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WEK 98302

EXPERT SYSTEM ON CROP ECOLOGY
ADVISER
WXES3182

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Acknowledgement

I would like to convey my heartiest thank you for the following individual for their enormous support, advises, motivations, understanding and help.

TO:

Prof. Madya Dr. Mohd. Sapiyan Baba (project supervisor)

Prof. Madya Dr. Syed Malek Fakar Duani (project moderator)

Mr & Mrs Michael Gumpil

Bobbie & Yeye

Jay Albert James

Kivik, Ika, Mini, Jane, Lyn, Guns, Zanie

And

those who had contributed wonderful ideas to the development of CEA system.

Abstract

The title of this project is CROP ECOLOGICAL ADVISER (CEA) system. It is an expert system project written using the Visual Prolog 5.2 language. CEA intended to help farmers by giving recommendations to them on the list of crops that are suitable to be planted on his area based on the ecological factors in his place. The factors include mean temperature, rainfall per annum and soil. The system can provide explanation on why certain crops are recommended instead of others. By this, the system can aid in making decision on which crop can be cultivated on his land based on the recommendations. Apart from that, the system can also provide explanation on how it derives the conclusion. If a farmer had grown crops, then he can use this system to determine the suitability of the crop planted on his land. CEA system is able to give explanation to user why certain crops are not suitable to be planted in an area.

CEA system is developed using rule-based approach. This approach is a benefits because the rules can be added and modified anywhere in the knowledge base. Furthermore, the changes here do not affect the control mechanism of CEA system. The inference engine strategy used in CEA is the forward chaining. It gathers data from system user and from there it will infer what can be concluded from it.

CEA offers advantages and limitations. Advantages of it can be seen from developer perspective - ease of rule addition and modifiability and explanation-how facilities can help to understand the processing of CEA - and from end-user perspective - justification of its recommendation, user friendly system, cater for

crops scientific names, range values usage for ecology factors and more than one recommendation to help farmers diversify crops in his or her area. However, CEA only caters for ecology factors, can be slow, rules require exact matching and exact information are the main drawbacks of CEA. Further works for CEA include additional rules not only from ecology perspective but also from the aspect of crop management, fertilizers and pesticides management.

	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12	Wk13	Wk14	Wk15
Phase 1															
Gathering crops info															
Find expert system examples															
Learn VP 5.2 and its GUI															
Phase 2															
Interface design															
Coding design															
Coding development & testing															
Full documentation															
Phase 3															
Test and debug															
Refinement															

Legend
Wk Week

1.0 Project Definition

1.1 Introduction

Agriculture is defined as the science or practice of cultivating the land and rearing animals (Oxford Advanced Learner's Dictionary, 1987). It is still one of the most important sector in many countries around the world. Apart from occupying world's labour force employment, it also contributes in form of foods to human and animal, medicinal values, sources of nutrients energy and products such as clothes, cosmetics, paper, woods and many more. In Malaysia, about RM18, 166 million was allocated for agriculture sector by government in the year 2000 (Economic Report 2000/2001, 2000). All sub-sectors in agriculture also expected to record positive growth. Although science and technologies industries have been blooming and growing rapidly but still, agriculture sector is important and one of the major source of national income to many third world countries.

Ernst Haeckel introduced the term *ecology*. It is defined as the study of economics of nature (Remmert, 1980). The field ecology is generally subdivided into three areas that is autecology, population ecology and research on ecosystem.

For this expert system project, CROP ECOLOGY ADVISER (CEA), it will show the influence of ecosystem ecology to crops. These ecology factors are temperature, rainfall and soil. World's ecology evokes different kind of respond from different plants, therefore it is important for farmers to be knowledgeable about the ecology factors in his area. To know this information then he can fully utilizes it and cultivates the most suitable crops. Without this knowledge, many

might just rely on their own experience or potential market and will decide to lesser suitable crops or might take longer decision to choose the suitable crop. Decisions are also subjectively made and not being consulted to an expert. As a result, crop productions might not reach its full potential or it might been affected because of excessive heat that causes drought or excessive rainfall that causes waterlog. CEA system will help farmers by giving recommendations on the list of crops that are suitable to be cultivated based on the ecology input by the system user. It can also determine the suitability of the already planted crops based on the ecology factors given by the user.

1.2 Objective

Objectives and aims of CEA are as follows (Latihan Ilmiah 1, 2001):

- To develop an expert system that designed to aid farmers in making decisions on which crop will be cultivated on his land based on the recommendations given by the system.
- To give alternatives to the farmers on other crops that can be cultivated on his land. By this, he can diversify crops on his land.
- If a farmer had a particular crop planted, this system benefit him as it gives him the information on the level of suitability of the crop planted based on the ecological factors of the area.
- It serves as an intelligent substitute if human experts are not there to be consulted by farmers and also to bulky reference books and handbooks.

1.3 Scope

There are many factors that influence crop cultivation. These factors are ecology factors, its propagation, husbandry, good crop management, fertilizers, farming methods and equipment and also advancement in science and technology farming techniques. However, only ecology factors are considered in this system - temperature, rainfall and soil. For crops, because there are millions of plants species in the world, CEA system will only consider monocotyledon plants that consist of 11 orders and 46 families of plants.

2.0 Domain Knowledge

Monocotyledon crops consist of 11 orders and 46 families. These crops have large number of species. Each species have different characterization according to its own group.

These crops are example of many species of monocotyledon plants with its ecology factors. All are included in CEA knowledge base.

Crop	Temperature (°C)	Rainfall (mm)	Soil
Agave Fourcroydes (Henequen)	10 - 38	720 - 1500	Calcerous
Agave Sisalana (Sisal)	20 - 27	1000 - 1250	Alluvial, colluvial, Red earth, gneiss, volcanic soil.
Furcraea Gigantea (Mauritius Hemp)	10 - 18	760 - 960	Rocky
Phormium Tenax (New Zealand Flax)	10 - 38	500 - 3800	Alluvial
Sanseviera Guineensis (Guineensis)	28 - 33	1000 - 2500	Calcerous
Allium Cepa (Onion)	25 - 32	1000 - 2500	Peat
Calocosia Esculenta (Taro)	25 - 32	2500 - 4000	Calcerous
Xanthosoma Saggitifolium (Tannia)	25 - 32	2500 - 4000	Calcerous
Ananas Comosus (pineapple)	10 - 32	635 - 2500	Peat, swamp
Dioscorea Trifida	25 - 30	1000 - 3000	Alluvial, colluvial

(Cush cush yam)			
Eleusine Corocana (Finger Millet)	18 -27	900 - 1250	Sand, lateric
Eragrotis Teff (Teff)	25 - 28	1000 - 2500	Alluvial
Oryza Sativa	28 - 35	1000 - 3000	Clay, sand, lateric, alluvial
Saccharum (Sugar cane)	32 - 38	1525 - 2500	Calcerous, alluvial, sand
Zea mays (Corn)	21 - 30	450 - 900	Colluvial, alluvial

Figure 2.1: Crops and its ecology factors

For the ecology factors, the most important factors that influence the cultivation of crops are the temperature, rainfall and soil. These factors are vital because each of it affected other organism's evolution (Remmert, 1980). According to Mr. John Siegfred (senior officer at the Department of Agriculture, Sabah division), expert usually recommend suitable crops by determining its growth potential corresponding to the temperature, rainfall and types of soil of the area. Then, other important factors such as crop management, fertilizing the soil, pesticides management and its market value are then considered. According to him, government usually subsidies farmers with seeds of new crops and provide expert consultation to those who are new to farming techniques and methods. Monocotyledons crops that are widely cultivate in our country are *Oryza Sativa* as it is the main source of our foods. There are other important crops as well but all those come from different crop classification.

According to Mr. John, during consultation with growers who are new to agriculture sector, they are concern with what type of crops that they can cultivate. The question asked although sounds easy but a lot of factors need to be considered. A crop might be suitable to be grown in a place but does the market have a niche for the particular crop? This is also the main concern among new farmers. Therefore, recommendations are given based on many factors and the most important factor is the potential growth of the crop corresponding to the ecology in the area. Ecology information is gathered so that expert can recommend suitable crops to be cultivated in the area. Thus, this is the basis of how CEA system will come out with the recommendations. It will gather information first and then give recommendation of what can be inferred from that information.

3.0 Design and Development

3.1 Literature review on other rule based systems

As CEA system is implemented using rule-based system, therefore it is essential to look to other systems that implement such procedure. One of system that implements rule-based approach is the Wheat Real-Irrigation (ESWI) system. This system will help farmers to make decision if irrigation is presently necessary based on crop water requirements, crop growth condition, current soil moisture and forecast in future three days. It will also help users to make decisions on winter wheat irrigation so that the goal of water saving in irrigation can be achieved and it also help farmer to make correct decisions on agricultural practice. In its knowledge base, it consists of detail information on temperature, crop, Forecast, meteorology. On example of rule contained in the knowledge base is:

IF state = becoming green and crop situation = strong

THEN suggestion = no irrigation and delay the growth of crop

Factors	Detail information on
Temperature	• Soil temperature • Wilting point • Field capacity • Current moisture • Soil content
Crop	• Crop type • Daily water requirement • Depth of root • Crop factor • Cropping area
Forecast	• Rainfall • Wind speed • Temperature

Meteorology	• Rainfall • Temperature • Relative humidity • Solar radiation • Wind speed • Sunshine hour

Figure 3.1: Rule information contained in ESWI system

The knowledge is reasoned with forward chaining technique. It produces an understanding of a situation from available information given by the user.

Another system that used rule-based approach is the MUSH system (Durkin, 1994). The Shiitake mushroom was chosen as a test case for MUSH system because it offers as excellent marketing potential and relatively few human experts exist who are capable of assisting growers with this crop. It is designed to aid farmers in the management of crops. To effectively grow and manage any crop, a grower must have knowledge in a variety of areas. For assistance, the grower will often consult with one of the available regional agriculture extension service offices, which maintains experts on various crops. However, factors such as time, distance, access during office hours and many other factors affecting, create obstacles to the grower for obtaining help. MUSH was developed to provide readily available assistance in the following areas of crop production: crop management problem diagnosis, financial planning and crop management tutoring. The system also provides sources of references to obtain additional information on various crop topics. The system inter-plays diagnostics with tutoring so that after problem is solved, the user is tutored on how to avoid the problem in the future. The system was built using KnowledgePro and it was developed at the University of Akron.

3.2 Expert system application for CEA system

The most important thing to consider when cultivating crops is to make decision what type of crop to cultivate. As what human expert had emphasized, several considerations need to be done. One of it is whether the crop is suitable to grow with such ecology factors. Only then, farmers can consider other factors such as propagating crops, farm and pesticides management and also the use of fertilizers. These factors came only after making the right decision on what crops to cultivate. This is because no matter how good the farmer manage his farm or apply large amount of fertilizer on his land the crop would not successfully grow if it does not suit with the area ecology. Therefore, an expert system for crop ecology is a way to help farmers to make decision on crops. Furthermore, when human expert cannot be consulted because of distance and time constraint then this system would be beneficial for farmers.

Expert system was developed because of its ability to model the problem solving ability of human expert. It is a quest for an intelligent machine. For CEA system, human expert knowledge was transferred into computer program that is written using Visual Prolog 5.2 so that it will help farmers to determine and make decision on what crops to be cultivated. It can give recommendation, just like an expert what type of crop that is suitable with the ecology factors. Furthermore, if the user need justification why the crop is recommended, CEA will be able to give explanation on that. Other than that, CEA can also be used to determine the suitability of crop already planted in an area. Crop suitability to the ecology is important because farmers will know what is the best crop can be cultivated in

his or her area. CEA system is also able to tell why certain crop is not suitable or if there are difference in temperature or rainfall, it tells whether the difference is tolerable or not. Then farmers can fully utilized this knowledge, cultivate the crop and the crop can grow successfully. Expert system can be modeled as follows:

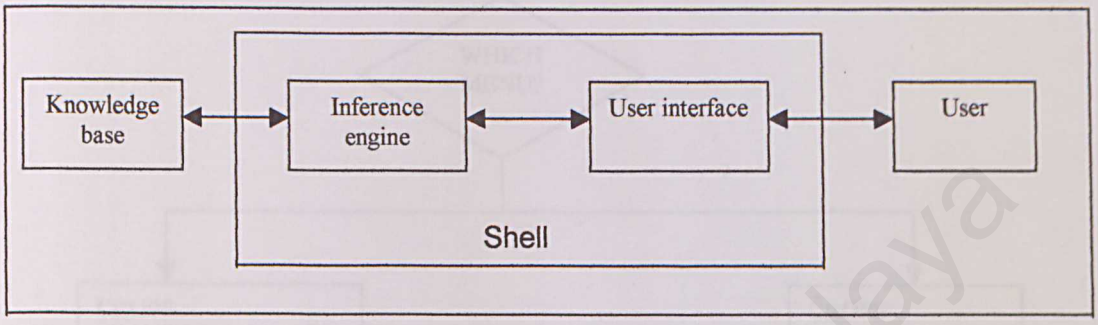

Figure 3.2: Expert system model

The knowledge base for CEA will contain the expert knowledge of what crop is suitable to cultivate based on temperature, rainfall and soil of the area. All the knowledge will be represented in rules.

The inference engine will serve as the processor of the system. For CEA, forward chaining technique is implemented to draw conclusion about the problem. From the information supplied by the user, its engine will search the rules and match to determine which one will fire. If more than one rule can fire then all the conclusion will be display to the user.

3.3 Flow Chart and Data Flow Diagram

3.3.1 Flow Chart for CEA

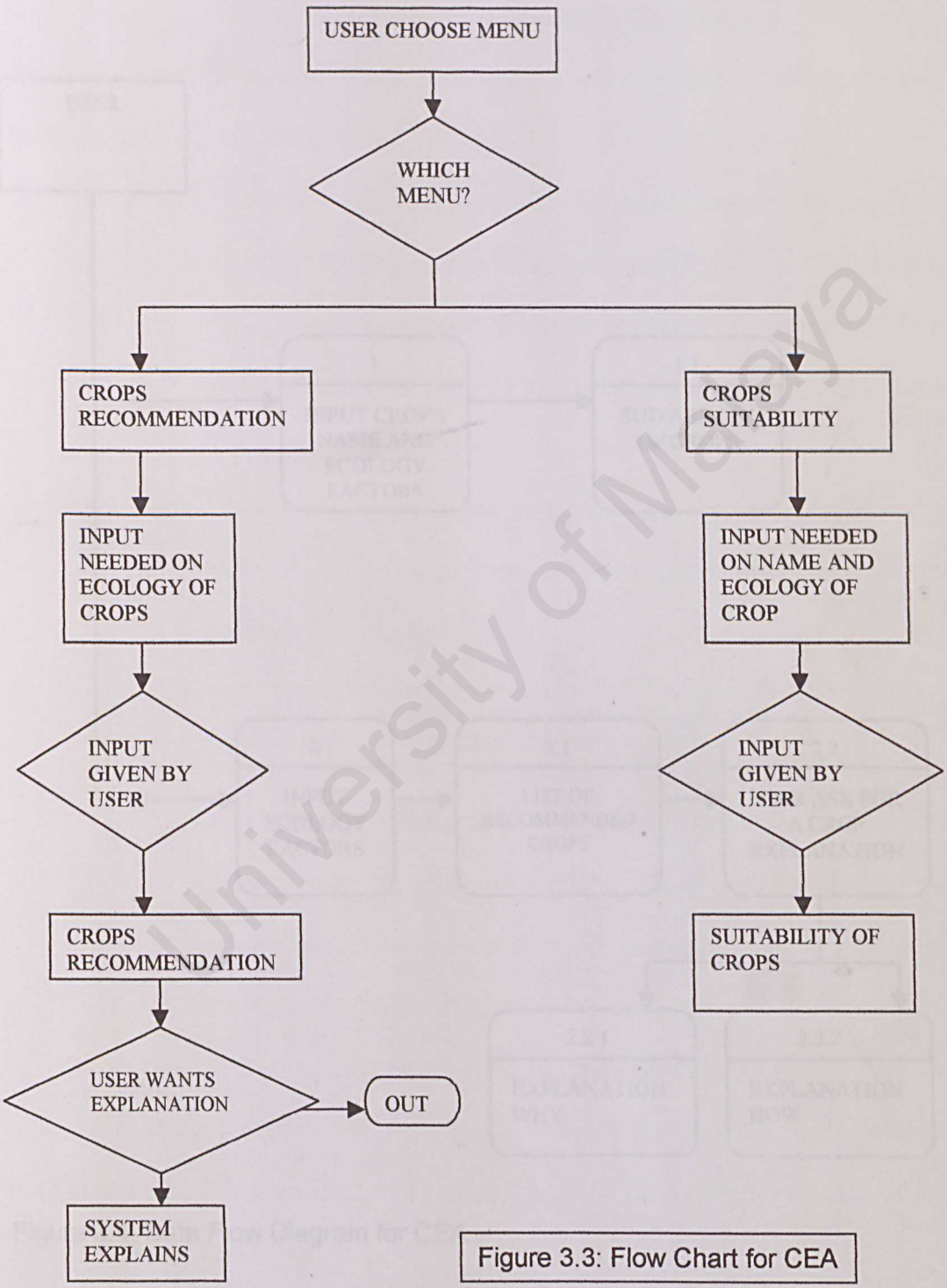

Figure 3.3: Flow Chart for CEA

3.3.2 Data Flow Diagram

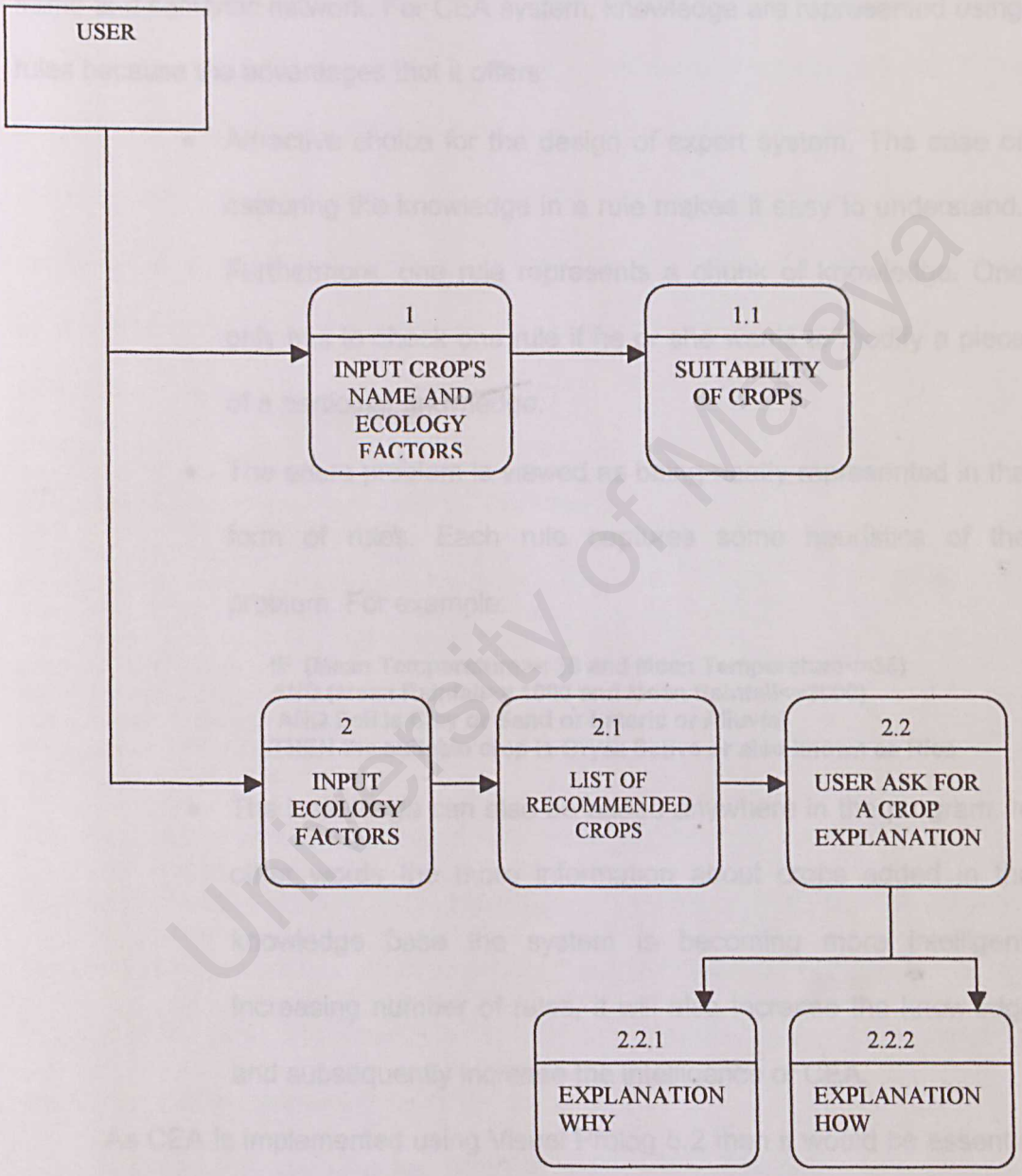

Figure 3.4: Data Flow Diagram for CEA

3.4 Rule-based approach for CEA

Knowledge obtained from expert must be represented in the knowledge base. There are several techniques of representing knowledge such as rules, frame and semantic network. For CEA system, knowledge are represented using rules because the advantages that it offers:

- Attractive choice for the design of expert system. The ease of capturing the knowledge in a rule makes it easy to understand. Furthermore, one rule represents a chunk of knowledge. One only has to check one rule if he or she wants to modify a piece of a particular knowledge.
- The entire problem is viewed as being neatly represented in the form of rules. Each rule captures some heuristics of the problem. For example:

  IF (Mean Temperature>= 28 and Mean Temperature<=35)
  AND (Mean Rainfall>= 1000 and Mean Rainfall<=3000)
  AND Soil is Clay or Sand or Lateric or Alluvial
  THEN the suitable crop is Oryza Sativa or also known as Rice

- The knowledge can also be added anywhere in the program. In other words the more information about crops added in the knowledge base the system is becoming more intelligent. Increasing number of rules, it will also increase the knowledge and subsequently increase the intelligence of CEA.

As CEA is implemented using Visual Prolog 5.2 then it would be essential to show how the rules are presented using the tools. An example of a rule written in Visual Prolog 5.2 is:

```
crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=28, MeanTemp<=35,
MeanRain>=1000, MeanRain<=3000,
Soil="Clay",
crop_name(Rule,X,"Rice"),
write(Rule, "  ", X),nl,fail.
```

When user enter the ecology information, the system will use the values (mean temperature, mean rainfall and soil) to search the rules which one will fire. If the condition in the rule is satisfied then it will search the crop_name clause to display the name of the crop by its scientific name and common name. This is essential because farmers might know the common name of a crop rather than its scientific name. The crop_name can be search from the following facts:

```
crop_name(1,"Agave Fourcroydes","Henequen").
crop_name(2,"Agave Sisalana","Sisal").
crop_name(3,"Furcraea Gigantea","Mauritius Hemp").
crop_name(4,"Phormium Tenax","New Zealand Flax").
crop_name(5,"Sanseviera Guineensis","Guineensis").
crop_name(6,"Allium Cepa","Onion").
crop_name(7,"Calocasia Esculenta","Taro").
crop_name(8,"Xanthosoma Saggitifolium","Tannia").
crop_name(9,"Ananas Comosus","Pineapple").
crop_name(10,"Dioscorea Trifida","Cush Cush Yam").
crop_name(11,"Eleusine Corocana","Finger Millet").
crop_name(12,"Eragrotis Tef","Teff").
crop_name(13,"Oryza Sativa","Rice").
crop_name(14,"Saccharum","Sugar Cane").
crop_name(15,"Zea Mays","Corn").
```

The crop_name clause is supplied with three arguments. The first one is the number of the rule, which indicate the crop entry to the system. This is vital when the system is generating an explanation it will ask the user to key in the rule number of the crop. The use of *fail* in CEA is important so that it can generate more than one recommendation to the user.

CEA system can give two types of explanation. The first one is when the user want to know why the crops are recommended to be cultivated at his or her farm. This is important to give justifications for its recommendation. Furthermore,

user might want to know why the crop is recommended instead of other crops. If more than one crop is recommended to the user then he can choose which crop that he wanted to have information about. Supplying the given rule number of the crop when the CEA gave its recommendation does this. Following is the coding of the explanation why facility:

```
explanation(Rule):-crop_explain(Rule,Explain),
                   write("CEA :\t"),
                   write(Explain),nl.
```

The explanation is generated by unifying the Rule variable entered by user with the rule number contained in the crop_explain facts. The clause crop_explain will find the first argument of the clause that match Rule. If it is found, then the explanation will be displayed to the user. An example of a crop_explain clause for crop *Agave Fourcroydes* is as follow:

crop_explain(1,"Requires plenty of heat therefore temperature between\n\t10 C to 38 C is suitable for its growth.\n\tIt can withstand drought but not waterlogging. \n\tShallow calcerous gravel on porous limestone is good.").

For the explanation-how facility, the user can also asked CEA how did it conclude the recommendation. This type of facility will help user or other programmer to understand how the solution is found. By this, it will aid further works to be done on CEA if other system developer wants to improve processing capabilities of CEA. Following is the coding for explanation-how:

```
explain_how(Rule):-
consult("crop_ecology.pro",crop_ecology),
consult("crop_name.pro", crop_name),
crop_explain(Rule,_),
write("CEA :\t"),
write("By using rule number ",Rule,","),
crop_name(Rule,Sci,Com),
write(" mean temperature, mean rainfall and"),nl,
write("\tsoil information given, I concluded that"),nl,
```

```
write("\tthe suitable crop for your farm is ", Sci),nl,
write("\tor also known as ", Com,"."),nl,
crop_ecology(Sci,Mintemp,Maxtemp,Minrain,Maxrain,Soil),
write("\tMean temperature value given lies between ", Mintemp, " and ", Maxtemp,
"(celcius)"),nl,
write("\tand mean rainfall value given lies between ", Minrain, " and ", Maxrain,"(mm)."),nl,
write("\tSuitable soil is ", Soil,"."),nl,
retractall(_,crop_ecology),
retractall(_,crop_name).
```

CEA system has global facts that can be referred anywhere in the program. Therefore it is essential to consult the global facts before reference is made to the facts. The explanation-how works by using the rule number entered by the system user to generate the crop_name clause to find which rule match with the rule number given by user. From that information, CEA have the information of the crop's scientific and common name. Then by using the crop_ecology clause, other information such as range temperature and range rainfall can be obtained. These are used to display what range of temperature and rainfall can the crop grow successfully.

The second part of CEA is to determine whether a particular crop is suitable to be cultivated based on the ecology factors given by the user. First, user has to give the name of the crop either in scientific name or in common name. These names are provided by CEA system and user does not have to type in its name. This is essential to make sure that he or she will not give the wrong spelling of the crop name. However, only those crop that is listed by CEA can be determined its suitability. As CEA development is only the prototype therefore not all monocotyledon crops are listed in this system. True system development can include almost all monocotyledon crops.

Checking crop recommendation begins by user give the name of the crop either by scientific name or common name. Then system will give confirmation on the chosen crop and it asks for the ecology information. Using the information given, CEA will find facts (crop_ecology clauses) that have the name of the crop. When the fact is found, it compares the given ecology information and the system's rule of ecology factor. If the mean temperature, mean rainfall and soil contained in the rule then the rule will fire. This will display that the crop is suitable to be cultivated in the area.

The example of code for determining crop's suitability is as follows:

```
suitability_input(CropName, MeanTemp, MeanRain, Soil):-
consult("crop_ecology.pro",crop_ecology),
openwrite(fileselector17,"suitability.txt"),
        writedevice(Current),
        writedevice(fileselector17),
        crop_suitability(CropName,MeanTemp,MeanRain,Soil),
        writedevice(Current),
        closefile(fileselector17),
        retractall(_,crop_ecology).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp>=MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
Soil = Soils,
write("CEA :\tCrop is suitable to be cultivated in your area."),nl,
write("\tI concluded this by using your information of ",CropName,","),nl,
write("\ttemperature ",MeanTemp," degree celcius, "),nl,
write("\trainfall of ",MeanRain,"mm and ",Soil," soil."),nl.
```

If the crop is suitable, the result will be written in the file name **suitability.txt** and it will used by the system when displaying result to the user.

CEA system is also able to give explanation on why certain crops are not suitable to be cultivated in an area. Its explanation based on what element is not suitable. For example if the soil is not suitable then CEA will provide explanation on this to the user. If temperature and rainfall is not in the range of best ecology

factors value, CEA system will be able to give explanation whether the differences are tolerable or not. Combination of non-suitability of the ecology factors is also included in the CEA reasoning. For example, if the temperature is too low and the mean rainfall is high or the soil is not suitable to cultivate the crop. The coding example for lower mean temperature is as follows:

```
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
Soil = Soils,
Diff = MinTemp - MeanTemp,
explanation_temp(Diff,CropName,MeanTemp,MinTemp),nl.


explanation_temp(Diff,CropName,MeanTemp,MinTemp):-
Diff<=3,
write("CEA :\tMonthly mean temperature in your area is ",MeanTemp," degree
Celcius."),nl,
write("\tMinimum temperature for good crop yields of ",CropName),nl,
write("\tis ",MinTemp,"degree Celcius."),nl,
write("\tThe difference by ",Diff," degree Celcius is tolerable"),nl,
write("\talthough crop might not reach its fullest potential."),nl.
```

3.5 Inference engine strategy for CEA

Inference engine for CEA is forward chaining. Forward chaining is an inference strategy that begins with a set of known facts, and continues this process until a goal state is reached or until no further rules have premises that match the known or derived facts (Durkin, 1994). This strategy works well with CEA because CEA is a system that interprete what can be concluded using the information given. In other words, forward chaining is good implementation when the problem naturally begins by gathering information and then seeing what can be inferred from it (Ibid, 1994). For example, in the crop recommendation part, CEA will gather information about mean temperature, mean rainfall and soil in the farm or area of where the user have his or her farm. Then from the information, CEA will interprete rule by rule that can match the ecology information given by the user. If there is a match then the system will display its result to the user. Similarly in determining crop suitability, CEA will gather first the name of the crop and its ecology information. Then, it will use rule to match the information and see what can be concluded from it.

Forward chaining can provide a considerable amount of information from data given by user:

DATA	INFORMATION
25° C, 1500mm, Alluvial	*Dioscorea Trifida, Eragrotis Tef*

Data given by user can be used by CEA to give more than one crop recommendation for the user to consider.

4.0 Description of CEA system interface

4.1 Main menu

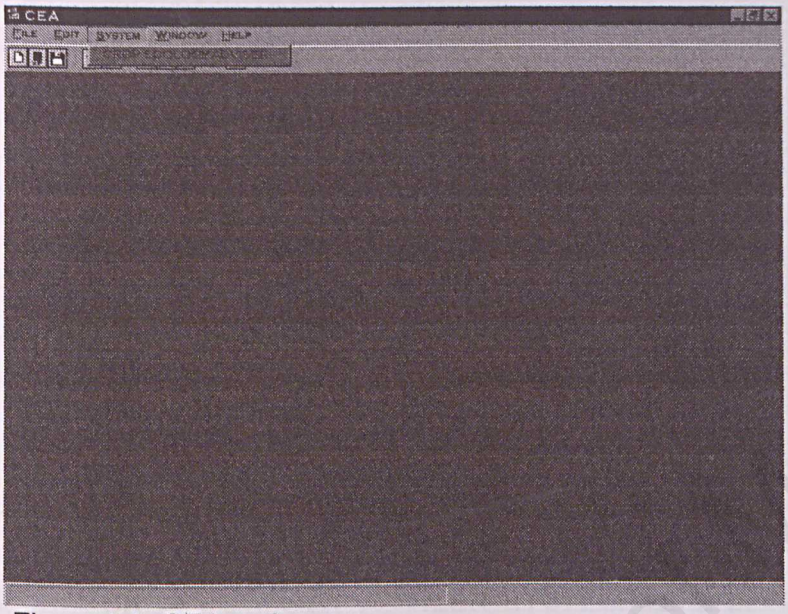

Figure 4.1: CEA main menu

This interface is the main menu of the system. Main menu contained task menu such as FILE, EDIT, SYSTEM, WINDOW and HELP. To start CEA application, CROP ECOLOGY ADVISER will be chosen.

The coding for creating task menu SYSTEM is generated by Visual Prolog 5.2 tools:

```
%BEGIN Task Window, id_System_crop_ecology_adviser
task_win_eh(_Win,e_Menu(id_System_crop_ecology_adviser,_ShiftCtlAlt),0):-!,
        dlg_crop_ecology_adviser_system_Create(_Win),!.
%END Task Window, id_System_crop_ecology_adviser
```

When user click CROP ECOLOGY ADVISER, the user-defined dialog CROP ECOLOGY ADVISER SYSTEM will pop-up.

4.2 CEA HOME

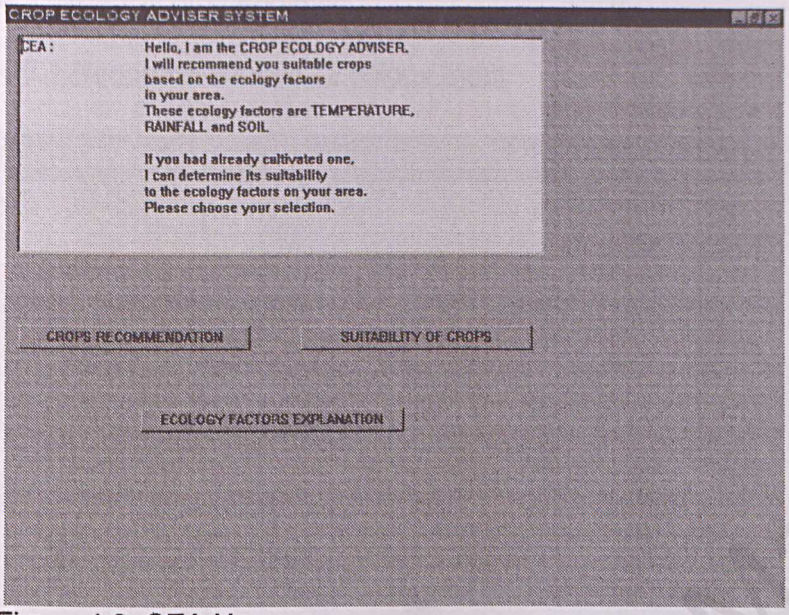

Figure 4.2: CEA Home

CROP ECOLOGY ADVISER SYSTEM has a box to display information from CEA. This is used to guide user especially those who are using CEA system for the first time.

It has two buttons - CROPS RECOMMENDATION and CROPS SUITABILITY. Each button refers to task that can be done using CEA system. If user select CROPS RECOMMENDATION, it will invoke the RECOMMENDATION - ECOLOGY INPUT dialog box while selecting CROPS SUITABILITY will invoke the SUITABILITY - ECOLOGY INPUT. Another button is the ECOLOGY FACTORS EXPLANATION where this is where the explanations about the tropical ecology (temperature, rainfall and soil) are given.

4.3 Crop Recommendation

4.3.1 Recommendation - Ecology Input

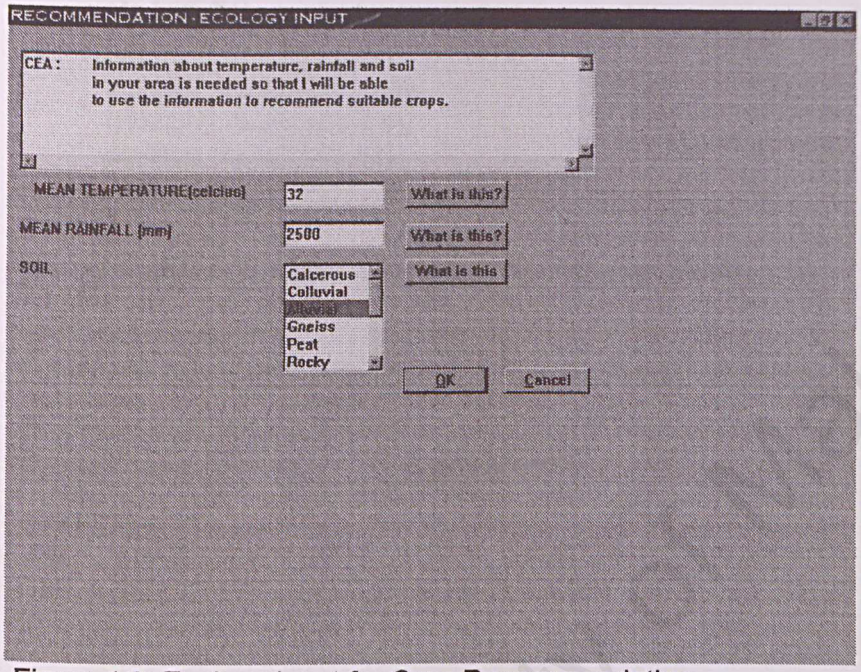

Figure 4.3: Ecology input for Crop Recommendation

RECOMMENDATION - ECOLOGY INPUT contained three items that must be filled in by the user. MEAN TEMPERATURE and MEAN RAINFALL will accept integer values while SOIL item can be chosen from list of soil provided by CEA. If the user need more explanation on this item, the respective button WHAT IS THIS? will invoke explanation to be displayed on the box.

When OK button is pressed, this code will send the given information to the rule that will search what crop would be recommended based on the ecology information:

%BEGIN RECOMMENDATION - ECOLOGY INPUT, idc_ok _CtlInfo

dlg_recommendation_ecology_input_eh(_Win,e_Control(idc_ok,_CtrlType,_CtrlWin,_CtlInfo),0):-!,

```
        Temp = win_GetCtlHandle(_Win, idc_meantemp),
        Rain = win_GetCtlHandle(_Win, idc_meanrain),
        Soil  = win_GetCtlHandle(_Win, soil),

        T = win_GetText(Temp),
        R = win_GetText(Rain),
        str_int(T,T1),
        str_int(R,R1),

        S = lbox_GetSelIndex(Soil),
        S1 = lbox_GetItem(Soil,S),
        ecology_input(T1,R1,S1),
        dlg_recommendation_result_Create(_Win),
        win_Destroy(_Win),
        !.
%END RECOMMENDATION - ECOLOGY INPUT, idc_ok _CtlInfo
```

In module crops.pro, **ecology_input(MeanTemp, MeanRain, Soil)** is defined here where it receive the ecology information.

4.3.1.1 Recommendation – Result

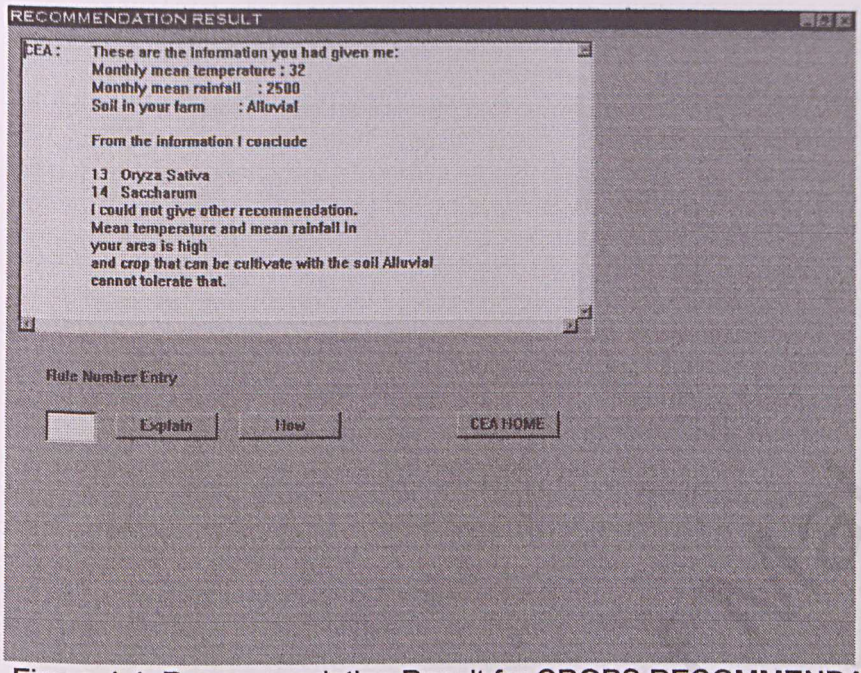

Figure 4.4: Recommendation Result for CROPS RECOMMENDATION

RECOMMENDATION - RESULT dialog box is displayed to show the list of crop recommended. The display includes a numerical value at each side of the crop name. The number is essential when the user wants justification (EXPLAIN button) for the recommended crop or if the user wants to know how conclusion is derived (HOW button) from the information given. For CEA, this number is important to trigger which rule it has to refer to.

4.3.1.2 Explanation – WHY

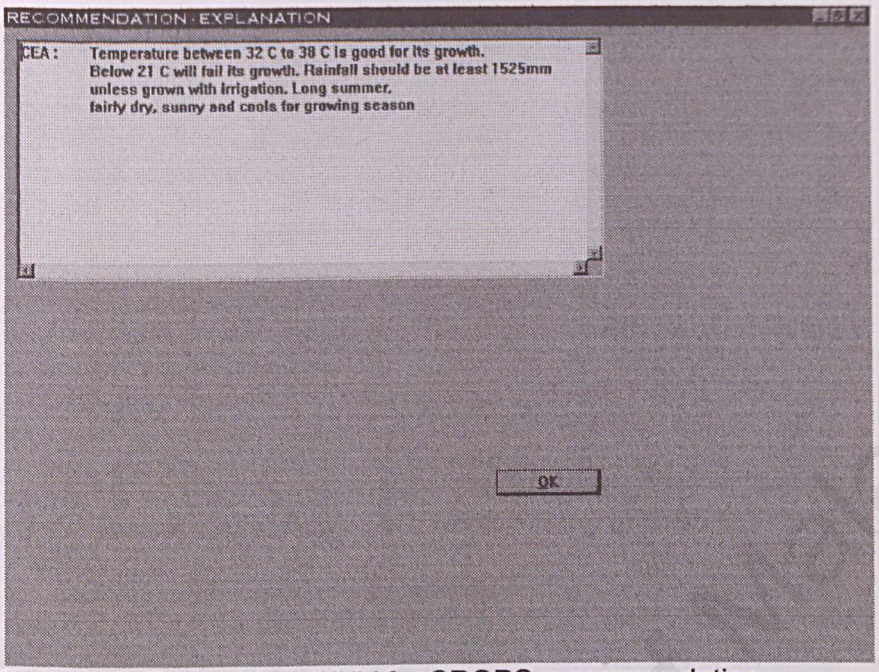

Figure 4.5: Explanation WHY for CROPS recommendation

This dialog box will display the explanation on why the crop is recommended. Explanation is determined using the rule number given by the user.

4.3.1.3 Explanation – HOW

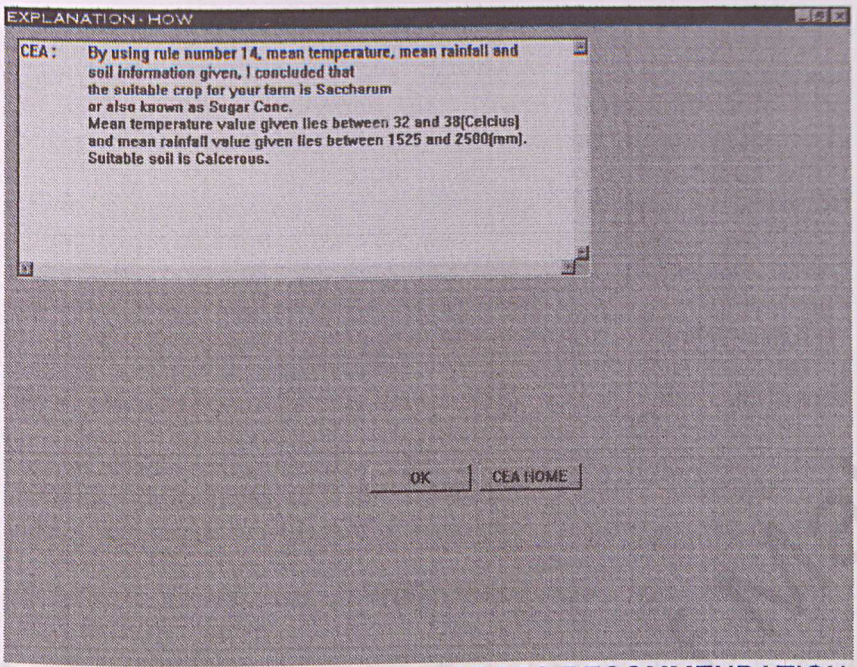

Figure 4.6: Explanation HOW for CROPS RECOMMENDATION

This dialog box will display how the conclusion is derived. This information is essential for those who want to gain more understanding on how the system works especially coming out with crop recommendations.

4.4 Crops Suitability

4.4.1 Suitability - Ecology Input

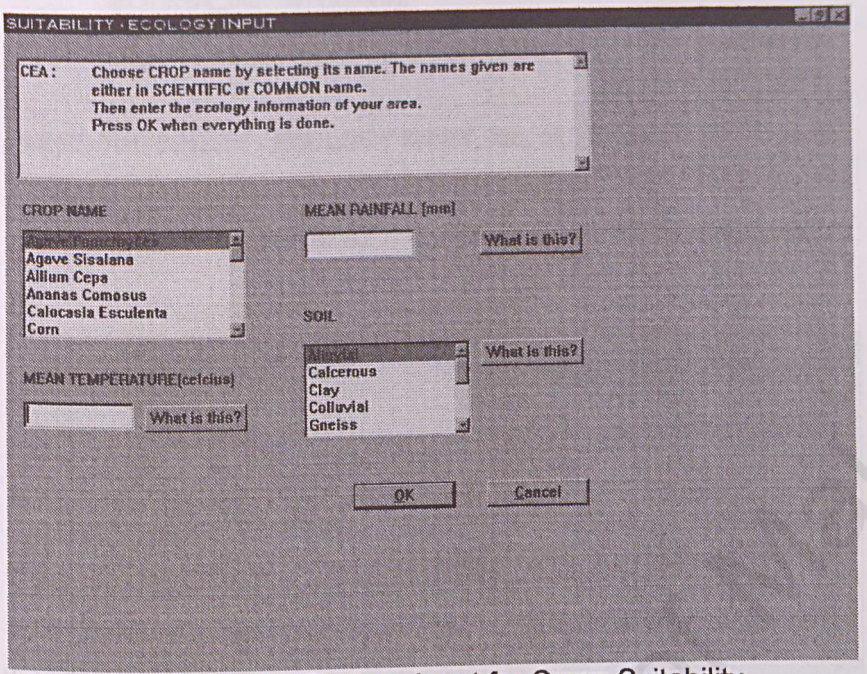

Figure 4.7: Suitability Ecology Input for Crops Suitability

This dialog box will accept the name of the crop and its ecology information. It also provides WHAT IS THIS? button to give further explanation on each of the item on the dialog box. OK button is pressed to invoke SUITABILITY - RESULT dialog box. When the button is pressed, the given information is passed to suitability_input rules to find match for the information given.

```
%BEGIN SUITABILITY - ECOLOGY INPUT, idc_ok _CtlInfo
  dlg_suitability_ecology_input_eh(_Win,e_Control(idc_ok,_CtrlType,_CtrlWin,_CtlInfo),0):-
!,
        Crop = win_GetCtlHandle(_Win,idc_crop_name),
        Temp = win_GetCtlHandle(_Win,idc_meantemp),
        Rain = win_GetCtlHandle(_Win,idc_meanrain),
        Soil = win_GetCtlHandle(_Win,soils),

        T = win_GetText(Temp),
        R = win_GetText(Rain),
        str_int(T,T1),
```

```
        str_int(R,R1),
        C = Ibox_GetSelIndex(Crop),
        C1 = Ibox_GetItem(Crop,C),
        S = Ibox_GetSelIndex(Soil),
        S1 = Ibox_GetItem(Soil,S),
        suitability_input(C1,T1,R1,S1),
        dlg_checking_suitability_Create(_Win),
        !.

%END SUITABILITY - ECOLOGY INPUT, idc_ok _CtlInfo
```

4.4.1.2 Checking Suitability

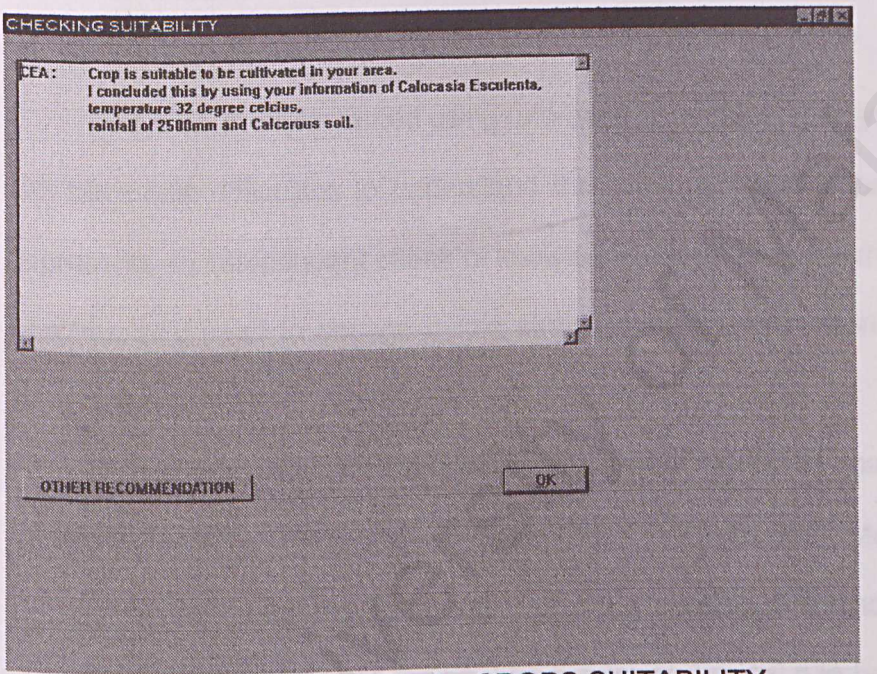

Figure 4.8: Checking Suitability for CROPS SUITABILITY

This dialog box will display whether the crop is suitable with the ecology information given. Suitable means that the crop can be grown successfully in the area. If not suitable, CEA will also explain on that by concluding from the differences in temperature, rainfall, soil or combination of the factors.

5.0 Discussion And Conclusion

5.1 Advantages of CEA system

CEA is a prototype system that is developed to model the real application system. The real system later will offer the advantages that this prototype system had shown. The advantages of CEA is divided into two parts, first from the system developer's perspective and secondly from the end-user's perspective.

5.1.1 Advantages to system developers

❖ **Rule-based system**

As CEA is implemented using rule-based approach, the system developer will have little difficulties to understand the whole knowledge base. Every rule represents an independent chunk of knowledge about a particular crop and he or she has only need to change a rule should ecology information of a particular crop change.

Apart from that, if the system developer wants to make CEA more intelligent, then he or she can add more rules to the system. More rules to the system means that the system can give many crop recommendations or even determine the suitability of crop. This is possible using rule-based approach. Furthermore, explanation about a particular crop can always be added to the system should the system developer think that the current explanation facilities does not enough to give justification to the system user just like how a crop expert did.

The rules can be added into the system without affecting the control of the system. This means no matter how many the rules about crops are included

in the system, the control will not be affected. The system still use the mean temperature, mean rainfall and soil to get conclusion about crop recommendation and suitability. Forward chaining strategy is not being affected too. Advantages of using rule-based approach is justified here as any modifications to the knowledge base will not affect the control of the system and any modification to the control system will not affect the knowledge base as well. This present an advantage to the system developer as any modification to either knowledge base or control will not affect each other. Thus, this approach saves much time and cost.

❖ **Explanation-how facilities**

This facility is developed to help system developer to understand how the system comes into the conclusion of crop recommendation. This is vital in order to help them to understand how CEA works in getting the recommendation.

5.1.2 Advantages to end-user

❖ **Explanation facilities**

CEA system offers three types of explanation facilities - one is the explanation why facility and the second is the explanation how facility and lastly explanation on the suitability of crops. All explanation facilities are important to end-user. The first one will further explain how did it come to the solution while the second one will further justify its recommendations. The third explanation facility will explain why certain crops are not recommended in an area by comparing the temperature, rainfall and soil. Those facilities can be modeled as what human expert can explain when approached by farmers. Therefore CEA

system can be modeled just like a human expert when human expert is not available at the moment to give recommendations and explanations to farmers.

Apart from that, the explanation and recommendation given by CEA is just as what will be recommended by human expert as well. This is justified from the process of knowledge acquisition from human expert and also from journals and books about monocotyledon crops.

❖ **User-friendly CEA**

The CEA system is developed using Visual Prolog 5.2 tools. One of the tools offered by VP 5.2 is the Visual Programming Interface (VPI). This interface provides graphical user interface to the system. Therefore, CEA is easy to use compare to text mode application that also can be developed using Visual Prolog 5.2 tools. In chapter 4, the interface of CEA had been shown. The interface is easy to use and can be understood easily. This is because each dialog box has its own explanation on what task should be done and it can also provide confirmation what the system user had entered. Apart from that, if the end-user require explanations about the information that they need to supply, CEA can give further explanation on what type of information they should give and why the information is vital to the CEA system.

❖ **Scientific and common name**

The usage of both names of crops is essential because if a particular crop is just identified using its common name then this system can only be used in one country or only several countries that have the same mother-tongue language. It is known that a common name for a particular crop might vary from

one country to another. Therefore the use of scientific name will further help CEA to become an international system. This means that with the usage of crop scientific names that is internationally standardized, CEA becomes an international system that can be used anywhere in the world.

❖ **Range values for temperature and rainfall value**

The rules for determining whether the temperature and rainfall is suitable for cultivation a particular crop is determined using the range values of temperature and rainfall. Range values are supplied in the rules because a crop can grow not limited to a particular temperature and rainfall. For example, Agave Fourcroydes can grow successfully when the temperature is 10 degree Celsius or 38 degree Celsius. Therefore, the rules are written in range so that it can cater the range of degree Celsius of a particular crop can grow. In generating explanation of crop non-suitability to ecology factors, range values are included to determine whether the differences are tolerable or not.

❖ **More than one recommendation**

Rules in CEA are written in order for it to be able to give more than one crop recommendations. This facility will enable to give more choices to farmers so that they can diversify their farms with more than one crops to be cultivated.

5.2 Limitations of CEA

❖ **Caters only for ecology factors**

There are many factors that influence the cultivation of crops. Although ecology factors are the most important factors, there are other factors that are equally important in crop cultivation such as crop management, pesticides and

fertilizer management. For CEA, only the ecology factors are considered. Therefore, this show that CEA still needs further development to include all the involving cultivation factors to make it a complete system that consider from the ecology factors to management of crop resources.

❖ **Ecology information is a must**

CEA will not be beneficial to system user that does not know the ecology information in his or her area. This is because the information are needed so that the system can recommend which crop is suitable or to determine its suitability with the area ecology. Although this information can be obtained free from the meteorological department, some might not aware of this facility. If farmers only know that the temperature in his area is 'hot' or rainfall is 'consistently much throughout the year', then CEA will not be able to give much recommendations or help to them. The information given must be exact and not information that is subjective only to a farmer.

❖ **Exact rule matching**

Although rule-based approach had been described offer much advantages to CEA, it also presents drawbacks to the development of CEA. CEA attempts to match the premises of available rules with facts contained in the working memory. For this process to be effective, this match must be exact, which in turn require strict adherence to consistent coding. Therefore, *Agave Fourcroydes* is different from *agave fourcroydes* and a*gave Fourcroydes* although in reality

these three are the same without considering the capital letters of its spelling. This is also the main reason why when required to give the name of the crop or the name of the soil, CEA provides list box for user to choose the item from. It is to prevent user from giving the different way of spelling of a crop name or soil name.

❖ **Can be slow**

CEA when implemented with large set of rules can be slow in its real time application. This occur because when the inference engine deciding which rule to apply, it must scan all the entire rules and thus, result in slow processing time.

5.3 Further works on CEA

Further works on the development of CEA centered on its knowledge base. This prototype system consider only the ecology factors, therefore further works of CEA can include information about crop management (husbandry and crop maintenance), fertilizers and pesticides management. These elements are important to further enhance the production of crops for commercial purposes. To produce large production of crops for commercial purposes, all the stated elements play a big role in ensuring successful production of crops. This is possible by acquiring knowledge from experts of each area and then integrating the knowledge into rules. Rule number is still used to refer to each rule in the knowledge base. For example, *Agave Fourcroydes* had been identified with rule number 1 and the justification of recommending the crop had been displayed. With the same rule number, the crop management rules are triggered and fired when its rule number matched with rule number 1. Since pesticides and fertilizers requirements depend on crop, types of soil and also weeds that can deny full production of crops then this information must be obtained from user. Then, the information can only be compared with the rules in the knowledge base.

Apart from that, further works of CEA can also include other ecology factors that can determine the production of crops. Examples of other ecology factors are pH values of soil and altitude of the area. With those information, only the most suitable crops can be grown with respect to the condition of soil and also the area. Climatic condition can also be included in the system. World's

climates are different from one region to another region. Therefore, the techniques of cultivation might differ. The system might acquire where the geographical area of the user's farm. Then with the information, the system can infer whether the area comes from tropical country or Mediterranean country. Thus, the system can determine the best crop that can be cultivated. In other words, the scope of crop recommendation is narrowed according to climatic conditions and ecology factors of the area - temperature, rainfall, types of soil, pH value of soil and altitude value of the area.

Apart from that, CEA system can be further developed by not only considering monocotyledon crops but also dycotyledon crops. Dycotyledon crops are crops that produce flowers and coffee, quinin (medicine) and important woods come from this family. Thus, CEA system can recommend many types of crops.

5.4 Conclusion

Prototype of CEA system had been developed to model the capability of real CEA system. This shows that expert system on crop ecology can be implemented using rule-based knowledge representation and forward chaining strategy. Ability of CEA in generating explanation from different aspect of ecology factors is the main advantages of it. Furthermore, by considering in range values for tolerable factors before declaring the crop not suitable is also the main advantage of CEA.

Developing CEA using Visual Prolog 5.2 shows clearly how inference engine (forward chaining) works. The ability to backtrack and depth first search strategy is fully utilized when developing this system.

To conclude, the development of CEA in real time application will help farmers to get crops recommendation and check for crop suitability if they have already cultivated one. Moreover, expert system is an intelligent system that can act as an expert and thus gives recommendation to farmers also like an expert.

APPENDIX 1

APPENDIX 1

User Manual

Installing CEA system

CEA system can be install in any IBM computer compatible with WINDOWS 95,98 and 2000 with at least memory of 3 MB. To start CEA system, the executable project icon is clicked.

Opening CEA application

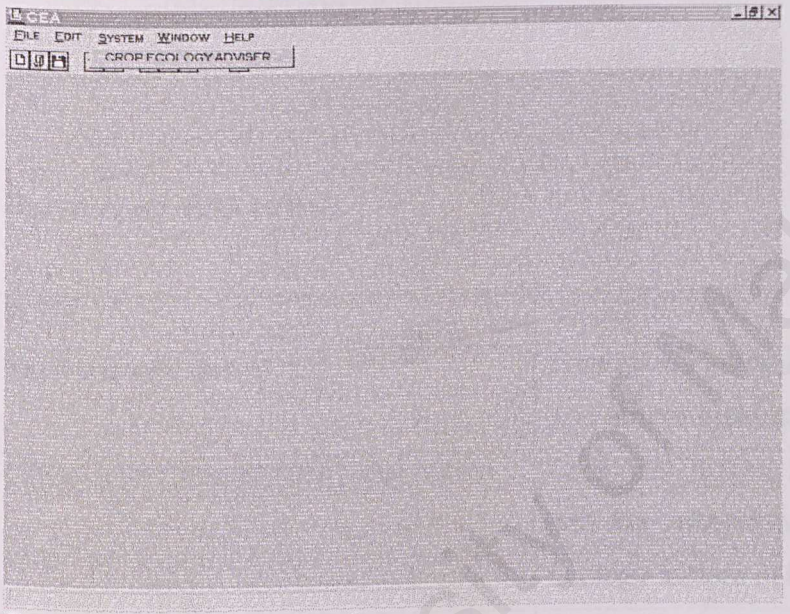

Figure App1: CEA application

To start consulting CEA, task menu System is clicked and submenu CROP ECOLOGY ADVISER will pop-up. Pressing CROP ECOLOGY ADVISER submenu will trigger the CEA HOME window.

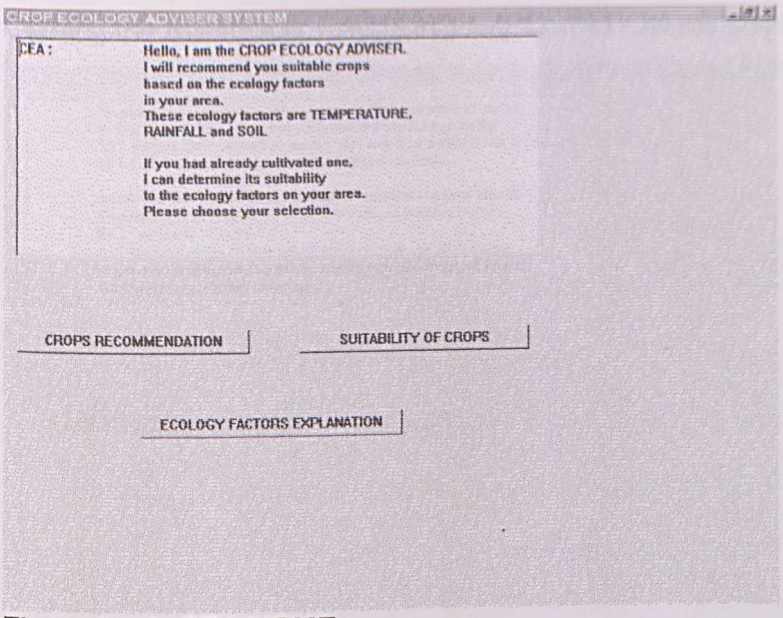

Figure App2: CEA HOME

ITEM	DESCRIPTION
Multi-line edit text	Display the introduction to CEA system and further instruction.
CROPS RECOMMENDATION button	Click this button to know what crops can be recommended based on the ecology factors in the area.
CROPS SUITABILITY button	Click this button to know whether a crop is suitable corresponding to the ecology factors in his or her area.
ECOLOGY FACTORS EXPLANATION	Click this button to get further explanation on temperature, rainfall ad soil in the tropics.

Clicking the ECOLOGY FACTORS EXPLANATION will display the following:

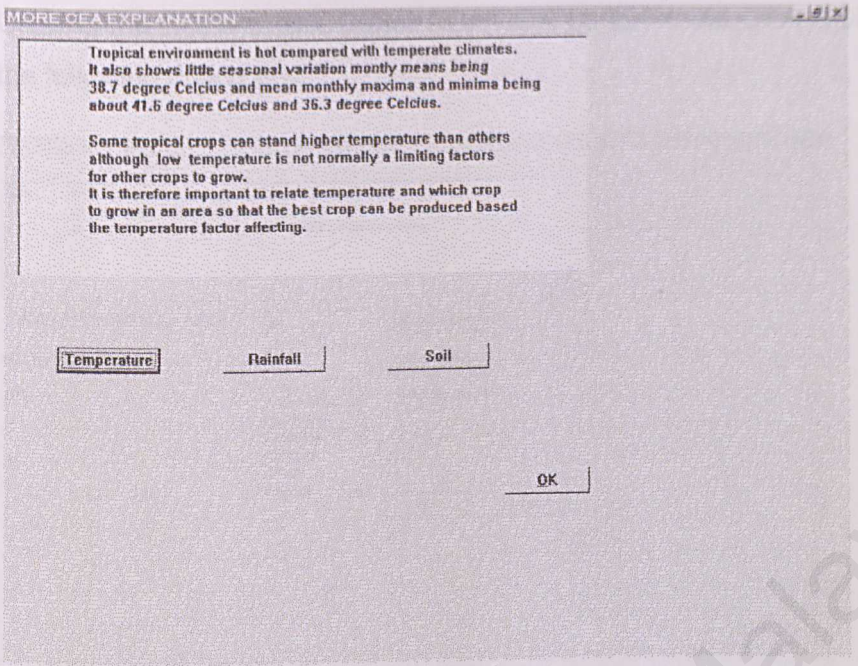

Figure App3: Ecology factors explanation

There are three buttons in this dialog box. User can clicked any of the buttons to generate explanation about the ecology factors in the tropics.

Clicking the CROPS RECOMMENDATION button in the CEA HOME will display the following dialog box:

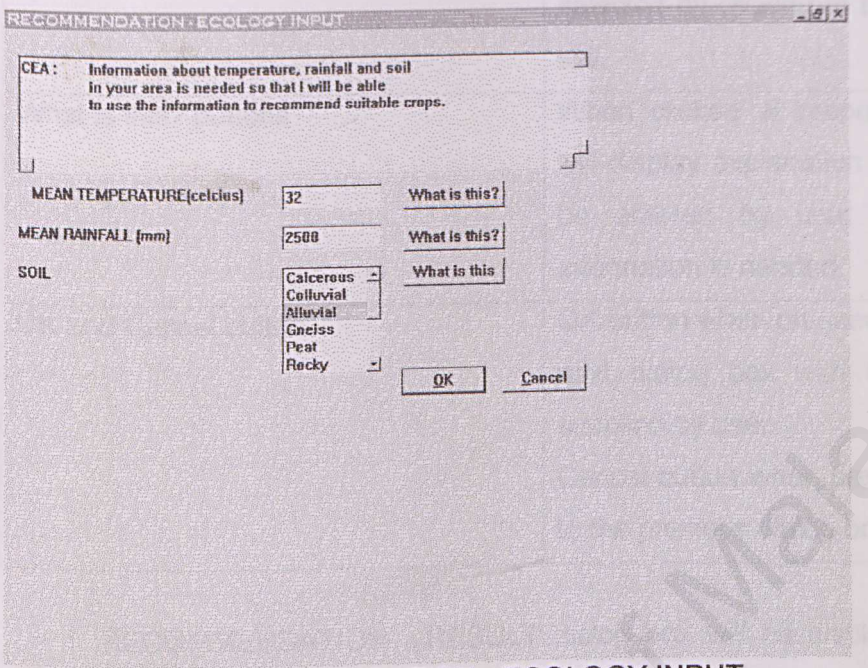

Figure App4: RECOMMENDATION - ECOLOGY INPUT

The dialog box RECOMMENDATION - ECOLOGY INPUT will be displayed. In this dialog box contained multi-line edit text, mean temperature and mean rainfall edit list, soil list box, What is this? buttons, OK and Cancel buttons. Following will be the descriptions what tasks can be done with all the items.

ITEM	DESCRIPTION
Multi-line edit text	To display instructions from CEA, display explanations when What is this? button of respective item is clicked.
Mean temperature edit list	User will supply value corresponding to the mean temperature of his or her area.

Mean rainfall edit list	User will supply value corresponding to the mean rainfall of his or her area.
Soil list box	Contained list of soil that can be selected by clicking at the name of the soil.
What is this? buttons	When clicked at respective button, it will display explanation of what should be entered by user and why the information is needed.
OK and Cancel button	OK button when pressed will trigger the next dialog box with the information supplied by user. Cancel button when pressed will return to the previous dialog box.

RECOMMENDATION - RESULT dialog box will be displayed when OK button is pressed.

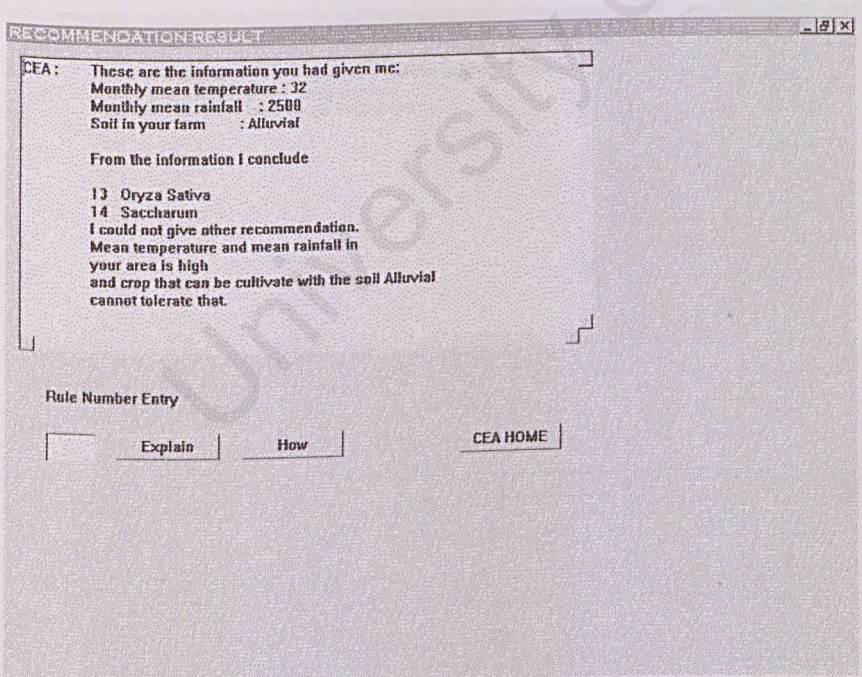

Figure App5: RECOMMENDATION RESULT dialog box

The descriptions of items in the dialog box is given as follows:

Item	Description
Multi-line edit text	Display the recommendation result based on the information supplied by user from the previous dialog box.
Rule Number Entry edit list	Receive a rule number that is displayed in the edit text. User gives this rule number when explanations are needed.
Explain button	This button is pressed when explanation is needed on the recommendation given.
How button	This button is pressed when user wants explanation about how the conclusion is derived.

The EXPLAIN button when pressed will display the EXPLANATION - WHY dialog box.

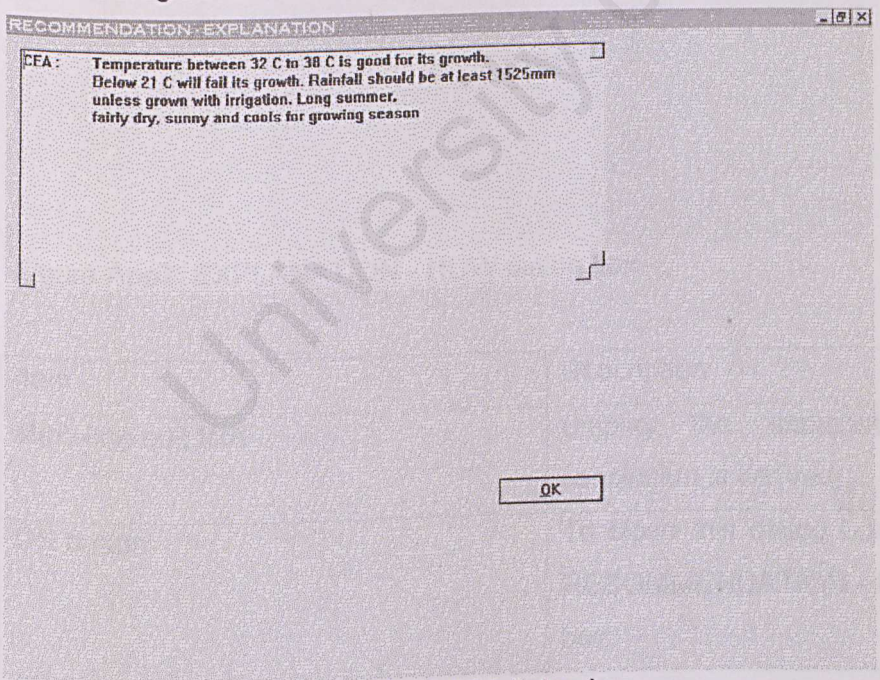

Figure App6: EXPLANATION - WHY dialog box

Item	Description
Multi-line edit text	Will display explanation on why the particular crop is recommended.
OK button	This dialog box will be closed and return to the previous dialog box.

In the RECOMMENDATION - RESULT dialog box, when HOW button is pressed the EXPLANATION - HOW dialog box will be displayed.

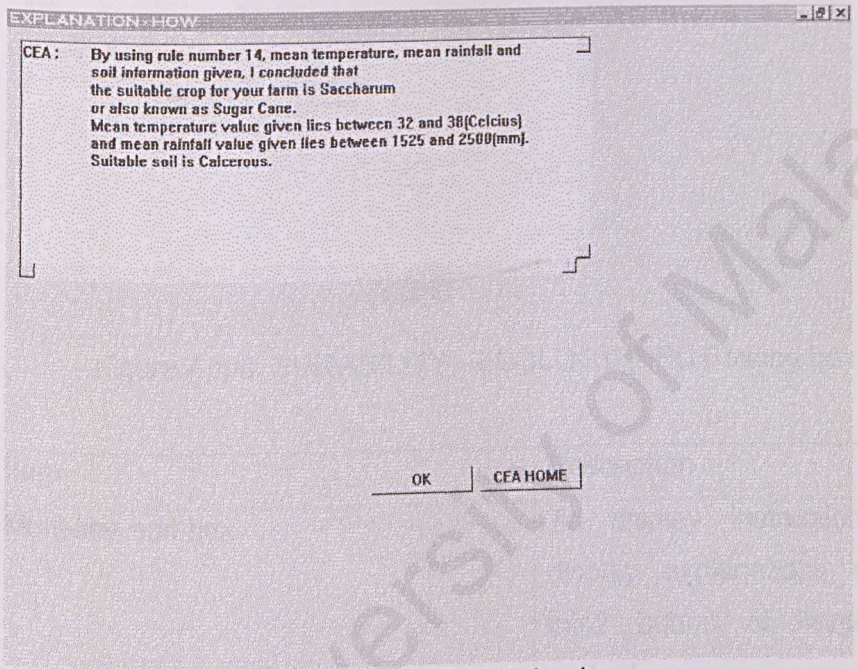

Figure App7: EXPLANATION - HOW dialog box

Item	Description
Multi-line edit text	Display the explanation on how conclusion is derived
OK button	To close this dialog box and return to RECOMMENDATION - RESULT dialog box.

If user had chose the CROPS SUITABILITY button in the CEA HOME, the SUITABILITY ECOLOGY INPUT will be displayed.

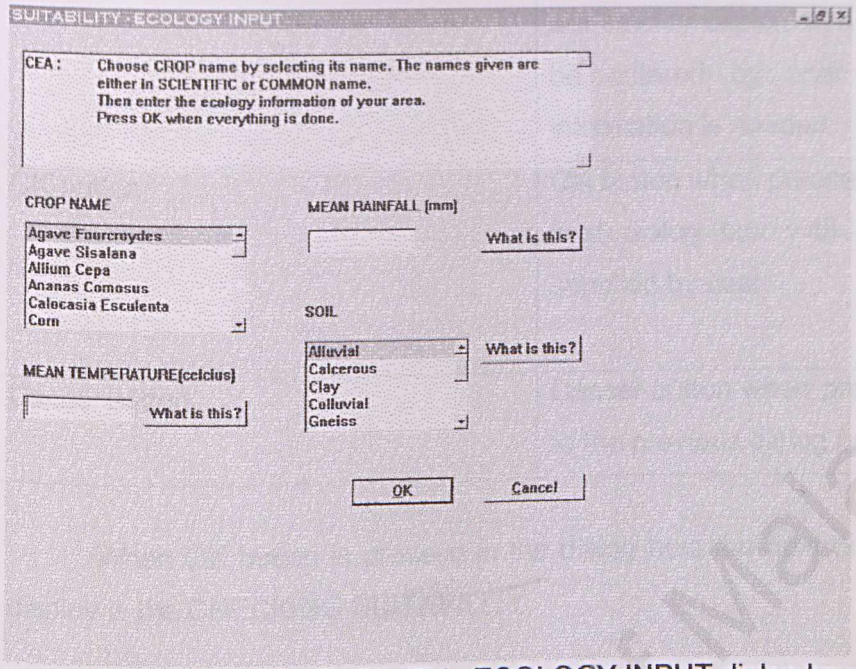

Figure App8: SUITABILITY - ECOLOGY INPUT dialog box

Item	Description
Multi-line edit box	To display instructions from CEA, display explanations when What is this? button of respective item is clicked.
Crop name list box	Display the all the crop names either in scientific or common name.
Mean temperature edit list	User will supply value corresponding to the mean temperature of his or her area.
Mean rainfall edit list	User will supply value corresponding to the mean rainfall of his or her area.
Soil list box	Contained list of soil that can be

	selected by clicking at the name of the soil.
What is this? buttons	When clicked at respective button, it will display explanation of what should be entered by user and why the information is needed.
OK button	OK button when pressed will trigger the next dialog box with the information supplied by user.
Cancel button	Cancel button when pressed will return to the previous dialog box.

When OK button is pressed in the dialog box, the next dialog box will be display is the CHECKING SUITABILITY.

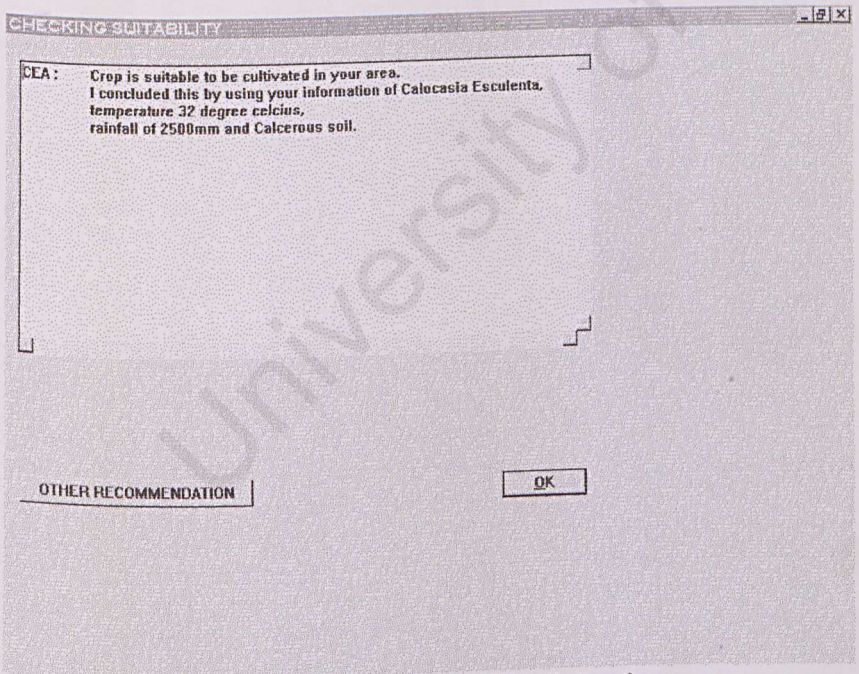

Figure App9: CHECKING SUITABILITY dialog box

Item	Description
Multi-line edit text	Display the result of suitability of the crop corresponding to what had been entered in the SUITABILITY - ECOLOGY INPUT dialog box.
OTHER RECOMMENDATION button	Generate another crop recommendation based on the ecology factors given by the user.
OK	Close the dialog box.

APPENDIX 2

Predicates declaration

```
/*****************************************************************************
                    Copyright (c) Joyce JM Gumpil

Project:  CEA
FileName: CEA.PRE
Purpose: Predicate definitions for CEA.PRO
Written by: Joyce Jessica Michael Gumpil
Comments:
*****************************************************************************/

%BEGIN_DECL, System generated global predicates
GLOBAL FACTS - recommendation
recommendation(string)

GLOBAL FACTS - crop_name
crop_name(integer,string,string)

GLOBAL FACTS - crop_ecology
crop_ecology(string,integer,integer,integer,integer,string)

GLOBAL PREDICATES

  project_ShowHelpContext(INTEGER Index) - (i)
  dlg_about_dialog_Create(WINDOW Parent) - (i)
  tb_project_toolbar_Create(WINDOW Parent) - (i)
  tb_help_line_Create(WINDOW Parent) - (i)
  dlg_recommendation_ecology_input_Create(WINDOW Parent) - (i)
  dlg_crop_ecology_adviser_system_Create(WINDOW Parent) - (i)
  dlg_recommendation_result_Create(WINDOW Parent) - (i)
  dlg_suitability_ecology_input_Create(WINDOW Parent) - (i)
  dlg_crop_name_Create(WINDOW Parent) - (i)
  dlg_suitability_result_Create(WINDOW Parent) - (i)
  dlg_checking_suitability_Create(WINDOW Parent) - (i)
  dlg_recommendation_rule_number_Create(WINDOW Parent) - (i)
  dlg_recommendation_explanation_Create(WINDOW Parent) - (i)
  dlg_explanation_how_Create(WINDOW Parent) - (i)
  dlg_more_cea_explanation_Create(WINDOW Parent) - (i)
  dlg_other_recommendation_Create(WINDOW Parent) - (i)

  nondeterm ecology_input(integer,integer,string) - (i,i,i)
  nondeterm crop_value(integer,integer,string) - (i,i,i)
  nondeterm explanation(integer) - (i)
  nondeterm crop_explain(integer,string)  - (i,o)
  nondeterm session_start
  nondeterm soil_list
  nondeterm mean_rain
  nondeterm mean_temp
  nondeterm expert_explain(integer,integer,string) - (i,i,i)
  nondeterm expert_session
  nondeterm explain_how(integer) - (i)
  nondeterm crop_name_session
  nondeterm suitability_input(string,integer,integer,string) - (i,i,i,i)
  nondeterm crop_suitability(string,integer,integer,string) - (i,i,i,i)
  nondeterm recommendation_session
  nondeterm explanation_temp(integer,string,integer,integer) - (i,i,i,i)
  nondeterm explanation_temp2(integer,string,integer,integer) - (i,i,i,i)
  nondeterm explanation_rain(integer,string,integer,integer) - (i,i,i,i)
  nondeterm explanation_rain2(integer,string,integer,integer) - (i,i,i,i)
  nondeterm explanation_soil(string) - (i)
  nondeterm explanation_temp_rain_LH(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
```

```
nondeterm explanation_temp_rain_HL(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_HH1(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_HH2(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_HH3(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_HH4(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_LL1(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_LL2(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_LL3(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm explanation_temp_rain_LL4(integer,integer,string,integer,integer,integer,integer) - (i,i,i,i,i,i,i)
nondeterm temperature
nondeterm rainfall
nondeterm soil_tanah
nondeterm explainCEA
nondeterm other_recommendation(integer,integer,string) - (i,i,i)
nondeterm explanation_soil_diff_soil(string,string,string) - (i,i,i)


%END_DECL
```

```
/*************************************************************************

                    Copyright (c) Joyce JM Gumpil

Project:  CEA
FileName: CROPS.PRO
Purpose: Rules for CEA system
Written by: Joyce Jessica Michael Gumpil
Comments:
*************************************************************************/

include "cea.inc"
include "cea.con"
include "hlptopic.con"

clauses
% FACTS FOR CROP EXPLANATION
crop_explain(1,"Requires plenty of heat therefore temperature between\n\t10 C to 38 C is suitable for its growth.\n\tIt can withstand
drought but not waterlogging. \n\tShallow calcerous gravel on porous limestone is good.").
crop_explain(2,"Moderate humidity for its growth. It cannot stand waterlogging.\n\tIt also can grown in variety of soils\n\tprovided
they are well drained and rich in bases\n\tparticularly calcium.").
crop_explain(3,"Prefer shade under trees therefore cannot stand excessive heat.\n\tTherefore temperature 10 C to 18 C is good for
its growth.").
crop_explain(4,"Not suitable to hot tropical lowlands because it cannot grow in\n\texcessive heat.").
crop_explain(5,"Grown in most tropical country because it can stand excessive heat.\n\tThe temperature between 28 C to 33 C is
good for its growth.\n\tLoamy calcerous soils is siutable for its growth.").
crop_explain(6,"Can be grown in wide range of climatic conditions, but best in mild climate.\n\tand without excessive rainfall").
crop_explain(7,"Require irrigation or growing in swampy places.\n\tIt can stand excessive rainfall of more than 2500mm. \n\tHeavy
and wet soils are preferred, with good fertility and adequate humus.").
crop_explain(8,"Grow best in tropical rain forest regions.\n\tIt can stand heat and excessive rainfall. \n\tAdequate soil moisture is
essential for its growth.").
crop_explain(9,"Can tolerate drought but not waterlogging because pineapple\n\thas special water storage cells. Survived in wide
range of rainfalls\n\tbut for commercial production is 1000mm to 1500mm.\n\tSoil can be sandy loam of pH 5 - 6.5.").
crop_explain(10,"Growth increases with temperature. Grown in range temperature\n\tof 25 C to 30 C. Dry season should not be
more than 2 months.\n\tReasonable soil fertility, best in loose, deep and free draining soil. ").
crop_explain(11,"Grown mainly in tropical country. Cannot grow below 18 C temperature.\n\tCan grow on sandy loams and red
lateritic loams").
crop_explain(12,"Good permeability of soils and heavy loam is preffered.\n\tMaximum rainfall it can receive is 2500mm because too
much water \n\twill affect its production.").
crop_explain(13,"A fairly dry, sunny and cool climate.\n\tSoil can be sandy loams, shallow lateritic to heavy clay,\n\tprovided there is
adequate water either from rain or irrigation.\n\tHeavy alluvial soils is better than lighter soils.").
crop_explain(14,"Temperature between 32 C to 38 C is good for its growth.\n\tBelow 21 C will fail its growth. Rainfall should be at
least 1525mm\n\tunless grown with irrigation. Long summer,\n\tfairly dry, sunny and cools for growing season").
crop_explain(15,"Not suited to semi-arid climates nor to the ever wet tropical\n\tevergreen rain forests. Fail when temperature below
10 C. Soil is well drained, well aerated, deep, warm loams and silt loams\n\tcontaining adequate organic matter and nutrients").


session_start:-

writef("CEA : "),
writef("\t\tHello, I am the CROP ECOLOGY ADVISER. "),nl,
writef("\t\tI will recommend you suitable crops  "),nl,
writef("\t\tbased on the ecology factors        "),nl,
writef("\t\tin your area.                      "),nl,
writef("\t\tThese ecology factors are TEMPERATURE,"),nl,
writef("\t\tRAINFALL and SOIL                                  "),nl,nl,
writef("\t\tIf you had already cultivated one,   "),nl,
writef("\t\tI can determine its suitability     "),nl,
writef("\t\tto the ecology factors on your area. "),nl,
writef("\t\tPlease choose your selection.       "),nl.

recommendation_session:-
```

```
write("CEA : "),
write("\tInformation about temperature, rainfall and soil   "),nl,
write("\tin your area is needed so that I will be able      "),nl,
write("\tto use the information to recommend suitable crops.").

soil_list:-
write("CEA : "),
write("Please select the type of soil in your farm."),nl.

mean_temp:-
write("CEA : "),
write("\tMonthly mean temperature in degree celcius.          "),nl,
write("\tI need this information to check whether the temperature"),nl,
write("\tis suitable for crops cultivation.                   "),nl,
write("\tThis information can be obtained free from           "),nl,
write("\tthe meteorological department in your respective area.  "),nl.

mean_rain:-
write("CEA : "),
write("\tPlease enter the monthly mean rainfall (milimeter/annum)"),nl,
write("\tin your area.                                        "),nl,
write("\tI need this information to check whether your area do not "),nl,
write("\treceive less or excessive rainfall that will affect     "),nl,
write("\tthe production of crops.                             "),nl,
write("\tThis information can be obtained free from           "),nl,
write("\tthe meteorological department.                       "),nl.

expert_explain(Temp,Rain,Soil):-
write("CEA : "),
write("\tThese are the information you had given me: "),nl,
write("\tMonthly mean temperature : ",Temp),nl,
write("\tMonthly mean rainfall    : ",Rain),nl,
write("\tSoil in your farm        : ",Soil),nl,nl,
write("\tFrom the information I conclude"),nl.


ecology_input(Temp,Rain,Soil):-
        consult("crop_name.pro",crop_name),
        consult("crop_ecology.pro",crop_ecology),
        openwrite(fileselector1,"crops.pro"),
        writedevice(Current),
        writedevice(fileselector1),
        expert_explain(Temp,Rain,Soil),nl,
        crop_value(Temp,Rain,Soil),
        writedevice(Current),
        closefile(fileselector1),
        retractall(_,crop_ecology),
        retractall(_,crop_name).

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=10, MeanTemp<=38,
MeanRain>=720, MeanRain<=1500,
Soil="Calcerous",
crop_name(Rule,X,"Henequen"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=20, MeanTemp<=27,
MeanRain>=1000, MeanRain<=1250,
Soil="Alluvial",
crop_name(Rule,X,"Sisal"),
write("\t",Rule, "   ", X),nl,fail.
```

```
crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=20, MeanTemp<=27,
MeanRain>=1000, MeanRain<=1250,
Soil="Colluvial" ,
crop_name(Rule,X,"Sisal"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=20, MeanTemp<=27,
MeanRain>=1000, MeanRain<=1250,
Soil="Red earth" ,
crop_name(Rule,X,"Sisal"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=20, MeanTemp<=27,
MeanRain>=1000, MeanRain<=1250,
Soil="Gneiss" ,
crop_name(Rule,X,"Sisal"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=20, MeanTemp<=27,
MeanRain>=1000, MeanRain<=1250,
Soil="Volcanic" ,
crop_name(Rule,X,"Sisal"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=10, MeanTemp<=18,
MeanRain>=760, MeanRain<=960,
Soil="Rocky",
crop_name(Rule,X,"Mauritius Hemp"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=10, MeanTemp<=18,
MeanRain>=500, MeanRain<=3800,
Soil="Alluvial",
crop_name(Rule,X,"New Zealand Flax"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=28, MeanTemp<=33,
MeanRain>=1000, MeanRain<=2500,
Soil="Calcerous",
crop_name(Rule,X, "Guineensis"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=25, MeanTemp<=32,
MeanRain>=1000, MeanRain<=2500,
Soil="Peat",
crop_name(Rule,X,"Onion"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=25, MeanTemp<=32,
MeanRain>=2500, MeanRain<=4000,
Soil="Calcerous",
crop_name(Rule,X,"Taro"),
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write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=25, MeanTemp<=32,
MeanRain>=2500, MeanRain<=4000,
Soil="Calcerous",
crop_name(Rule,X,"Tannia"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=10, MeanTemp<=32,
MeanRain>=635, MeanRain<=2500,
Soil="Peat" ,
crop_name(Rule,X,"Pineapple"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=10, MeanTemp<=32,
MeanRain>=635, MeanRain<=2500,
Soil="Swamp" ,
crop_name(Rule,X,"Pineapple"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=25, MeanTemp<=30,
MeanRain>=1000, MeanRain<=3000,
Soil="Alluvial" ,
crop_name(Rule,X,"Cush Cush Yam"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=25, MeanTemp<=30,
MeanRain>=1000, MeanRain<=3000,
Soil="Colluvial",
crop_name(Rule,X,"Cush Cush Yam"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=18, MeanTemp<=27,
MeanRain>=900, MeanRain<=1250,
Soil="Sand" ,
crop_name(Rule,X,"Finger Millet"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=18, MeanTemp<=27,
MeanRain>=900, MeanRain<=1250,
Soil="Lateric" ,
crop_name(Rule,X,"Finger Millet"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=25, MeanTemp<=28,
MeanRain>=1000, MeanRain<=2500,
Soil="Alluvial",
crop_name(Rule,X,"Teff"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=28, MeanTemp<=35,
MeanRain>=1000, MeanRain<=3000,
Soil="Clay",
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crop_name(Rule,X,"Rice"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=28, MeanTemp<=35,
MeanRain>=1000, MeanRain<=3000,
Soil="Sand" ,
crop_name(Rule,X,"Rice"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=28, MeanTemp<=35,
MeanRain>=1000, MeanRain<=3000,
Soil="Lateric",
crop_name(Rule,X,"Rice"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=28, MeanTemp<=35,
MeanRain>=1000, MeanRain<=3000,
Soil="Alluvial" ,
crop_name(Rule,X,"Rice"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=32, MeanTemp<=38,
MeanRain>=1525, MeanRain<=2500,
Soil="Calcerous",
crop_name(Rule,X,"Sugar Cane"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=32, MeanTemp<=38,
MeanRain>=1525, MeanRain<=2500,
Soil="Alluvial",
crop_name(Rule,X,"Sugar Cane"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=32, MeanTemp<=38,
MeanRain>=1525, MeanRain<=2500,
Soil="Sand",
crop_name(Rule,X,"Sugar Cane"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=21, MeanTemp<=30,
MeanRain>=450, MeanRain<=900,
Soil="Alluvial",
crop_name(Rule,X,"Corn"),
write("\t",Rule, "   ", X),nl,fail.

crop_value(MeanTemp,MeanRain,Soil):-
MeanTemp>=21, MeanTemp<=30,
MeanRain>=450, MeanRain<=900,
Soil="Colluvial",
crop_name(Rule,X,"Corn"),
write("\t",Rule, "   ", X),nl,fail.

%REASONING WHEN CEA COULD NOT COME WITH ANY RECOMMENDATION
crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,MinTemp,_,MinRain,_,Soils),
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```
Soil=Soils,
MeanTemp<>MinTemp, MeanTemp<MinTemp,
MeanRain<>MinRain, MeanRain<MinRain,
write("\tI could not give other recommendation."),nl,
write("\tMean temperature and mean rainfall in"),nl,
write("\tyour area are lower "),nl,
write("\tand crop that can be cultivate with the soil ",Soil),nl,
write("\tcannot tolerate that."),nl.

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,MinTemp,_,MinRain,_,Soils),
Soil<>Soils,
MeanTemp<>MinTemp, MeanTemp<MinTemp,
MeanRain<>MinRain, MeanRain<MinRain,
write("\tI could not give other recommendation."),nl,
write("\tMean temperature and mean rainfall in"),nl,
write("\tyour area are lower"),nl,
write("\tand soil ",Soil," also not suitable.").

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,MinTemp,_,MinRain,_,Soils),
Soil=Soils,
MeanTemp<>MinTemp, MeanTemp<MinTemp,
MeanRain>=MinRain, MeanRain<=MinRain,
write("\tI could not give other recommendation."),nl,
write("\tMean temperature in your area is lower "),nl,
write("\tand crop that can be cultivate with the soil ",Soil),nl,
write("\tcannot tolerate that."),nl.

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,MinTemp,_,MinRain,_,Soils),
Soil<>Soils,
MeanTemp<>MinTemp, MeanTemp<MinTemp,
MeanRain>=MinRain, MeanRain<=MinRain,
write("\tI could not give other recommendation."),nl,
write("\tMean temperature in your area is lower "),nl,
write("\tand soil ",Soil," also not suitable.").

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,MinTemp,_,MinRain,_,Soils),
Soil=Soils,
MeanTemp>=MinTemp, MeanTemp<=MinTemp,
MeanRain<>MinRain, MeanRain<MinRain,
write("\tI could not give other recommendation."),nl,
write("\tMean rainfall in your area is lower "),nl,
write("\tand crop that can be cultivate with the soil ",Soil),nl,
write("\tcannot tolerate that."),nl.


crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,MinTemp,_,MinRain,_,Soils),
Soil<>Soils,
MeanTemp>=MinTemp, MeanTemp<=MinTemp,
MeanRain<>MinRain, MeanRain<MinRain,
write("\tI could not give other recommendation."),nl,
write("\tMean rainfall in your area is lower "),nl,
write("\tand soil ",Soil," also not suitable.").

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,_,MaxTemp,_,MaxRain,Soils),
Soil=Soils,
MeanTemp<>MaxTemp, MeanTemp>MaxTemp,
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```
MeanRain<>MaxRain, MeanRain>MaxRain,
write("\tI could not give other recommendation."),nl,
write("\tMean temperature and mean rainfall in"),nl,
write("\tyour area is high"),nl,
write("\tand crop that can be cultivate with the soil ",Soil),nl,
write("\tcannot tolerate that."),nl.

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,_,MaxTemp,_,MaxRain,Soils),
Soil<>Soils,
MeanTemp<>MaxTemp, MeanTemp>MaxTemp,
MeanRain<>MaxRain, MeanRain>MaxRain,
write("\tI could not give other recommendation."),nl,
write("\tMean temperature and mean rainfall in"),nl,
write("\tyour area is high"),nl,
write("\tand soil ",Soil," also not suitable.").

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,_,MaxTemp,_,MaxRain,Soils),
Soil=Soils,
MeanTemp<>MaxTemp, MeanTemp>MaxTemp,
MeanRain>=MaxRain, MeanRain<=MaxRain,
write("\tI could not give other recommendation."),nl,
write("\tThe mean temperature in your area is high"),nl,
write("\tand crop that can be cultivate with the soil ",Soil),nl,
write("\tcannot tolerate that."),nl.

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,_,MaxTemp,_,MaxRain,Soils),
Soil<>Soils,
MeanTemp<>MaxTemp, MeanTemp>MaxTemp,
MeanRain>=MaxRain, MeanRain<=MaxRain,
write("\tI could not give other recommendation."),nl,
write("\tThe mean temperature in your area is high"),nl,
write("\tand ",Soil," also not suitable."),nl.

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,_,MaxTemp,_,MaxRain,Soils),
Soil=Soils,
MeanTemp>=MaxTemp, MeanTemp<=MaxTemp,
MeanRain<>MaxRain, MeanRain>MaxRain,
write("\tI I could not give other recommendation."),nl,
write("\tThe mean rainfall in your area is high"),nl,
write("\tand crop that can be cultivate with the soil ",Soil),nl,
write("\tcannot tolerate that."),nl.

crop_value(MeanTemp,MeanRain,Soil):-
crop_ecology(_,_,MaxTemp,_,MaxRain,Soils),
Soil<>Soils,
MeanTemp>=MaxTemp, MeanTemp<=MaxTemp,
MeanRain<>MaxRain, MeanRain>MaxRain,
write("\tI I could not give other recommendation."),nl,
write("\tThe mean rainfall in your area is high"),nl,
write("\tand soil ",Soil," also not suitable."),nl.

crop_value(_,_,_).

%JUSTIFICATION OF EXPLANATION
explanation(Rule):-
crop_explain(Rule,Explain),
write("CEA :\t"),
write(Explain),nl.
```

```
%EXPLANATION ON HOW CONCLUSION IS DERIVED
explain_how(Rule):-
consult("crop_ecology.pro",crop_ecology),
consult("crop_name.pro", crop_name),
crop_explain(Rule,_),
write("CEA :\t"),
write("By using rule number ",Rule,","),
crop_name(Rule,Sci,Com),
write(" mean temperature, mean rainfall and"),nl,
write("\tsoil information given, I concluded that"),nl,
write("\tthe suitable crop for your farm is ", Sci),nl,
write("\tor also known as ", Com,"."),nl,
crop_ecology(Sci,Mintemp,Maxtemp,Minrain,Maxrain,Soil),
write("\tMean temperature value given lies between ", Mintemp, " and ", Maxtemp, "(Celcius)"),nl,
write("\tand mean rainfall value given lies between ", Minrain, " and ", Maxrain,"(mm)."),nl,
write("\tSuitable soil is ", Soil,"."),nl,
retractall(_,crop_ecology),
retractall(_,crop_name).

/*****************************************************************************
                              CROPS SUITABILITY
*****************************************************************************/

crop_name_session:-
write("CEA :\t Choose CROP name by selecting its name. The names given are"),nl,
write("\t either in SCIENTIFIC or COMMON name.                    "),nl,
write("\t Then enter the ecology information of your area.                    "),nl,
write("\t Press OK when everything is done.                    "),nl.


suitability_input(CropName,MeanTemp,MeanRain,Soil):-
consult("crop_ecology.pro",crop_ecology),
openwrite(fileselector17,"suitability.txt"),
        writedevice(Current),
        writedevice(fileselector17),
        crop_suitability(CropName,MeanTemp,MeanRain,Soil),
        other_recommendation(MeanTemp,MeanRain,Soil),
        writedevice(Current),
        closefile(fileselector17),
        retractall(_,crop_ecology).

%RECOMMENDATION OF OTHER CROPS
other_recommendation(MeanTemp,MeanRain,Soil):-
consult("crop_name.pro",crop_name),
openwrite(others,"other_recommendation.txt"),
writedevice(Current),
writedevice(others),
expert_explain(MeanTemp,MeanRain,Soil),
crop_value(MeanTemp,MeanRain,Soil),
writedevice(Current),
closefile(others),
retractall(_,crop_name).

%EXPLANATION FOR TEMPERATURE VALUES
explanation_temp(Diff,CropName,MeanTemp,MinTemp):-
Diff<=3,
write("CEA :\tUSER INFORMATION:"),nl,
write("\tCROP NAME       = ",CropName),nl,
write("\tMEAN TEMPERATURE = ",MeanTemp, " degree Celcius "),nl,nl,
write("\tCEA INFORMATION :"),nl,
```

```
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tTemperature difference of ",Diff, " degree Celcius is tolerable"),nl,
write("\talthough crop might not reach its fullest potential"),nl,
write("\tbecause of the cooler temperature.").

explanation_temp(Diff,CropName,MeanTemp,MinTemp):-
Diff>3,
write("CEA :\tUSER INFORMATION:"),nl,
write("\tCROP NAME       = ",CropName),nl,
write("\tMEAN TEMPERATURE = ",MeanTemp, " degree Celcius "),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tTemperature difference of ",Diff, " degree Celcius is NOT tolerable"),nl,
write("\tbecause cooler environment will affect its production."),nl.

explanation_temp2(Diff,CropName,MeanTemp,MaxTemp):-
Diff<=3,
write("CEA :\tUSER INFORMATION:"),nl,
write("\tCROP NAME       = ",CropName),nl,
write("\tMEAN TEMPERATURE = ",MeanTemp, " degree Celcius "),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
write("\tTemperature difference of ",Diff, " degree Celcius is tolerable"),nl,
write("\talthough crop might not reach its fullest potential"),nl,
write("\tbecause of the warmer temperature.").

explanation_temp2(Diff,CropName,MeanTemp,MaxTemp):-
Diff>3,
write("CEA :\tUSER INFORMATION:"),nl,
write("\tCROP NAME   = ",CropName),nl,
write("\tMEAN TEMPERATURE = ",MeanTemp, " degree Celcius "),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
write("\tTemperature difference of ",Diff, " degree Celcius is NOT tolerable"),nl,
write("\tbecause too much heat will affect the crop production.").

%EXPLANATION FOR RAINFALL VALUES
explanation_rain(Diff,CropName,MeanRain,MinRain):-
Diff<=100,
write("CEA :\tUSER INFORMATION:"),nl,
write("\tCROP NAME    = ",CropName),nl,
write("\tMEAN RAINFALL = ",MeanRain,"mm."),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum rainfall for good crop yields = ",MinRain, "mm."),nl,
write("\tRainfall difference by ",Diff,"mm is tolerable although"),nl,
write("\tcrop might not reach its fullest potential."),nl.

explanation_rain(Diff,CropName,MeanRain,MinRain):-
Diff>100,
write("CEA :\tUSER INFORMATION:"),nl,
write("\tCROP NAME    = ",CropName),nl,
write("\tMEAN RAINFALL = ",MeanRain,"mm."),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum rainfall for good crop yields = ",MinRain,"mm."),nl,
write("\tRainfall difference by ",Diff,"mm is NOT tolerable."),nl,
write("\tCrop production might be affected because of less rainfall."),nl.

explanation_rain2(Diff,CropName,MeanRain,MaxRain):-
Diff<=100,
write("CEA :\tUSER INFORMATION:"),nl,
write("\tCROP NAME    = ",CropName),nl,
write("\tMEAN RAINFALL = ",MeanRain,"mm."),nl,nl,
```

```
write("\tCEA INFORMATION :"),nl,
write("\tMaximum rainfall for good crop yields = ",MaxRain,"mm."),nl,
write("\tRainfall difference by ",Diff,"mm is tolerable although"),nl,
write("\tcrop might not reach its fullest potential."),nl.

explanation_rain2(Diff,CropName,MeanRain,MaxRain):-
Diff>100,
write("CEA :\tUSER INFORMATION: "),nl,
write("\tCROP NAME    = ",CropName),nl,
write("\tMEAN RAINFALL = ",MeanRain,"mm."),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum rainfall for good crop yields = ",MaxRain,"mm."),nl,
write("\tRainfall difference by ",Diff,"mm is NOT tolerable"),nl,
write("\tbecause excessive water will affect its growth."),nl.

%EXPLANATION FOR DIFFERENT VALUES TEMPERATURE AND RAIN
explanation_temp_rain_LL1(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain):-
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMinimum rainfall for good crop yield    = ",MinRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is tolerable."),nl.

explanation_temp_rain_LL2(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain):-
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMinimum rainfall for good crop yield    = ",MinRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is tolerable."),nl.

explanation_temp_rain_LL3(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain):-
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMinimum rainfall for good crop yield    = ",MinRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is NOT tolerable."),nl.

explanation_temp_rain_LL4(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain):-
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMinimum rainfall for good crop yield    = ",MinRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is NOT tolerable."),nl.

explanation_temp_rain_LH(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MaxRain):-
DiffTemp>3, DiffRain<=100,
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write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm."),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is tolerable."),nl,
write("\tCrop might still can grow with such temperature and rainfall"),nl.


explanation_temp_rain_LH(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MaxRain):-
DiffTemp<=3, DiffRain>100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm."),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is NOT tolerable."),nl,
write("\tThis will affect the crop production because of excessive rainfall."),nl.

explanation_temp_rain_LH(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MaxRain):-
DiffTemp>3, DiffRain<=100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm."),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is tolerable."),nl,
write("\tThis will affect the crop production because of excessive rainfall."),nl.

explanation_temp_rain_LH(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MaxRain):-
DiffTemp>3, DiffRain>100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMinimum temperature for good crop yield = ",MinTemp," degree Celcius."),nl,
write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm."),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is NOT tolerable."),nl,
write("\tThis will affect the crop production because of excessive heat and rainfall."),nl.

explanation_temp_rain_HL(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MinRain):-
DiffTemp<=3, DiffRain>100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
write("\tMinimum rainfall for good crop yield    = ",MinRain,"mm."),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is NOT tolerable."),nl,
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write("\tThis will affect the crop production because of excessive rainfall."),nl.

explanation_temp_rain_HL(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MinRain):-
DiffTemp>3, DiffRain<=100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
write("\tMinimum rainfall for good crop yield    = ",MinRain,"mm."),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is tolerable."),nl,
write("\tThis will affect the crop production because of excessive heat."),nl.

explanation_temp_rain_HH1(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain):-
DiffTemp>3, DiffRain>100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is NOT tolerable."),nl,
write("\tCrop will not grow successfully with such temperature and rainfall."),nl.

explanation_temp_rain_HH2(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain):-
DiffTemp<=3, DiffRain<=100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is tolerable."),nl,
write("\tCrop can grow with such temperature and rainfall."),nl.

explanation_temp_rain_HH3(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain):-
DiffTemp>3, DiffRain<=100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is NOT tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is tolerable."),nl,
write("\tCrop will not grow successfully with such heat."),nl.

explanation_temp_rain_HH4(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain):-
DiffTemp<=3, DiffRain>100,
write("CEA : \tUSER INFORMATION :"),nl,
write("\tCrop in your area is ",CropName),nl,
write("\tMonthly mean temperature = ",MeanTemp," degree Celcius."),nl,
write("\tMonthly mean rainfall    = ",MeanRain,"mm."),nl,
write("\tCEA INFORMATION :"),nl,
write("\tMaximum temperature for good crop yield = ",MaxTemp," degree Celcius."),nl,
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write("\tMaximum rainfall for good crop yield    = ",MaxRain,"mm"),nl,
write("\tThe ",DiffTemp," degree Celcius difference in temperature is tolerable."),nl,
write("\tThe ",DiffRain,"mm difference in rainfall is NOT tolerable."),nl,
write("\tCrop will not grow successfully with such rainfall."),nl.

%EXPLANATION FOR DIFFERENT SOIL
explanation_soil(CropName):-
crop_ecology(Crop,_,_,_,_,Soils),
CropName = Crop,
write(Soils," soil, "),fail.

explanation_soil(_).

explanation_soil_diff_soil(CropName,Soil,Soils):-
crop_ecology(Crop,_,_,_,_,Soils),
Soil<>Soils,
CropName = Crop,
write(Soils," soil, "),fail.

explanation_soil_diff_soil(_,_,_).

%CHECKING FOR FACTORS WITHIN RANGE
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp>=MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
Soil = Soils,
write("CEA :\tCrop is suitable to be cultivated in your area."),nl,
write("\tI concluded this by using your information of ",CropName,","),nl,
write("\ttemperature ",MeanTemp," degree celcius, "),nl,
write("\trainfall of ",MeanRain,"mm and ",Soil," soil."),nl,fail.

%CHECKING FOR TEMPERATURE LOWER THAN THE SPECIFIED MINIMUM TEMPERATURE
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
Soil = Soils,
Diff = MinTemp - MeanTemp,
explanation_temp(Diff,CropName,MeanTemp,MinTemp),nl.

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
Soil <> Soils,
Diff = MinTemp - MeanTemp,
write("CEA :\tSoil ",Soil," not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp(Diff,CropName,MeanTemp,MinTemp),nl.


%CHECKING FOR HIGHER TEMPERATURE THAN THE SPECIFIED MAXIMUM TEMPERATURE
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
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Soil = Soils,
Diff =  MeanTemp - MaxTemp,
explanation_temp2(Diff,CropName,MeanTemp,MaxTemp),nl.

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
Soil <> Soils,
Diff = MeanTemp - MaxTemp,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp2(Diff,CropName,MeanTemp,MaxTemp),nl.

%CHECKING LOWER RAINFALL THAN SPECIFIED MINIMUM RAINFALL
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName = Crop,
MeanTemp>=MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
Soil = Soils,
Diff = MinRain - MeanRain,
explanation_rain(Diff,CropName,MeanRain,MinRain),nl.

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
Soil <> Soils,
Diff = MinRain - MeanRain,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_rain(Diff,CropName,MeanRain,MinRain),nl.

%CHECKING HIGHER RAINFALL THAN SPECIFIED MAXIMUM RAINFALL
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp>=MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
Soil = Soils,
Diff = MeanRain - MaxRain,
explanation_rain2(Diff,CropName,MeanRain,MaxRain),nl.

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName = Crop,
MeanTemp>=MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
Soil <> Soils,
Diff = MeanRain - MaxRain,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_rain2(Diff,CropName,MeanRain,MaxRain),nl.
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%CHECKING FOR LOWER TEMPERATURE AND LOWER RAINFALL THAN SPECIFIED
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp<=3, DiffRain<=100,
explanation_temp_rain_LL1(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp<=3, DiffRain<=100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_LL1(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp>3, DiffRain<=100,
explanation_temp_rain_LL2(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp>3, DiffRain<=100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_LL2(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp<=3, DiffRain>100,
explanation_temp_rain_LL3(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).
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```
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp<=3, DiffRain>100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_LL3(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp>3, DiffRain>100,
explanation_temp_rain_LL4(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MinRain-MeanRain,
DiffTemp>3, DiffRain>100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_LL4(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MinRain).


%CHECKING FOR LOWER TEMPERATURE AND HIGHER RAINFALL THAN SPECIFIED
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MeanRain-MaxRain,
explanation_temp_rain_LH(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MaxRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp<MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MinTemp-MeanTemp,
DiffRain=MeanRain-MaxRain,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
```

```
explanation_temp_rain_LH(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MinTemp,MaxRain).

%CHECKING FOR HIGHER TEMPERATURE AND LOWER RAINFALL THAN SPECIFIED
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MinRain-MeanRain,
explanation_temp_rain_HL(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MinRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain<MinRain, MeanRain<=MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MinRain-MeanRain,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_HL(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MinRain).

%CHECKING FOR HIGHER TEMPERATURE AND HIGHER RAINFALL THAN SPECIFIED
crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp>3, DiffRain>100,
explanation_temp_rain_HH1(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp>3, DiffRain>100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_HH1(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).


crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp<=3,DiffRain<=100,
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explanation_temp_rain_HH2(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp<=3,DiffRain<=100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_HH2(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp>3,DiffRain<=100,
explanation_temp_rain_HH3(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp>3,DiffRain<=100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_HH3(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil=Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp<=3,DiffRain>100,
explanation_temp_rain_HH4(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
Soil<>Soils,
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp>MaxTemp,
MeanRain>=MinRain, MeanRain>MaxRain,
DiffTemp=MeanTemp-MaxTemp,
DiffRain=MeanRain-MaxRain,
DiffTemp<=3,DiffRain>100,
write("CEA :\tSoil ",Soil, " not suitable to cultivate ",Crop,"."),nl,
```

```
write("\tI recommend "),
explanation_soil(Crop),nl,nl,
explanation_temp_rain_HH4(DiffTemp,DiffRain,CropName,MeanTemp,MeanRain,MaxTemp,MaxRain).

%CHECKING FOR DIFFERENT SOIL

crop_suitability(CropName,MeanTemp,MeanRain,Soil):-
crop_ecology(Crop,MinTemp,MaxTemp,MinRain,MaxRain,Soils),
CropName=Crop,
MeanTemp>=MinTemp, MeanTemp<=MaxTemp,
MeanRain>=MinRain, MeanRain<=MaxRain,
Soil <> Soils,
write("CEA :\tUSER INFORMATION: "),nl,
write("\tCrop Name       = ",CropName),nl,
write("\tMean Temperature = ",MeanTemp),nl,
write("\tMean Rainfall    = ",MeanRain),nl,
write("\tSoil                          = ",Soil),nl,nl,
write("\tI conclude that ",Soil, " not suitable."),nl,
write("\tI recommend soil "),
explanation_soil_diff_soil(CropName,Soil,Soils),nl,
write("\tfor the cultivation of the crop."),nl,
write("\tMean temperature and mean rainfall suitable"),nl,
write("\tto cultivate ", CropName).

crop_suitability(_,_,_,_).
```

Crop Name

crop_name(1,"Agave Fourcroydes","Henequen").
crop_name(2,"Agave Sisalana","Sisal").
crop_name(3,"Furcraea Gigantea","Mauritius Hemp").
crop_name(4,"Phormium Tenax","New Zealand Flax").
crop_name(5,"Sanseviera Guineensis","Guineensis").
crop_name(6,"Allium Cepa","Onion").
crop_name(7,"Calocasia Esculenta","Taro").
crop_name(8,"Xanthosoma Saggitifolium","Tannia").
crop_name(9,"Ananas Comosus","Pineapple").
crop_name(10,"Dioscorea Trifida","Cush Cush Yam").
crop_name(11,"Eleusine Corocana","Finger Millet").
crop_name(12,"Eragrotis Tef","Teff").
crop_name(13,"Oryza Sativa","Rice").
crop_name(14,"Saccharum","Sugar Cane").
crop_name(15,"Zea Mays","Corn").

Crop Ecology

```
crop_ecology("Agave Fourcroydes",10,38,720,1500,"Calcerous").
crop_ecology("Agave Sisalana",20,27,1000,1250,"Alluvial").
crop_ecology("Agave Sisalana",20,27,1000,1250,"Colluvial").
crop_ecology("Agave Sisalana",20,27,1000,1250,"Red earth").
crop_ecology("Agave Sisalana",20,27,1000,1250,"Gneiss").
crop_ecology("Agave Sisalana",20,27,1000,1250,"Volcanic").
crop_ecology("Furcraea Gigantea",10,18,760,960,"Rocky").
crop_ecology("Phormium Tenax",10,38,500,3800,"Alluvial").
crop_ecology("Sanseviera Guineensis",28,33,1000,2500,"Calcerous").
crop_ecology("Allium Cepa",25,32,1000,2500,"Peat").
crop_ecology("Calocasia Esculenta",25,33,2500,4000,"Calcerous").
crop_ecology("Xanthosoma Saggitifolium",25,32,2500,4000,"Calcerous").
crop_ecology("Ananas Comosus",10,32,1000,1500,"Peat").
crop_ecology("Ananas Comosus",10,32,1000,1500,"Swamp").
crop_ecology("Dioscorea Trifida",25,30,1000,3000,"Alluvial").
crop_ecology("Dioscorea Trifida",25,30,1000,3000,"Colluvial").
crop_ecology("Dioscorea Trifida",18,27,900,1250,"Sand").
crop_ecology("Dioscorea Trifida",18,27,900,1250,"Lateric").
crop_ecology("Eragrotis Tef",25,28,1000,2500,"Alluvial").
crop_ecology("Oryza Sativa",28,35,1000,3000,"Clay").
crop_ecology("Oryza Sativa",28,35,1000,3000,"Sand").
crop_ecology("Oryza Sativa",28,35,1000,3000,"Lateric").
crop_ecology("Oryza Sativa",28,35,1000,3000,"Alluvial").
crop_ecology("Saccharum",32,38,1525,2500,"Calcerous").
crop_ecology("Saccharum",32,38,1525,2500,"Alluvial").
crop_ecology("Saccharum",32,38,1525,2500,"Sand").
crop_ecology("Zea Mays",21,30,450,900,"Colluvial").
crop_ecology("Zea Mays",21,30,450,900,"Alluvial").
crop_ecology("Henequen",10,38,720,1500,"Calcerous").
crop_ecology("Sisal",20,27,1000,1250,"Alluvial").
crop_ecology("Sisal",20,27,1000,1250,"Colluvial").
crop_ecology("Sisal",20,27,1000,1250,"Red earth").
crop_ecology("Sisal",20,27,1000,1250,"Gneiss").
crop_ecology("Sisal",20,27,1000,1250,"Volcanic").
crop_ecology("Mauritius Hemp",10,18,760,960,"Rocky").
crop_ecology("New Zealand Flax",10,38,500,3800,"Alluvial").
crop_ecology("Guineensis",28,33,1000,2500,"Calcerous").
crop_ecology("Onion",25,32,1000,2500,"Peat").
crop_ecology("Taro",25,33,2500,4000,"Calcerous").
crop_ecology("Tannia",25,32,2500,4000,"Calcerous").
crop_ecology("Pineapple",10,32,1000,1500,"Peat").
crop_ecology("Pineapple",10,32,1000,1500,"Swamp").
crop_ecology("Cush Cush Yam",25,30,1000,3000,"Alluvial").
crop_ecology("Cush Cush Yam",25,30,1000,3000,"Colluvial").
crop_ecology("Finger Millet",18,27,900,1250,"Sand").
crop_ecology("Finger Millet",18,27,900,1250,"Lateric").
crop_ecology("Teff",25,28,1000,2500,"Alluvial").
crop_ecology("Rice",28,35,1000,3000,"Clay").
crop_ecology("Rice",28,35,1000,3000,"Sand").
crop_ecology("Rice",28,35,1000,3000,"Lateric").
crop_ecology("Rice",28,35,1000,3000,"Alluvial").
crop_ecology("Sugarcane",32,38,1525,2500,"Calcerous").
crop_ecology("Sugarcane",32,38,1525,2500,"Alluvial").
crop_ecology("Sugarcane",32,38,1525,2500,"Sand").
crop_ecology("Corn",21,30,450,900,"Colluvial").
crop_ecology("Corn",21,30,450,900,"Alluvial").
```

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