Advising Farmers on Crop Selecting Using Expert Systems

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Abstract- Agriculture and plantation is an important and interesting research area everywhere in the world and Sri Lanka is no exception. Nowadays available land area for a plantation is becoming scarce. This scarce resource is frequently wasted through our bad practices and improper management. Cultivation is a more economical but complex process. Selecting and maintaining suitable crops for the maximum profit involves a sequence of tasks. These tasks and the whole process need a lot of expert knowledge and experience. But unfortunately, people having this type of knowledge are very limited. Their assistance is not available when the person who is going to cultivate needs it.

We propose a knowledge-based approach to land evaluation for the selection of suitable agricultural crops - Crop Advisor."Crop Advisor" is a Knowledge-based Decision Support System (KBSS) for crop selection. The expert system is powered primarily by human knowledge collected from crop experts. It also considers economic feasibility of raising a crop by taking market price, cost of production, access to market and yield levels. The "Crop Advisor" expert system then suggests with consultation with farmer (through a graphical user interface) a suitable agricultural crop that can be grown in a land unit with reasoning.

Key Words: *Expert system, Inference Engine, Knowledge Base*

1. Introduction

Agriculture plays a major role in our country's economy. Approximately 21% of the gross domestic product and 23% of the total export earnings are derived from agriculture. The crop subsector has a large number of small farmers on 1.8 million small holdings. Nearly half of the holdings are less than 0.5 ha.

But unfortunately, present farm family income is comparatively low. Hence farming is becoming a non attractive sector in the economy. The yields of most crops have remained stagnant for over a decade. Some lands are uncultivated. Food imports are increasing. Crops cultivated in marginal lands give very low yields which should be avoided. This project indicates new approaches in order to transform the present low productivity farming into more productive farming systems with the goal of significantly increasing the farm family incomes much above the poverty line.

This system contains information about distribution of a number of crops, considering soil, biological, social and economic considerations.

Currently, when the farmer wants to cultivate his land he wants to get an appointment for the necessary information. Without this correct information, sometimes farmers will be lost at the end. This can happen in many ways such as,

- Agricultural instructors contain little knowledge,
- Instructions are not available at the correct time.

In order to alleviate this problem, our project identified a powerful tool with extensive potential in agriculture.

The goal of this project is to increase the yield quality of agricultural production through the introduction of expert systems to enhance crop management and farm support.

The rest of the paper is organized as follows. Section 2 describes about the background information related to the project. Section 3 is on the design aspects considered in the development, and section 4 reports on the implementation of the proposed system incorporating the expert system. The evaluation process carried out on this research, the evaluation results and their explanations are described in Section 5.

2. Background Information

2. 1. Climate and Rainfall

Most parts of Sri Lanka are hot and humid. Despite the relatively small size of the country, there is a considerable variation in climate over time and space.

The rainfall pattern in Sri Lanka is bimodal with two periods of monsoonal precipitation resulting in two distinct cultivation seasons. The major cultivation season, called Maha, is from October to February. The precipitation during this season comes from the northeast monsoon of October-December. The harvesting period of crops cultivated in Maha is at the end of January, usually a dry period. The second crop season is called Yala and it extends from May to July. The rains in this season come from the southwest monsoon during mid-April to June. The remaining months of the year are dry, and almost no cultivation occurs during this period.

The annual average rainfall varies from below 1000 mm (39") over a small region in the semi-arid parts of the north-west and south-east of the island to over 5000 mm (197") at a few places on the south-western slopes of the central hills.

There are four rainfall seasons during the year. These are:

1. The south-west monsoon period (May to September)
2. The inter-monsoon period following the south-west monsoon (October to November)
3. The north-east monsoon period (December to February)
4. The inter-monsoon period following the north-east monsoon (March to April)

2.2 Temperature

There is little seasonal variation of temperature in Sri Lanka. It depends on the elevation ranges. The temperature variation through the year is low with the mean ranging between 21.1 and 31.7°C.

2.3. Zones and Regions

With in the two main rainy seasons, rainfall distribution across the country is determined by topography. The whole island benefits from the northeast monsoon. The southwest monsoon is intercepted by the central mountains resulting in 2000-5000 ml of rain per year in the highlands and southwest part of the island. This is the "wet" zone of the country covering 1.53 million ha. The "intermediate" zone covering 4.17 million ha receives 2000-2250 ml of rainfall per year, and is hotter than the "wet" zone. The dry zone receives only 900-1000 ml of rain, with the highest temperatures ranging between 28 and 30°C. In terms of "Wet Zone" in the southwestern region, it includes central hill country, and "Dry Zone" covering predominantly, northern and eastern part of the country, being separated by an "Intermediate zone," skirting the central hills except in the south and the west

2.4.Cultivation Time

Most vegetables are grown about equally in both Maha and Yala, except for some up-country vegetables, such as onion, which are mainly grown in the Yala season, and tropical vegetables, such as chili, which are mainly grown in the Maha. Total production of vegetables in Maha is slightly higher than that in Yala. No significant difference in the yield of most vegetables grown in Maha and Yala was observed.

2.5. Soils of Sri Lanka

The soils of Sri Lanka have been classified at Great Group level for the whole country and Series level for some parts.

The chemical fertility of Wet Zone soils is poor because these soils have been extensively leached due to high rainfall. The base saturation of the Dry Zone soils remains at a higher range.

Apart from chemical soil categories, basically soil can be categorized in to three , according to the soil texture.

- Sand
- Silt
- Clay

When considering their mixtures there are 11 sub categories.

- Clay
- Silty clay
- Silty clay loam
- Silty loam
- Silt
- Loam
- Sandy loam
- Sand
- Sandy clay loam
- Clay loam

2. 6. Introduction about Expert System

An expert system is a computer program designed to simulate the problem-solving behavior of a human who is an expert in a narrow domain or discipline.

An expert system is normally composed of a knowledge base (information, heuristics, etc.), inference engine (analyzes the knowledge base), and the end user interface (accepting inputs, generating outputs).

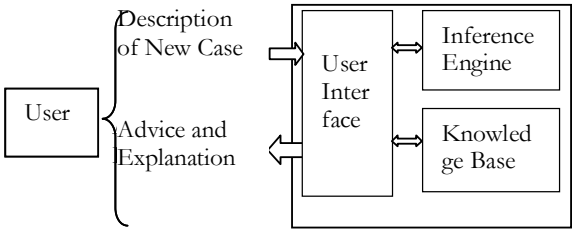

Figure 2.1: Major parts of an expert system

3. System Overview

The Expert System for Agriculture uses a rule base which uses the experience and knowledge of a human expert captured in the form of IF-THEN rules and facts which are used to solve problems by answering questions. Questions can be typed at a keyboard attached to a computer.

Yield of the particular crop depends on several factors; such as rainfall pattern, land elevation, soil texture, soil pH, soil drainage, temperature. Experts related to the Department of Agriculture have identified some categories of above mentioned factors.

According to the rainfall pattern, Sri Lanka has basically three zones. They are,

- Wet Zone
- Dry Zone
- Intermediate Zone

When considering the elevation and temperature, all these zones can be categorized in to another three groups.

- Up Country
- Mid Country
- Low Country

According to these factors there are special regions called Agro ecological zones. Sri Lanka has 22 Agro ecological zones.

- WU_1, WU_2, WU_3, WM_1, WM_2, WM_3, WL_1, WL_2, WL_3,
- IU_1, IU_2, IU_3, IM_1, IM_2, IM_3, IL_1, IL_2, IL_3,
- DL_1, DL_2, $DL_{3\&4}$, DL_5

WU_1 – Wet zone up country
IM_1 – Intermediate zone mid country
DL_5 – Dry zone low country

Soil is very important to the crop cultivation. It depends on the land elevation and also soil texture. I have explained the majority of soil textures in Sri Lanka in chapter two.

Land elevation can be considered as high land or low land. These two factors make the soil as,

- Well Drain
- Poor Drain
- Imperfect

After studying the factors which affect the healthy growth and quantity of yield, we have identified some input information for the expert that the user wants to deal with the system. Selection of the crop depends on these parameters.

Mainly "Crop advisor" consists of three modules. These modules are designed for the user known information and for the user unknown information. These modules are

- Crop Selection
- Fertilizer Plan Selection
- Soil Selection

First two modules are for the user known information and the last module for the user unknown information.

3. 1. Input Parameters

After studying of the background information and most of the other information, we have identified that there are five input parameters to give the data to the expert. Those are

➢ Zone
- Wet Zone (WZ)
- Dry Zone (DZ)
- Intermediate Zone (IZ)

- Sub Zone
  - WU_1, WU_2, WU_3, WM_1, WM_2, WM_3, WL_1, WL_2, WL_3, IU_1, IU_2, IU_3, IM_1, IM_2, IM_3, IL_1, IL_2, IL_3, DL_1, DL_2, $DL_{3\&4}$, DL_5

- Soil & Drainage
  - Clay (C)
  - Silt clay (StC)
  - Silt clay loam (StCL)
  - Silt loam (StL)
  - Silt (St)
  - Loam (L)
  - Sandy loam (SL)
  - Sand (S)
  - Sandy clay loam (SCL)
  - Clay loam (CL)
  -
- Land Orientation
  - High Lands
  - Low Lands

Figure 3. 1 – Land Orientation

- Crop Period
  - January – March (JM)
  - April – June (AJ)
  - July – September (JS)
  - October - December (OD)

If one doesn't know what his/her sub zone is, he/she can give the **district** and also **agrarian services area** as the input. Then the system will find the correct subzone accordingly, through the SQL data base.
If the soil type is not known, there is a module to select soil texture for user unknown information.

3.2. Design of the Knowledge Base

When designing a knowledge base we have studied many theories related to the knowledge representation.

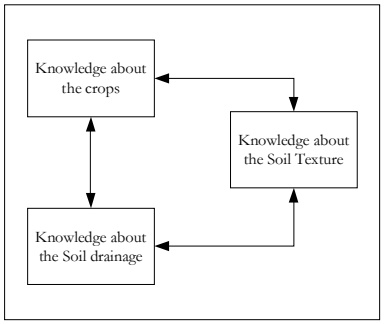

Figure 3. 2 – Knowledge Base

Then we have designed a rule based system to store the above knowledge, whose basic components are:(Shown in figure - 3.3, figure – 3.4, and figure – 3.5.)

Attributes :$X_1, X_2, \ldots, X_{n1}$
Conditions :$C_1, C_2, \ldots, C_{n2}$
Rules :$R_1, R_2, \ldots, R_{n3}$
Actions :$A_1, A_2, \ldots, A_{n4}$

We only need to execute an action when a rule containing it is fired. A rule is fired only when all of its conditions are satisfied. If there is a missing parameter, several rules have to be fired. To detect this we assigned a value to each condition and use it to keep track of exactly how many of the conditions in the rule are currently satisfied. Thus we only check to see if a rule is ready to fire when one of its conditions has become true. From our inference algorithm we can select the most corrective actions from the total evaluation points.

Here are mainly two types of rules.

- Main Rules
- Sub Rules

At the beginning, the system considers only main type rules. It contains five conditions. It involves making decisions about suitable crops according to the given input factors. Following figure shows the format of main rule.

R	A	C1	C2	C3	C4	C5
		X1	X2	X3	X4	X5
		3 Point	5 Points	7 Points	11 Points	19 Points

Figure 3. 3 – Format of Main Rule

we have assigned values for each condition. It is based on the priority.

C_1 = Zone
C_2 = Sub Zone
C_4 = Soil
C_5 = Soil Drainage
C_6 = Crop Period
A = Most suitable Crop/s
R = Rule Number

Expert systems have to handle incomplete inputs in decision making. CROP ADVISOR also has this common problem. Therefore, the knowledge base must contain knowledge to handle the incomplete inputs. Sub rules contain this type of knowledge. Sub rules involve decision making, only some parameters missing at the inputs.

R	A	C1	C2
		X1	X2

Figure 3. 4 – Format of Sub Rule

This type of rule can be used to two purposes.

It can be used to select the soil drainage, because it is not an input parameter. The system finds it using other parameters. Given below is the condition and action of this rule.

C_1 = Soil

C_2 = Land Orientation

A = Soil Drainage

the other purpose is to find the soil of the particular land, when it is missing in the input parameters. Using information about the sub zone and orientation of the land we can find the soil as an action.

C_1 = Sub Zone
C_2 = Land Orientation
A = Majority Soil

But some input parameters can not be found from other inputs such as sub zone, land elevation, and crop period. When a user misses this type of input, system will show all crops related to the other given inputs.

When rules are examined by the inference engine, actions are executed if the information supplied by the user satisfies the conditions in the rules.

Conditions are expressions involving attributes and the logical connective . For example,

Zone = wet and
Subzone = WM1 and
Soil = CL and
Drainage = Well
Crop period = JM

We do not consider the cultivation method under Rain fed, because under sub zone and crop period, system can identify the amount of rain for the particular sub zone.

Thus, a full example of a rule would be as the following.

Main Rule:

Most suitable Crop (xxxx) :- Zone(wet), Sub Zone(WM1), Soil(St), Soil Drainage(well), Crop Period (JM)

Sub Rule:

Soil Drainage (Well Drained) :- Soil(St), Land Orientation(High)

Majority Soil(C) :- Sub Zone (WM1), Land Orientation (High)

After the selection of the suitable crops, CROP ADVISOR may advise on fertilizers. When selecting a fertilizer plan for the selected crop, there is another type of rules needed to fire.

R	A	C1	C2	C3	C4
		X1	X2	X3	X4

Figure 3. 5 – Format of secondary knowledge base Rule

C_4 = Period
C_3 = Soil
C_2 = Sub Zone
C_1 = Crop
A = Most suitable fertilizer Plan

3.3. Working memory

- The contents of the working memory are constantly compared to the production rules.
- When the contents match the condition of a rule, whenever a condition is matched, it is added to certain points, and the rule contains the maximum points copy to the another place to fire and its action is executed.

– The system then fires the rules sequentially, within the working memory.

– More than one production rule may match the working memory.

3. 4. The Inference engine

Two methods of inferences are used often;forward chaining and backward chaining. In our project we present an inference engine which operates by the method of forward chaining.

In order to execute a rule based expert system using the method of forward chaining, it is merely needed to fire actions whenever they appear on the action list of a rule whose conditions are true. This involves assigning parameters to attributes, evaluating conditions, and checking to see if all of the conditions in the rule are satisfied. A general algorithm for this might be,

While parameters for attributes remains to be input
Read parameters an assign to attribute
Evaluate conditions
Fire rules whose conditions are satisfied

Several points about this require consideration. First, decide which rules are fired first. In here it is to fire the selected rules sequential.

There are several activities to do within an inference engine.

- Check input parameters against the conditions contain rules.
- Calculate the total points.
- Ask for missing parameters.
- Guess missing parameters using sub rules.
- Explanation against the inputs.
- Select most suitable crops.
- Give priority with compare of demand forecasting

4. Implementation

4. 1. User interfaces

The system has several interfaces to communicate with the user

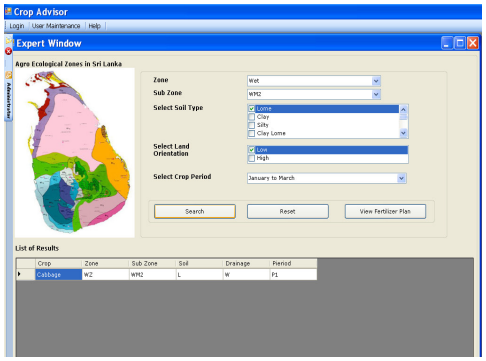

Figure4.1- Main interface of the system

This interface indicates all parameters. If a user misses some parameters,the CROP ADVISOR can identify those inputs from the given inputs.

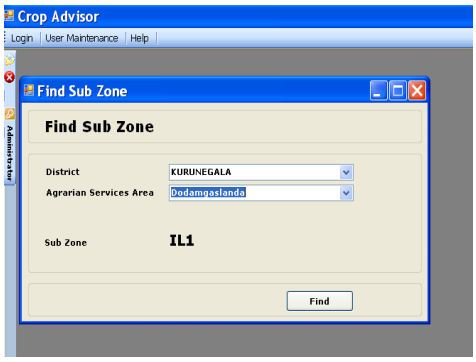

Figure 4.2 – Interface to find the sub zone

4. 2. Implementation Tools

- Visual Studio 2005 C#.net - inference engine design and interfaces.
- Microsoft Access – Develop knowledge base.

5. Evaluation and conclusion

The main goal is to help the crop selecting task and this has been achieved. Experts at the Ganoruwa research center and the Department of Agriculture helped to analyze the system and to build a 90% accurate knowledge base.

Another goal is to develop a fertilizer plan for the particular crop which could not be achieved.

The system has been tested with about 100 people and farmers. Outputs were 80% accurate.

Since it is difficult to apply anything learnt from books directly in the real world we faced some operational problems.

Another lesson was about planning. In industry, plans can be made with 100% accuracy but going according to that plan is very much difficult. Practically a lot of problems come and they have to be changed accordingly.

5.1. Future Work

A system like this is some what new to the department of agriculture, and also to the farmers who are used to traditional methods. Therefore it has to be people; especially farmers who should be educated on this regard. This system can be developed further including some new features and improving the existing features.

The future work of this system can be described as followed. The responsible operator/ user should be able to use the system.

The targeted main users are farmers. Then they will be able to use this system. Therefore, first and foremost, the system must be user friendly with the option of selecting a familiar language to work.

Another extension is to develop web enable system with this knowledge base. It will give more facilities to the farmers.

Other than the input factors, there are various factors affecting the crop production,such as soil pH and temperature conditions. But in this stage we have not considered those factors and we are hoping to improve the knowledge base and also the whole system using these most of factors.

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