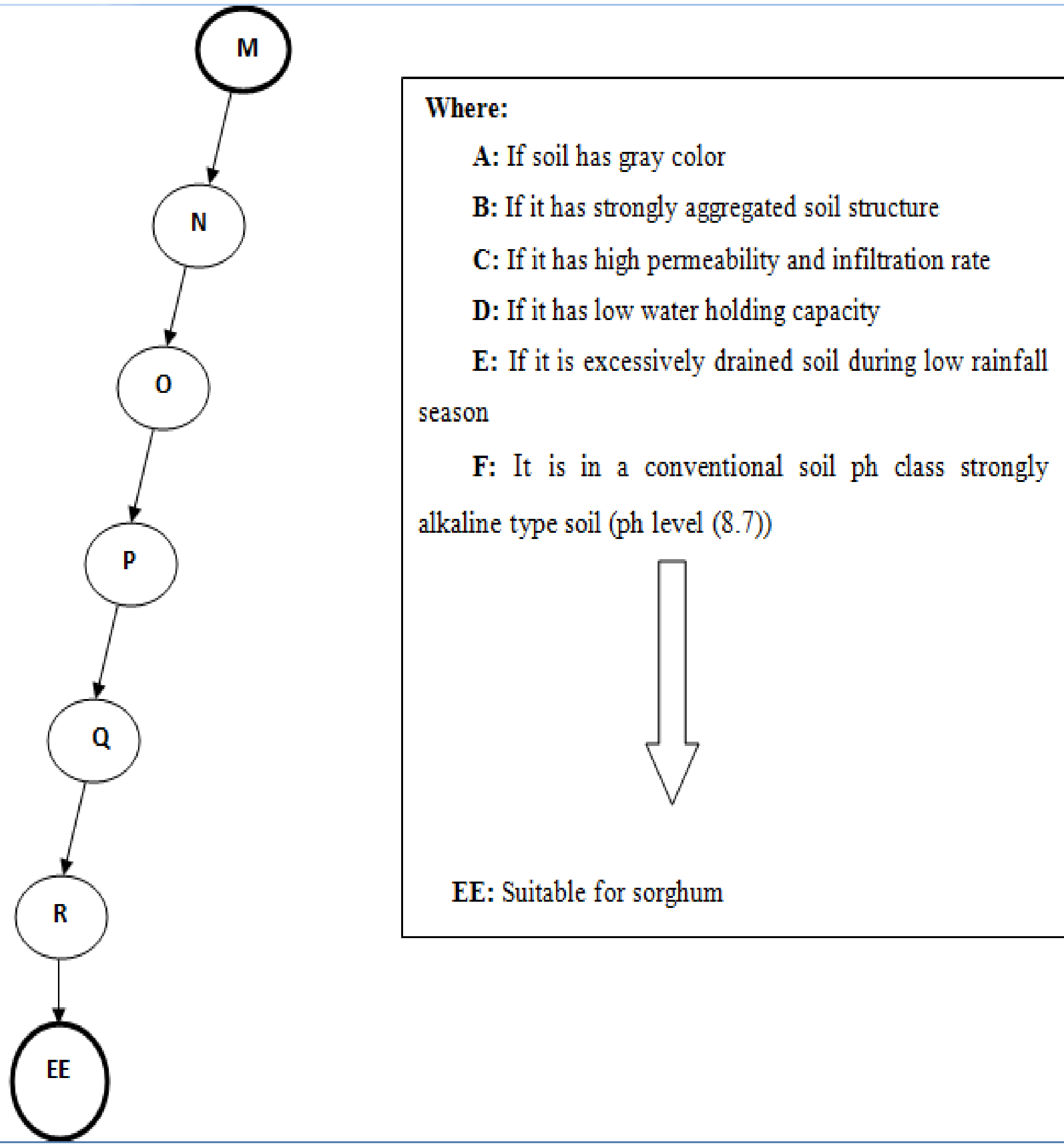

Figure 4.3 Gray color soil and recommended crop type to be cultivated

As shown in figure 4.1, 4.2 and 4.3, assigning comparative importance to each primary node is an important task after designing of appropriate rules for tree structure. In this case, assigning comparative importance to nodes means identifying the nodes (primary, secondary or tertiary) and should have a particular value. For example: consider the node soil-color represented by letter A, G and M has ultimate importance for differentiating the soil type and its quality from one to the other. As a result, the node beginning with letter 'A' represents for the land type that constitute sand soil with their unique property in terms of soil color(A), structure(B), permeability & infiltration(C), drainage feature(D),water holding capacity (E)and standard soil pH value(F). On the other hand, the node beginning with letter G can also represents the land type known as silt type soil with their associated white soil color following Letter (H) represents their unique soil structure, letter (I) represents permeability & infiltration, letter(J) represents drainage feature, k represents water holding capacity and letter (L) represents standard soil pH value Lastly, the node beginning with letter M is also represents the land type composed of clay type soil with previously defined chemical and physical soil attribute beginning with unique gray colored soil type. Therefore based on the decision tree constructed, the prototype system is going to be implemented in the next chapter with knowledge base frameworks using prolog programming language tool with forward chaining (goal driven) technique.

To conclude, this chapter presents the model of land identification system in knowledge acquisition. The conceptual models which are developed from interpretation of domain expert knowledge and farmers indigenous knowledge is intended to solve some of the problems observed in agriculture sector for land identification with special attention of cereal crop land. The model consists of three different representations in the form of decision tree as depicted in figure 4.1, 4.2 and 4.3. In figure 4.1, the model shows the evaluation of sand soil type land for the suitability of five different cereal crops with the main intension to check whether the land is suitable for teff, maize, wheat, barley or sorghum production based on the specific attribute of the soil and the crop standard soil PH level under consideration.

As a result the land evaluated in fig 4.1 is found suitable for the production of barely and sorghum. The land evaluated with silt soil in fig 4.2 was found suitable for the production of teff, maize, wheat, barley and sorghum based on the standard soil PH required for teff cultivation from the specified soil. On the other hand, the land evaluated in fig 4.3 with clay type soil is only found suitable for the production of sorghum. The next chapter shows the implementation of the designed knowledge based cereal crop land identification system by using prolog programming language platform.

CHAPTER FIVE

PROTOTYPE SYSTEM DEVELOPMENT

The design and implementation part of this chapter involves the actual development of a rule base knowledge based system for cereal crop land identification system specifically teff land identification system. Thus, by collecting all necessary information from agricultural expert's, farmers and documents rules are developed, the next step is coding the knowledge into computer using appropriate and efficient knowledge representation platform. For this study, prolog programming language was used to code the proposed knowledge based system using forward chaining method. Forward chaining starts from the set of facts (the available data) and then checks if the given rules are satisfied.

5.1 Designing the Architecture of proposed land identification system

Architecture of the land identification system shown in figure 5.1 depicts how the prototype works during teff land identification process. Once the system is developed by constituting the required information, user can access and communicate with the system through user interface. User interface is the system by which people (users) interact with the computer. A knowledge base is intended to help professionals to get with the essential knowledge needed for their professional practices. The user provides information about the problem to be solved and the system then attempts to provide insights derived (or inferred) from the knowledge base. These insights are provided by the inference engine after examining the knowledge base. This interaction is illustrated by the picture in figure 5.1.

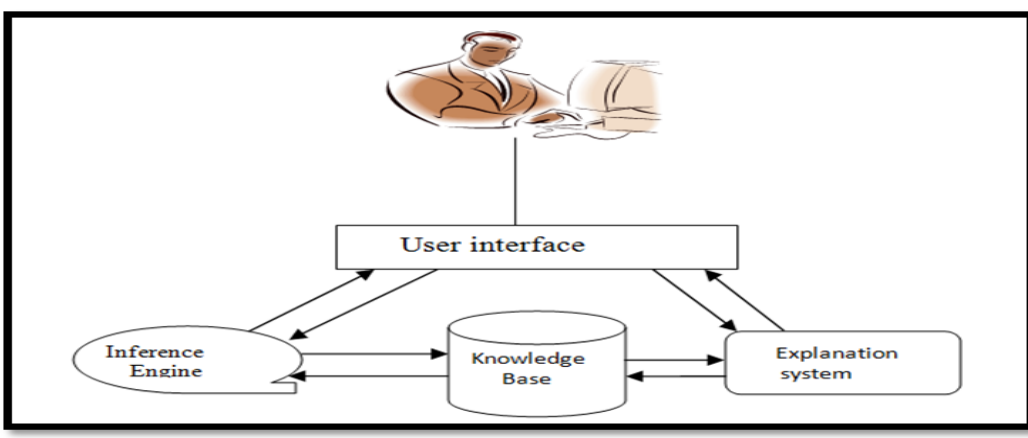

Figure 5. 1 proposed land identification system

5.2 Proposed System user Interface

To interact with the system the user interface is needed. User interface is a bidirectional communication between the system and the user. It is the window through which the system is able to return information to the user. Once the file 'WCCLI.pl' is opened, the end-users can start land identification by writing the word "identify" followed by full stop "." and the welcome window is displayed along with the menu containing **do_you_have: agri_land? (Yes or no):** choices as shown in Figure 5.2. Then the system asks users a series of questions and the users respond by saying "yes" or "no". The system requests end-users to choose the type of soil on their farmland in terms of color and types of crop need to cultivate on their farmland. Based on the user's response, the system provides conclusions for the users request through the user interface.

```
16 ?- identify.
===========================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM========================

===============================Type identify to proceed with the designed system========================

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Phone: 0936726496

do_you_have:agri_land? (yes or no): yes.
```

Figure 5. 2 cereal crop land identification system

Before getting in to the land identification process through the developed system, always the system requests user either they have agricultural land or not to go further for the identification process. Following, the system provides three different soil type varied from one the other based on their color such that black colored soil, white colored soil and gray colored soil. Then, once user can choose the soil color type observed on their farmland from the given alternative by saying 'yes', the system continue to inform related facts about the selected soil type and can go further for additional information as shown below.

```
17 ?- identify.
============================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM========================

================================Type identify to proceed with the designed system=========================

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do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): yes.
```

Figure 5. 3 agri_land having black color soil

```
17 ?- identify.
============================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM========================

================================Type identify to proceed with the designed system=========================

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do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): yes.
structure:weakly_aggregated? (yes or no): yes.
permeability_infiltration:low? (yes or no): yes.
water_holding_capacity:low? (yes or no): yes.
drainage:well_drained? (yes or no): yes.
it_is_in_a_conventional_soil_ph_class:strongly_acidic_type_soil(ph_level(5.5))?yes.

What Do you want to cultivate in your farm land? type?
1 : teff
2 : maize
3 : wheat
4 : barely
5 : sorghum
Enter the number of choice> 1.
```

Figure 5.4 black color soil with recommendation for user what to cultivate

As shown above in figure 5.4 once user get into the system by typing ‘identify’ the developed system request a number of questions to be answered either by ‘yes’ or ‘no’. As a result, as shown in fig 5.4, if user has black colored soil on their farmland, the system ensures that the specified soil color type has the following property, has weakly aggregated soil structure, has low permeability/infiltration level, has low water holding capacity, drainage feature with well drained soil type during low rainfall season and has 5.5 soil PH levels. The system continues with additional request as depicted in the next figure to identify the land type for a specific crop.

```
17 ?- identify.
===========================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM=======================

===============================Type identify to proceed with the designed system===========================

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do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): yes.
structure:weakly_aggregated? (yes or no): yes.
permeability_infiltration:low? (yes or no): yes.
water_holding_capacity:low? (yes or no): yes.
drainage:well_drained? (yes or no): yes.
it_is_in_a_conventional_soil_ph_class:strongly_acidic_type_soil(ph_level(5.5))?yes.

What Do you want to cultivate in your farm land? type?
1 : teff
2 : maize
3 : wheat
4 : barely
5 : sorghum
Enter the number of choice> 1.


The land is sand_type_soil_and_is_more_suitable_for_cultivating_barely_and_sorghum_because_the_soil_PH_found_in_the_soil_is_matche_with_the_range_of_soil_PH_required_
for_barely(5.5-7.5)-and_sorghum(5.5-8.7)-production
true
```

Figure 5.5 sand type soil with allowed crop type.

Fig 5.5 indicates the continuing interface from fig 5.4 showing the land identification process for the land that contains sandy type soil. In fig 5.5, the system continues to recommend user what they need to cultivate on the specified land type by letting users to choose five different crop types. Then, once user choose their crop preferences to cultivate on their farmland, the system reach decision based on the accumulated information in the knowledge base. In this case the system suggest user to cultivate barely and sorghum rather than teff in the given soil type by matching the soil PH level found in the soil and the standard soil PH required for optimal production of barely and sorghum.

```
18 ?-
|    identify.
============================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM=========================

================================Type identify to proceed with the designed system====================

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do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): no.
soil_color:white? (yes or no): yes.
```

Figure 5. 6 agri_land having white color soil

```
18 ?-
|    identify.
===========================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM=======================

===============================Type identify to proceed with the designed system===================

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Phone: 0936726496

do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): no.
soil_color:white? (yes or no): yes.
structure:moderately_aggregated? (yes or no): yes.
permeability_infiltration:high? (yes or no): yes.
water_holding_capacity:high? (yes or no): yes.
drainage:poorly_drained? (yes or no): yes.
it_is_in_a_conventional_soil_ph_class:slightly_alkaline_type_soil(ph_level(7.5)yes.

What Do you want to cultivate in your farm land? type?
1 : teff
2 : maize
3 : wheat
4 : barely
5 : sorghum
Enter the number of choice> 1.
```

Figure5.7 white color soil with recommendation for user what to cultivate

```
18 ?-
|    identify.
===========================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM======================

===============================Type identify to proceed with the designed system==================

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do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): no.
soil_color:white? (yes or no): yes.
structure:moderately_aggregated? (yes or no): yes.
permeability_infiltration:high? (yes or no): yes.
water_holding_capacity:high? (yes or no): yes.
drainage:poorly_drained? (yes or no): yes.
it_is_in_a_conventional_soil_ph_class:slightly_alkaline_type_soil(ph_level(7.5)yes.

What Do you want to cultivate in your farm land? type?
1 : teff
2 : maize
3 : wheat
4 : barely
5 : sorghum
Enter the number of choice> 1.

The land is silt_type_soil_and_is_more_suitable_for_cultivating_teff_maize_wheat_and_sorghum_because_the_soil_PH_found_is_matches_with_the_range_of_soil_PH_required_f
or_teff(6.0-7.5)-maize(6.3-8.0)-wheat(6.3-8.0)-and_sorghum(5.5-8.7)-production
true
```

Figure 5.8 silt type soil with allowed crop to be cultivated on the given land.

As indicated on the above figure 5.8, the land identification system provide for the user another choice related with the type of soil color found or observed on their farmland. In this case if user has an agricultural land with white color soil, the system continues to ensure that the indicated soil type has the following unique characteristics as compared with other soil type such that, it has moderately aggregated structure, high permeability/infiltration rate, high water holding capacity, drainage feature with poorly drained soil type during low rainfall season and has 7.5 standard soil ph level. As a result, after informing the user about the selected soil specification, it provide crop type to be chosen in order to cultivate on the given soil type or farmland. In this case the soil is known as silt soil and suitable to cultivate four type of crop such that teff, maize, wheat and sorghum by matching the soil ph level found in the soil and the standard soil PH required for optimal production of teff, maize, wheat and sorghum.

```
19 ?- identify.
============================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM========================

================================Type identify to proceed with the designed system==========================

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Phone: 0936726496

do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): no.
soil_color:white? (yes or no): no.
soil_color:gray? (yes or no): yes.
```

Figure 5. 9 land identification for agri_land having gray color soil

```
19 ?- identify.
===========================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM========================

================================Type identify to proceed with the designed system====================

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Phone: 0936726496

do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): no.
soil_color:white? (yes or no): no.
soil_color:gray? (yes or no): yes.
structure:strongly_aggregated? (yes or no): yes.
permeability_infiltration:low? (yes or no): yes.
water_holding_capacity:low? (yes or no): yes.
drainage:excessively_drained? (yes or no): yes.
it_is_in_a_conventional_soil_ph_class:strongly_alkaline_type_soil(ph_level(8.7)yes.

What Do you want to cultivate in your farm land? type?
1 : teff
2 : maize
3 : wheat
4 : barely
5 : sorghum
Enter the number of choice> 1.
```

Figure 5.10 gray color soil with recommendation for user what to cultivate

```
19 ?- identify.
============================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM========================

================================Type identify to proceed with the designed system===========================

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do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): no.
soil_color:white? (yes or no): no.
soil_color:gray? (yes or no): yes.
structure:strongly_aggregated? (yes or no): yes.
permeability_infiltration:low? (yes or no): yes.
water_holding_capacity:low? (yes or no): yes.
drainage:excessively_drained? (yes or no): yes.
it_is_in_a_conventional_soil_ph_class:strongly_alkaline_type_soil(ph_level(8.7)yes.

What Do you want to cultivate in your farm land? type?
1 : teff
2 : maize
3 : wheat
4 : barely
5 : sorghum
Enter the number of choice> 1.


The land is clay_type_soil_and_is_more_suitable_for_cultivating_sorghum_because_the_soil_PH_found_is_matches_with_the_range_of_soil_ph_required_for_sorghum(5.5-8.7)-p
roduction
true
```

Figure 5.11 clay type soil with allowed crop type to be cultivated.

Fig 5.11 illustrates the land identification process by accepting the third soil color class known as gray colored soil for clay type soil. Once the user chose the type of farmland with respect to associated soil color (in this case if the soil is gray colored), the system continues to inform the user with additional characteristics of the specified soil in order to reach decision. In this case after taking user choice for crop type in the given land, the system decide the specified type of land with respect to confined soil property is suitable for only cultivating sorghum by matching the PH level found in the soil and the standard soil PH required for optimal production of sorghum.

```
20 ?- identify.
===========================WELCOME TO CEREAL CROP LAND IDENTIFICATION SYSTEM=======================

===============================Type identify to proceed with the designed system=========================

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E-mail:teke.style@gmail.com

Phone: 0936726496

do_you_have:agri_land? (yes or no): yes.
soil_color:black? (yes or no): no.
soil_color:white? (yes or no): no.
soil_color:gray? (yes or no): no.
I can't identify the land
true.
```

Figure 5.12 There is no particular land type selected in terms of associated soil color

As shown in fig 5.12 during land identification if users do not specify the soil color observed on their farmland for the system, for instance do_you_have_agri_land? (Yes or no): **yes**, soil_color: black? (Yes or no): **no**, the system continues to get the second user soil type preference by providing another question like, do_you_have_agri_land? (Yes or no): **yes**, soil_color: white? (Yes or no): **no,** and again the system continue to provide the third question from the knowledge base if both the first and second soil type option do not satisfied. The third alternative can also provide questions such that do_you_have_agri_land? (Yes or no): **yes**, soil_color: gray? (Yes or no): **no**, Thus, if all the soil type option provided by the system do not chosen, the system reaches decision and display message like '**I cannot identify the land'**.

Generally, the developed system provides user with three alternative soil types varied from one the other with color and when interacting with the system, the selected soil color type for a typical farmland can be identified only all the six soil property (parameters used) stored in the knowledge base must be answered with 'yes' confirmation. The developed system display message like '**I cannot identify the land'** when user respond to the system request with no answer. Our primary objective in this study is to provide a system that helps agricultural DA worker with the suitable land identification process for cereal crop land identification.

CHAPTER SIX

PERFORMANCE EVALUATION OF THE PROTOTYPE

6.1 System Testing and Evaluation

Once the knowledge based system is developed, it should be tested and evaluated to measure its performance in identifying suitable land for cereal crop varieties determined whether the system satisfies the requirements of its users and applicable in the domain area. Testing and evaluation of the prototype system is the final step that can assist the knowledge engineer to measure, if the objective of the developed system is met or not. To check if the system fits its purpose, system performance testing and user acceptance testing need to conduct.

6.1.1 User acceptance testing

For the developed system, user acceptance testing is undertaken to assess the performance of the system from domain experts' perspective and measure how well the system accomplished its tasks in the domain area. Researchers' prepared checklists for domain experts to make evaluations and comments while interacting with the system. Thus, nine domain experts are selected purposively from jimma agricultural and research center. For user acceptance testing, questionnaires are customized from (Adane, 2016).

Finally, all experts are requested to evaluate the system based on a given question. The evaluators are given questions which are answered as excellent, very good, good, fair and poor. For those questionnaires, the evaluators are given their judgment as shown in Table 6.1. For the purpose of analysis, values for all attributes are given as excellent=5, very good=4, good=3, fair=2 and poor=1. Based on the given scale, system evaluators provide a value for each closed ended questions. Thus, this method helps the researchers' to examine the users' acceptance based on the given response. The user acceptance of the system is computed manually using Equation (1).

/

$$AveS = SV1 * \frac{nr1}{tnr} + SV2 + \frac{nr2}{tnr} + \cdots \sum_{i=1}^{n} SVi * {nri}/{tnr} \quad (1)$$

Where, ***AveS*** average score, ***SV*** scale value, ***tnr*** total number of respondent and ***nr*** is number of respondent.

To get the result of user acceptance average performance is calculated out 100%.

$$Avp = AveS/Ns \ *100 \qquad (2)$$

Where, ***NS*** is number of scale and ***Avp*** is average performance. The average score of each questionnaire is calculated using the sum of values of excellent, very good, good, fair and poor and divided the sum by four as illustrated in equation (1).

Table 6.1 Domain expert performance evaluation

Domain expert performance evaluation								
No.	**Evaluation Question**	**Poor(1)**	**Fair(2)**	**Good(3)**	**Very good(4)**	**Excellent(5)**	**Average score**	**Average performance%**
1	Simplicity to use and interact with the prototype system	0	2	0	4	3	3.87	77.55
2	Efficiency in time	0	0	1	4	4	4.32	86.4
3	The accuracy of the prototype system in reaching decision to identify suitable land for cereal crops.	0	0	1	4	4	4.32	86.4
4	Coverage of domain knowledge is sufficient	0	0	2	4	3	4.09	81.8
5	The ability of the prototype system in making right conclusions and recommendations	0	0	2	4	3	4.09	81.8
6	Contribution of the prototype system in the domain area	0	0	1	2	6	4.54	90.8
		Total average					4.205	84.12

Based on data indicated in Table 6.1, 33.33% of the evaluators scored the simplicity to use and interact with the prototype system criteria of evaluation as excellent, 44.44% as very good, and 22.22% as fair. Because, the evaluator wants to retrieve queries via user interface in his local language and wants the system to make decisions in his local language, so as to understand the decisions made by the system. The efficiency in time of the proposed system showed a greater rate of efficiency, in which 44.44% of evaluators rated the system as excellent, 44.44% as very good, and the rest 11.11% as good. 44.44% of the respondents rated the accuracy of the prototype system in reaching decision to identify suitable land as excellent, 44.44% as very good and 11.11% of them rated as good. And when asked if the prototype system incorporated sufficient knowledge to identify proper crop land, 33.33% of the respondents rated the prototype system as excellent and 44.44% rated as very good and 22.22 % as good. The ability of the prototype system in making right conclusions and recommendations, 33.33% is scored as excellent while 44.44% as very good and 22.22% of the respondent scored it with good. Similarly, concerning the contribution of the system in the domain area, 66.67% of the respondents gave the prototype system excellent while 22.22% rated the prototype system as very good. As a result, based on the responses of nine system evaluators, the average performance obtained is 4.205. This value is the result obtained from the values assigned for each close ended question. The result indicates that about 84.12% of evaluators are satisfied by the performance of the knowledge based system. This implies that the developed prototype system performs well in making right advice on identifying crop or suitable teff land.

6.1.2 Performance testing

Performance testing is the process of determining the accuracy of the developed system. The performance of the system is tested and validated using test case. A test case is a set of test inputs, execution conditions and expected results developed for a particular objective such as to exercise a particular program path or to verify compliance with a specific requirement (Laurie, 2010). Thus, a total of twenty three test cases are selected in order to validate the accuracy of a prototype knowledge based system. Test cases that have similar parameters with the prototype system are selected purposively. These cases are: sandy soil case, silt soil case, clay soil case and range of soil ph required for each crop for normal growth case. The testing procedure is carried out by nine system evaluators from JARC to classify the test cases as correctly diagnosed case or incorrectly diagnosed case and compare the decisions made by the system with that of the experts' decision on those cases. Then system evaluators validate the numbers of correct decisions made by the system. The result of the comparison shows that the rule based system has made close decision in the process of suitable land identification for cereal crops as human expert do. As indicated in Table 6.2, the test case result provided by system evaluators showed that the developed knowledge based system is 91.30% accurate in identification of the land.

Table 6.2 Performance testing

Selected case	**No. of cases selected for testing**	**CIC**	**IC.IC**	**Accuracy**
Sand soil case	6	5	0	83.33%
Silt soil case	6	6	1	100%
Clay soil case	6	5	1	83.3%
Range of soil ph required for each crop for normal growth case	5	5	0	83.3%
Total	23	21	2	91.30%

Key: CIC (**C**orrectly **I**dentified **C**ase), **IC.IC** (**I**ncorrectly **I**dentified **C**ase)

Twenty three test cases are selected purposively to validate the accuracy of the system and six cases are assigned for each soil test and five cases for each soil ph requirement for crop normal growth**.** As a result, for sand and silt soil cases five of them are correctly diagnosed from the given six cases. Similarly, from the given six cases again five of them are correctly identified for clay soil cases. Finally, the system correctly identify soil ph requirement for crop normal growth cases and it achieves the maximum performance. The result indicated that all the cases are directly similar with knowledge incorporated in the knowledge base.

Generally, as shown in chapter six under table 6.1 and 6.2, the average evaluation result filled by the domain experts in the domain area is 84.12% and the accuracy of the prototype system is calculated as 91.30% respectively. The overall performance of the prototype system is 87.71%. Depending on the results found the main strength of the prototype system are as follows:

A. The system might help in the areas where there is lack of skilled agriculture experts.
B. The system is helpful to solve problems accurately with the help of accumulated knowledge in the knowledge base.
C. The system can reduce knowledge gap observed in agricultural professionals.
D. The system can act as a tool for knowledge sharing.
E. The system can help as knowledge sharing and training tool for DA (development agent) workers.
F. The system can improve the skill of agricultural stakeholders in land identification and decision making.
G. Regardless of the strength of the system, the researchers have faced challenges. These challenges are:
H. The performance of the prototype system depends directly on the quality of the knowledge acquired from domain experts. However, knowledge elicitation from domain experts is the most difficult task due to the tacit nature of persons.

Ultimately, as per the researcher knowledge, there is no indication on local research attempts made to develop KBS for identification of cereal crop land, but there are different researches that used Rule based KBS for identifying land for other purposes. By considering the above performance results 87.71%, it is important to compare with previous Rule based KBS done by different researchers in the same area as indicated in the Table 6.3.

Table 6.3 Comparison of developed KBS with previously done KBS in the area

Title and researcher	Used tool	Performance measurements and results (in %)	Target user
Knowledge-based crop recognition system. Cohen (2007).	Integrated through internet infrastructure	79.1%, overall performance	stakeholder
The development of rule based knowledge based system for wheat disease diagnosis. Desalegn (2017).	prolog	89.78%, overall performance	Farmers
Knowledge based expert system for agricultural land use planning. Thirumurugan,p(2007).	Visual Basic, Ms Access and ArcGIS	83%,overall performance	For Agricultural DA and farmers.

Knowledge based expert system for agricultural land use planning was developed by Thirumurugan (2007). The knowledge base consists of representative rules to reflect physical, economic, environmental and social factors that affect the choice of land use. The expert system makes use of geographic information system (GIS) tools to manage spatial information that are required for the evaluation process. Visual basic, Ms Access and ArcGIS tools was used to fit into the development framework. The research conducted by Thirumurugan (2007) shows the prototype system performance evaluation sections and it achieves 83% an overall system performance.

Knowledge-based crop recognition system by Cohen (2007),were developed using agricultural knowledge, the relations between natural vegetation and crop types, spectral and phenological properties and precipitation and soil types were engineered. Remote sensing analysis and geographical information in hierarchical way was used for model building. Spot pan images were merged to reduce heterogeneity by enhancing field boundaries. Multi-temporal NDVI maps generated from these images were classified into eight crop types using unsupervised classification algorithm. These relations were used as binary rules in an experimental knowledge-based crop recognition system. The binary rules were activated by iterative “split-and-merge” mechanism of the mixed unsupervised classification clusters aimed at refining the map products given by the application of unsupervised classification algorithm alone. The prototype system performance evaluation section shows 79.7 % an overall system performance.

Study presented by Desalegn (2017) the development of rule based knowledge based system for wheat disease diagnosis that provides advice for research centers and development agents to facilitate the diagnostic process. To develop the system, data and knowledge were acquired from documented and non-documented sources. The acquired knowledge is modeled by using decision tree structure that represents concepts and procedures involved in the diagnosis of wheat disease. The system has been tested and evaluated and registered overall performance of 87.78%.

But, the work conducted in this paper is different from previously overviewed work with points like:-

- It uses soil physical and chemical property for the evaluation of land for cereal crop production.
- It uses indigenous and domain expert knowledge as inputs for model building and prototype development.
- The soil texture class identified as sand, silt and clay soil were features used to classify suitable land for cereal crop.

Generally, in contrast with previously conducted researches, in this study prologue programming language were used to show other direction instead of previously used tools such as java platform, visual basic and integrating through internet infrastructure because of the capability of prolog feature that allows easy modification and updates. In addition, the crop type used is different from other study overviewed above. In this study, five crop type such that teff, maize, wheat, barley and sorghum were used as one of native Ethiopian consumption cereal crop family demanded by most of the population. Three type of soil texture class were used as the standing point for land identification system. The knowledge was acquired from both agricultural experts and farmers. Decision tree was used as the main modeling tool for the acquired knowledge and goal driven rule base knowledge based technique was employed for knowledge representation.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

In this paper, rule based knowledge based system is developed to identify suitable land for cereal crop production. Today as the market demand and consumption level of crop increases locally and internationally, the production technique should increase in parallel. The systematic use of implicit indigenous and domain expert knowledge to solve local and international problem must be done in advance. Thus, the developed system could serve the farming sector by providing accurate information about land selection for maximum cereal crop production. In Ethiopia as agriculture becomes the main source of income requires proper agricultural management and improved technology to maximize productivity and ensure sustainable growth. In this study the land type selection based on the contained soil attribute is a promising feature.

Among the three land type evaluated in the study for maximum cereal crop production, the land evaluated with sand soil having a standard soil ph 5.5 was found to be suitable for the production of barely and sorghum. On the other hand, the land evaluated with silt soil holding standard soil ph 7.5 was found suitable for the production of teff, maize, wheat and sorghum. Lastly, the land evaluated with clay type soil is also found to be suitable only for sorghum production. As a result, the developed cereal crop land identification system proofed that the suitable land for most cereal crop production is the land with white soil color (silt soil) having moderately aggregated soil structure, high permeability/infiltration rate, high water holding capacity, poorly drained feature in low rainfall season and Slightly Alkaline type soil with conventional soil ph value = 7.5. The second average land type found more suitable for cultivating cereal crop is the land with black color soil (sand soil) having weakly aggregated structure, low permeability and infiltration rate, low water holding capacity, well drained soil during low rainfall season with conventional soil ph class strongly acidic type soil (ph level (5.5)). The least suitable land found for the production of cereal crop in this study was the land with gray color soil having strongly aggregated soil structure, has low permeability and infiltration rate, low water holding capacity, excessively drained during low rainfall season with a conventional soil ph class Strongly Alkaline type soil (ph level (8.7))

Moreover, the knowledge incorporated in the knowledge base contains necessary rules in order to identify suitable cereal crop land. The knowledge base could also be improved further; the research provides the basic framework on which the system can be expanded to meet user needs. It can also help for research centers and development agents to facilitate the land identification process. The system is evaluated using different evaluation methods and achieved 87.76% of the overall performance. It is believed that the prototype system achieved good performance and meets the objectives of the study.

7.2 Recommendation

However, in order to make the system applicable in the domain area for identifying of cereal crop land, user interface should support various local languages to meet the needs of local users and more research work must be done to incorporate varying parameters in order to identify the land suitable for a particular crop.

The proposed tool has potential to use as a decision tool for identifying land by taking the physical and chemical property of the soil that best matches with the soil nutrient requirement for a specific crop. However, it still needs a future validation with more cases. As this KBS is powered by human knowledge and laboratory analysis, the expert system makes use of geographic information system (GIS) tools to manage spatial information that are required for evaluation process. In addition, expert decision is regularly hard to measure with precise numerical data. So in the future, fuzzy set theory will need to be integrated in to the developed knowledge based system.

7.3 Future Research direction

The research proved the workability of a knowledge based approach to land evaluation and identification of farm units. The next step would be to strengthen it with extensive knowledge bases by collecting detailed knowledge rules on various disciplines and factors associated with land evaluation. Instead of a single knowledge base table used in this research, several different knowledge bases can be used as inputs for the expert system by taking spatial analysis module for further processing to generate results. At present, the developed expert system suggests suitable cereal crop choice for a given land type using prolog programming language platforms. It can be further developed with inputs from climate prediction models such that humidity and rainfall pattern to predict future land use choices for a land unit based on predicted change. Additional land uses with their knowledge rules to reflect their land use requirements can be added, so that the functionality of the expert system can be extended. The research can also be extended to create a web based expert system that connects with various knowledge bases to access knowledge rules in real-time to deliver agriculture recommendations. This can be achieved by having multiple knowledge bases connected by a communication network which would serve the expert system human experts can keep knowledge bases updated and accurate.

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Appendix

JIMMA UNIVERSITY

COLLEGE OF NATURAL SCIENCE

DEPARTMENT OF INFORMATION SCIENCE

QUESTIONNAIRE PREPARED FOR DATA COLLECTION AND FILLED BY EXPERTS PROFESSIONAL AT JIMMA AGRICULTURAL AND RESEARCH CENTER (JARC)

Thank you for your willingness! The aim of the questionnaire is to identify types of land in terms of soil texture necessary to cultivate cereal crop.

Your factual and kindly response for the question presented below is very important for identification of problems and taking appropriate intervention.

Note: Tick (√) your answer

1. Personal information

   1.1. Gender Male ☐ Female ☐

   1.2. Educational status

   ☐ Professor ☐ Msc other ☐

   ☐ Doctor ☐ Bsc

   1.3 Your responsibility in the organization:

   ____

   1.4 Duration in the organization:

   ____

2. What are the most probable causes for reduced agricultural products?

____

____

____

2. Do you think that agricultural products can be affected with the soil type utilized in the field? Yes ☐ No ☐
3. Do you think that the selection of specific land for agriculture in terms of accompanied soil texture class will maximize product?

Yes ☐ No ☐

4. Do you think that the soil type labelled as sand, silt and clay can have its own impact on cereal crop production and cultivation?

   Yes ☐ No ☐

5. Is there any difference between soil types in the land surface in terms of nutrient and organic matter content composition?

   Yes ☐ No ☐

6. If yes for Q.3, Is there any difference between crops for nutrient requirement from soil for growth and maximum product?

   Yes ☐ No ☐

7. Which of them do you think the most common soil type utilized in most farm land? Sandy soil, silt soil, clay soil? Did they have a local name such that black soil, white soil or/etc?

   ____

   ____

   ____

8. Do you think that the soil type labelled sand, silt and clay can have its own impact on cereal crop production and cultivation?

   Yes ☐ No ☐

9. Is there any difference between soil textures described above in terms of color, size etc?

   ____

   ____

   ____

10. Do you think that production of cereal crop such that teff, maize, wheat, barley and sorghum require specific soil type for maximized product?

    ____

    ____

11. Do you think the structure of soil can influences plant growth factors viz. water supply, aeration, availability of plant nutrients, heat, root penetration, microbial activity etc?

    Yes ☐ No ☐

12. Which soil structure is more suitable for agricultural practise and crop production?

    (Weakly aggregate: loosely formed soil **Moderately aggregate:** somewhat concrete soil **Strongly aggregate:** concrete soil**)**

    ☐ Weak ☐ moderate ☐ Strong

13. Which soil structure has high pore space which helps for the transportation of water, nutrient and air within and plant root?

☐ Weak ☐ Moderate ☐ Strong

14. Which soil type has the structure identified as *Weak*, *Moderate* or *Strong* type soil structure?

-Sandy soil	**- clay soil**	**-silt soil**
☐ Weak	☐ Weak	☐ Weak
☐ Moderate	☐ moderate	☐ moderate
☐ Strong	☐ strong	☐ strong

14. Do you think the structure of soil is related with soil erosion in agricultural practise?

☐ Yes ☐ No

15. Which soil type is more susceptible to erosion?

Sandy	**silt**	**clay**
☐ Very Low	☐ Very Low	☐ Very Low
☐ Low	☐ Low	☐ Low
☐ Medium	☐ Medium	☐ Medium
☐ High	☐ High	☐ High
☐ Very High	☐ Very High	☐ Very High

16. Do you think that the structure of a specific soil type has its own effect on plant root depth and length in the soil?

☐ Yes ☐ No

17. Which soil structure has high field capacity (water holding capacity)?

☐ Weak ☐ Moderate ☐ strong

18. Which soil type has high water holding capacity?

☐ Sand ☐ silt ☐ clay

19. Which soil structure can easily be drained by losing its water content?

☐ Sand ☐ silt ☐ clay

20. Which soil type has high cation exchange (CEC) or macro and micro-nutrient composition necessarily for plant growth such as p, ca, k or Mg?

☐ Sand ☐ silt ☐ clay

21. What are the drainage class(level) for the soil type given below?

Sandy	**silt**
☐ Very poorly drained	☐ Very poorly drained
☐ Poorly drained	☐ poorly drained
☐ Somewhat poorly drained	☐ somewhat poorly drained
☐ Moderately well drained	☐ moderately well drained
☐ Well-drained	☐ Well-drained
☐ Somewhat excessively drained	☐ somewhat excessively drained
☐ Excessively drained	☐ excessively drained

Clay

☐ Very poorly drained

☐ Poorly drained

☐ Somewhat poorly drained

☐ Moderately well drained

☐ Well-drained

☐ Somewhat excessively drained

☐ Excessively drained

22. As we know the existence of high cation exchange (CEC) or nutrient composition rate within a soil can determine the soil ph level (acidic, basic or neutral level).Thus, what are the general soil ph level for the soil type listed below?

Sandy soil: ______________________

Clay soil: ________________________

Silt soil: _________________________

23. Which soil structure has nutrient composition considered as having acidic feature for plant growth and development?

☐ Sandy soil ☐ Clay soil ☐ Silt soil

24. What are the standard soil ph levels required for cultivating the following cereal crop?

Teff: __________________

Maize: ________________

Wheat: ________________

Sorghum: ______________

Barely: _________________

25. What are the conventional soil PH for the soil type given below?

Sandy soil	**silt soil**	**clay soil**
☐ Extremely acidic	☐ Extremely acidic	☐ Extremely acidic
☐ Very strongly acidic	☐ Very strongly acidic	☐ Very strongly acidic
☐ Strongly acidic	☐ strongly acidic	☐ strongly acidic
☐ Moderately acidic	☐ moderately acidic	☐ moderately acidic
☐ Slightly acid	☐ Slightly acid	☐ Slightly acid
☐ Neutral	☐ Neutral	☐ Neutral
☐ Slightly alkaline	☐ Slightly alkaline	☐ Slightly alkaline
☐ Moderately alkaline	☐ Moderately alkaline	☐ Moderately
☐ Strongly alkaline	☐ Strongly alkaline	☐ Strongly alkaline
☐ Very strongly alkaline	☐ Very strongly alkaline	☐ Very strongly alkaline

26. Which soil type has high cation exchange (CEC) capacity?

☐ Sandy soil ☐ Clay soil ☐ Silt soil

Checklists used to guide interview with experts

1. What are the most yield limiting factor in the soil for cereal crop production?

   ____

   ____

2. Is there difference between macronutrient, micronutrient in the soil? What are the element type grouped as macro nutrient and micronutrient?

   ____

   ____

3. The application of manure and compost in the soil can change the natural property or capacity of soil?

   ____

   ____

4. The soil formation factor such that climate, topography, etc can have its own impact on the soil type and agricultural productivity?

   ____

   ____

5. From which soil formation factor is the soil texture class identified as sand soil, silt soil and clay soil derived?

   ____

   ____

6. What are the physical chemical and biological attributes used to measure the quality of soil in general?

   ____

   ____

7. How can we identify the quality and the productivity level of one soil type from the other?

   ____

   ____

8. Which soil attribute (chemical, physical and biological) is an inherent (natural) attribute of soil which doesn't change over time?

   ____

   ____

9. Can we determine the soil texture type (sand, silt, clay) by simple observation or touching in hands?

____

____

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IN-DEPTH INTERVIEW PREPARED FOR DATA COLLECTION WITH FARMERS IN THE FIELD

1. PERSONAL INFORMATION
   1.1. Gender Male ☐ Female ☐
   1.2. Region:__________________
   1.3. Wereda:_________________
   1.4. City :___________________
   1.5. Kebele:_________________
2. How long have you been in farming?
   1-year ☐ 2-year ☐ 3-year ☐ >5year ☐
3. Is there an agriculture extension advisor assigned in your community from agriculture extension office?
   Yes ☐ No ☐
4. If yes for Q.3, what they suggest in order to improve your farm land to be productive?
   ____
   ____
5. If No for Q.3, what are the possible measure you take on your farmland to improve productivity?
   ____
   ____
6. What are the most frequently cropped plant in your farm land?
   ____
   ____
7. Do you think, is there difference between soils in the farm land in general and in your community particular?
   ____

8. Do you think that variation in soil type can influence agricultural activity and cereal crop production?

____

9. What is the name of the soil here in your farm land? For what cereal crop is more suitable and yields maximum product (i,e teff, maize, wheat, barley, sorghum?)

____

____

10. What is the local name given for the soil type found in your farmland?

____

____

11. From Q.10, Which class of soil is more suitable for cereal crop production from your experience? Sand? Silt? Clay?

____

12. What is the water holding capacity for sandy, silt and clay soil in your agriculture site? High? Low? Medium?

____

____

13. Which soil type can hold more water for long period of time? Sand? Silt? Clay?

____

____

14. What is the soil fertility status of sand, silt and clay soil for cereal crop production in your agricultural site?

____

____

15. What is the suitability or workability level of sand, silt and clay soil in your agricultural site?

____

____

16. What are the limitations you are experienced when working with the soil type listed above?

____

____

JIMMAA UNIVERSIITII

KOOLLEJJII SAAYISII UUMAMAA

MUUMEE INFORMEESHIN SAAYNSII

Gaafi fi deebi gadi fagenyaan qonnan bulttota dirree irratti data funnanuu fi qopha'ee.

1. Odeeffannoo dhunfa.
   1.1. Saala
   Dhiira ☐ ☐ dhalaa
   1.2. Amantaa ____________________________
   1.3. Anaa _______________________________
   1.4. Maagala_____________________________
   1.5. Ganda ______________________________
2. Yeroo hangamifi hojji qonna irra turtani/ture.
   Wagga 1 ☐ waggaa 2 ☐ waggaa 3 ☐ waggaa >5 ☐
3. Gorsii kara eeggumsa qonna hawaasa keessanifi biro kella qonna birra isinifi kenname jira?
   Eeyyee ☐ ☐ lakki
4. Gaaffi 3ffa dhaffi deebin kee eeyyee yoo ta'ee, buaa gaarii lafa qonne irratti dhuugoomsuu dhafi yaaddi keemaali ?
   ____
   ____
5. Gaaffi 3ffa dhaffi deebin kee lakki yoo ta'ee buaa' lafa qonna dhugoomsu dhaaf furmmata maali keenitefi?
   ____
   ____
6. Biqiltoota hawaasa nannoo keessani kessa yerroo bayyee midhannumaf feyyademtan kami?
   ____
   ____

7. Gara garrumma biyyee lafa qonna fi biyyee nannoo keessani kessa jira jete yaada?

____

____

8. Gara garummaan biyyee firri lafa qonna irratti dhiibba ni gessisa jete ni yaada?

Eeyyee ☐ ☐ lakki

9. Maqaan biyyee lafa qonna keetti irratti argammu mal jedhama?

____

____

10. Maqaan gosa biyyee lafa qonna keettif nanno keettin kenname mal jedhama?

____

____

11. Gaafi 10ffa illalchise kuta biyyee keessa qonna fuddurati muudura dhaaf bayessa kan ta'ee muuxxanno hargatteen issa kami keessuma iyyu? Saandi? Silt? Clay?

____

____

12. Biyyee kan akka biyyee ciracha, biyye samba, biyyee katta keessa dandeeti bishaan qabachu dhaan kan ooyyiruu qonnafi fillatama kan ta'ee isaa kami?

Guracha/Koticha:____

Daro:____

Ambocha/dalacha:____

13. Biyyee ciracha, sambi katta keessa bishaan bayyee yerroo dheera fi of keessatti qabe tursukan danda'uu isaa kami?

Guracha/Koticha:____

Daro:____

Ambocha/dalacha:____

14. Gosa biyye jiran keessa (ciracha, samba, katta) ooyyiruu qonnafi kan mija'ae ta'ee isa kami

Guracha/Koticha	**Daro**	**Ambocha/dalacha**
☐ Rakkissa	☐ Rakkissa	☐ Rakkissa
☐ Bayye salpha	☐ Bayye salpha	☐ Bayye salpha
☐ Giddu gallessa	☐ Giddu gallessa	☐ Giddu gallessa
☐ Salpha	☐ Salpha	☐ Salpha

15. Gosa biyye ciracha, samba, kata jiran kessa oyyirru qonna dhafi mija'aa fi kan hojji dhafi filetammu kammi?

Guracha/Koticha	**Daro**	**Ambocha/dalacha**
☐ Rakkissa	☐ Rakkissa	☐ Rakkissa
☐ Bayye salpha	☐ Bayye salpha	☐ Bayye salpha
☐ Giddu gallessa	☐ Giddu gallessa	☐ Giddu gallessa
☐ Salpha	☐ Salpha	☐ Salpha

16. Gosa giyye jiran kessa hanqinna muxxannoo dhan jiruu biyyiru qonna irratti argaatani maali?

____

____

Sample Code

```
identify:-write('================================WELCOME TO CEREAL CROP LAND
        IDENTIFICATION SYSTEM============================'),nl,nl,

        write('=====================================Type identify to proceed with the designed
        system================================'),nl,nl,

          write('==========================Designed and developed by: Tekalign Abdisa
        Dandana,2010/2018========================='),nl,nl,

          write('==================JIMMA UNIVERSITY COLLEGE OF NATURAL SCIENCE
        DEPARTMENT OF INFORMATION SCIENCE=============='),nl,nl,
          write('Advised by: '),nl,
          write('principal advisor: Amanuel Ayde(Ass.proff)'),nl,
          write('co-Advisor: Berhanu Megerssa(Ass.proff)'),nl,
        write('contact detail:'),nl,nl,
               write('E-mail:teke.style@gmail.com'),nl,nl,
              write('Phone: 0936726496'),nl,nl,
 retractall(known(_,_,_)),      % clear stored information
 agri_land(X),
 write('The land is '),write(X),nl.
identify:-
 write('I can''t identify the land'),nl.

land(sand):-
        do_you_have(agri_land),
        soil_color(black),
        structure(weakly_aggregated),
        permeability_infiltration(low),
        water_holding_capacity(low),
        drainage(well_drained),
        it_is_in_a_conventional_soil_ph_class(strongly_acidic_type_soil(ph_level(5.5))).

land(silt):-
```

```
    soil_color(white),
        structure(moderately_aggregated),
        permeability_infiltration(high),
        water_holding_capacity(high),
        drainage(poorly_drained),
        it_is_in_a_conventional_soil_ph_class(slightly_alkaline_type_soil(ph_level(7.5))),
        type(teff).

land(clay):-
        soil_color(gray),
        structure(strongly_aggregated),
        permeability_infiltration(low),
        water_holding_capacity(low),
        drainage(excessively_drained),
        it_is_in_a_conventional_soil_ph_class(strongly_alkaline_type_soil(ph_level(8.7))),
    type(teff).

crop(teff):-
        land(sand),
        type(teff).
crop(maize):-
        land(silt),
        it_is_in_a_conventional_soil_ph_class(slightly_alkaline_type_soil(ph_level(7.5))),
    type(maize).

crop(barely):-
        land(clay),
        type(barely),
        type(wheat).
crop(wheat):-
        land(silt),
    land(sand).
```

```
agri_land(sand_type_soil_and_is_more_suitable_for_cultivating_barely_and_sorghum_because_t
        he_soil_PH_found_in_the_soil_is_matche_with_the_range_of_soil_PH_required_for_bar
        ely(5.5-7.5)-and_sorghum(5.5-8.7)-production):-
        land(sand),
        crop(teff),
    it_is_in_a_conventional_soil_ph_class(strongly_acidic_type_soil(ph_level(5.5))).
agri_land(suitable_for_wheat):-
        land(silt),
        it_is_in_a_conventional_soil_ph_class(slightly_alkaline_type_soil(ph_level(7.5))),
    crop(maize).
agri_land(silt_type_soil_and_is_more_suitable_for_cultivating_teff_maize_wheat_and_sorghum_
        because_the_soil_PH_found_is_matches_with_the_range_of_soil_PH_required_for_teff(
        6.0-7.5)-maize(6.3-8.0)-wheat(6.3-8.0)-and_sorghum(5.5-8.7)-production):-
     land(silt),
         it_is_in_a_conventional_soil_ph_class(slightly_alkaline_type_soil(ph_level(7.5))).
agri_land(clay_type_soil_and_is_more_suitable_for_cultivating_sorghum_because_the_soil_PH_f
        ound_is_matches_with_the_range_of_soil_ph_required_for_sorghum(5.5-8.7)-
        production):-
     land(clay),
         it_is_in_a_conventional_soil_ph_class(strongly_alkaline_type_soil(ph_level(8.7))).
agri_land(suitable_for_sorghum):-
         land(silt),
         crop(wheat),
         it_is_in_a_conventional_soil_ph_class(slightly_alkaline_type_soil(ph_level(7.5))),
         permeability_infiltration(high).
```