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Computer Aided Decision Support System in Land Evaluation - A Case Study

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Abstract : *Performance of land depends on a large number of factors changing markedly with time, space, bio-physical resources and socio-economic conditions. Information about potentials and constraints of a given land for a specific use can quickly be provided by using a computer system that processes database and reasoning. An expert system, such as Automated Land Evaluation System (ALES) and a model built using its framework such as Land Evaluation for Central Ethiopia (LEV-CET), expresses reasoning of expert judgements and makes use of locally available knowledge and data to make land suitability assessments. Application of LEV-CET provides quick answers to land performance problems in central Ethiopia. The model output corresponds fairly well with the present land use and crop yields in much of the studied areas. In few places there are discrepancies owing to factors other than the bio-physical conditions which are not considered in the model.*

In agriculture, the terminology 'Decision Support System (DSS)' has been used to describe a wide range of computer softwares that aid various types of decision making (Yost *et al* 1988; Rossiter 1988; Bogges *et al.* 1989; Plant 1989). generally, summarizes a reasoning process in a manner that allows systematic identification and evaluation of possible alternatives.

An expert system incorporates accumulated experience into a computer programme and uses it as a criterion to make judgements (for example on suitability of a given land for a specific crop). When the question is asked, it gives similar answers as an expert in the field, including the reasoning behind the decision and the intermediate assumptions.

In building a model, the real system (e.g. crop production) is usually simplified. The emphasis is given to the main variables and constraints with respect to the considered use in the decision procedure. The system compares attributes of land with rules and logic in the knowledge base using diagnostic operations and presents

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interpretations to users. It mainly identifies potential problem areas, displays them for users and categorizes them as to the type and probable magnitude of the limitations.

The FAO concept of land evaluation (FAO 1976; 1983) is based on matching land attributes with requirements of land use types (or crops being considered). Land suitability assessment consists of the integration of a number of concurrent and sequential activities, including collection, analysis, integration and interpretation of data sets to appraise the fitness of a given land (Teshome 1994). Data sets include climate, soil, crop resources and socio-economic information. Degree of integration of bio-physical and socio-economic information, as well as objectives of the study, proboems to be solved and availability of data determine whether evaluation results be expressed qualitatively, quantitatively or using a mixed approach.

A model represents reality in an objective way and often simplifies the real system by considering only a small fraction of the variables, that largely determine the behaviour of a system. There is no single accepted classification for models. In practice, a given model may consist of sub-models each, of which may be of a different kind.

Three common types of models, with a possibility of using a combination, are:

- Empirical or mathematical/statistical models which have been found to work in practice, but the exact mechanism of which is mostly not well understood; many variables not explicitly considered in the equation are implicitly assumed to be constant.
- Deterministic models which are process-oriented models, which at least in a plausible way claim to emulate physical laws and/or known causes and effects of a process.
- Heuristic or expert models which are the most common models in agriculture used by many farmers as a 'rule of thumb' in deciding what crop to plant, where and at what time to plant; generally based on experience of what works in practice.

In this paper, an expert system and its application in assessing the suitability of two test areas in central Ethiopia are discussed. A decision procedure called Land Evaluation System for Central Ethiopita (LEV-CET) is developed using the framework of Automated Land Evaluation System (ALES) to evaluate three food crops grown under rainfed conditions in central Ethiopia.

The major objectives of the study are :

- To demonstrate the use of a computer aided decision support system as a basis for an efficient use of locally available data and expert knowledge;
- To apply a simple, quick and flexible, but consistent computerized land evaluation system developed for use in central Ethiopia, based on an expert system shell; and
- To assess physical suitability of areas in central Ethiopia for barley (*Hordeum vulgare*), maize (*Zea mays*) and tef (*Eragrostis tef*).

MATERIAL AND METHODS

Two pilot areas are selected from central Ethiopia (Fig.1) to demonstrate the application of an expert system in land evaluation. Selected agro-climatic properties of representative stations are documented in Table 1. Identified land units are represented by a letter-figure combination in figures 2 and 3. The letter shows major physiographic units while the number indicates soil and landscape conditions of the land units (legends of fig. 2 & 3).

Pilor one (PILOT1) covers about 138 000 ha between Lat. 8°45'N and 9°12'NLat., and between 38°45'E and 39°00'E Long. (Fig.2). Altitudes range from 1800 m to over 3200 m above MSL. Annual rainfall varies from 750 to over 950 mm (Table 1). Six major physiographic units have been identified (Mitiku 1987); hills and hill footslopes (H), river valleys (V), basins and alluvial plains (L), pyroclastic plains (Y), mountains and mountain tops (M) and plateau (P) areas. The major soil types are Vertisols, Nitosols, Phaeozems, Andosols and associated Lithosols and Regosols. For the purpose of this study, physiographic units are grouped into land units derived from-typical pedons, with specific land properties (Fig. 2).

Pilot two (PILOT2) covers about 318000 ha in the southern part of Shoa administrative region, between Lat. 7°06'N and 7°30'N, and Long. 38°06'E and 38°45'E (Fig.3). Altitudes range from below 1500 m to over 3000 m above MSL. Annual rainfall varies from 710 to 976 mm (Table 1). Eight major physiographic

TABLE 1. Selected agro-climatic attributes of reference stations in the two pilot areas

Attribute	PILOT1				PILOT2		
	Akaki	Debre-zeit	Send-afa	Addis Ababa	Alaba-kolito	Shashe-mene	Awasa
Length of growing period (days)	137	124	157	204	210	194	201
Rainfall, growing period (mm)	597	584	699.	777	666	523	577
Annual rainfall(mm)	772	772	899	976	766	710	738
Mean Temp growing period(°C)	18.8	18.9	5.9	16.3	18.9	17.4	19.1
Mean min. Temp. growing period (°C)	10.0	11.3	8.3	9.5	11.5	10.5	12.0
Frost hazard	none	none	mod. erate	slight	none	none	none
Altitude (m)	2100	1900	2485	2400	1750	2010	1720

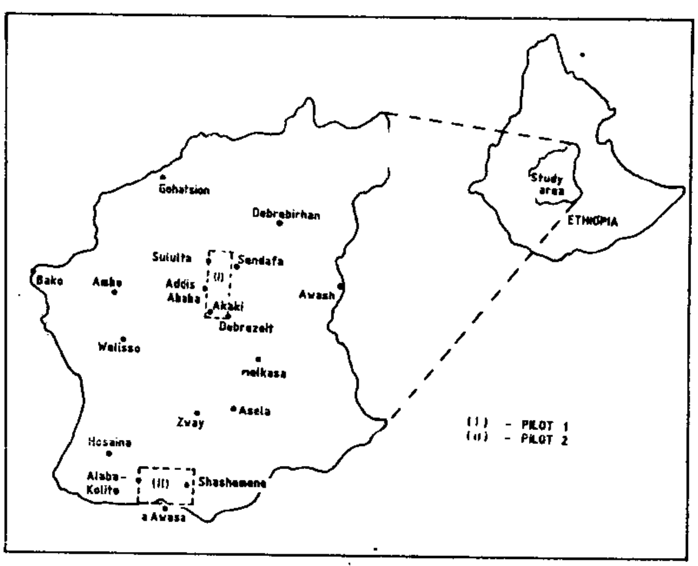

Fig. 1. Location map of the study area (PILOT1 and PILOT2) in central Ethiopia.

Legend (adapted from Nitiku, 1987) for figure 1.

Code	Physiography
M	Mountain tops, flanks and footslopes
P	Plateau
H	Hilly slopes and footslopes
Y	Pyroclastic plains
L	Basins, alluvial plains and intermountain plains
V	Inter-river valleys
20	Deep; moderately well to well drained; fairly stony; clayey Vertisols on hill footslopes (slopes <4%); organic matter content (O.M) >0.85%, sum of exchangeable bases (SEB) >60 cmol(+) kg^{-1} soil, pH 7.3-7.4
21	Deep; moderately well to well drained; fairly stony to stony; clayey Vertisols on intermountain palins and river valleys (slopes <10%); (O.M) >1%, (SEB) >39 cmol(+) kg^{-1} soil, pH 5.5-5.9
22	Moderately deep to deep; impoerfectly drained; slight flood risk; clay to silty clay Vertisols on mountain foot slopes, pyroclastic plains and alluvial plains (slope < 1%); O.M > 0.8%, SEB >50 cmol(+) kg^{-1} soil, pH 7.2-7.4
23	Shallow; excessively drained; stony and rocky ; silt loam Phaeozems and Regosols mainly on mountain flanks (slope >20%), but also on pyroclastic plains and hill footslopes; O.M > 1.5%, SEB >35 cmol(+) kg^{-1} soil, pH 6.4-6.6
24	Deep; moderately well to well drained; clayey Phaeozems on hill footslopes and intermountain plains (slope < 3%); O.M > 1.6%, SEB >35 cmol(+) kg^{-1} soil, pH 6.5-7.0
25	Deep; moderately well to well drained; slight flood risk; slightly rocky, clayey Phaeozems on mountain foot slopes and pyroclastic plains (slope < 2%); O.M > 2.5%, SEB >25 cmol(+) kg^{-1} soil, pH6.0-6.3
26	Deep; well drained; slightly rocky and stony, loamy Vertic Cambisols mainly on hill slopes and mountain footslopes (slope < 6%); O.M > 1.7%, SEB >20 cmol(+) kg^{-1} soil, pH 1.7-7.3
27	Deep; somewhat excessively drained, silty clay loam Andosols on hill slopes and pyroclastic plains (slope <2%); O.M > 1.7%, SEB >30 cmol(+) kg^{-1} soil, pH 7.0-7.4
28	Deep; well drained; stony and rocky, clay to silty clay Nitosols on mountain slopes and tops (<3% slope); O.M >3%, pH 5.6-5.7; SEB > 15 cmol(+) kg^{-1} soil
29	Deep; well drained; clay to silty clay Nitosols on the plateau (<3% slope); O.M >1.5%, pH 5.5-5.8; SEB > 11 cmol(+) kg^{-1} soil
W	Water bodies

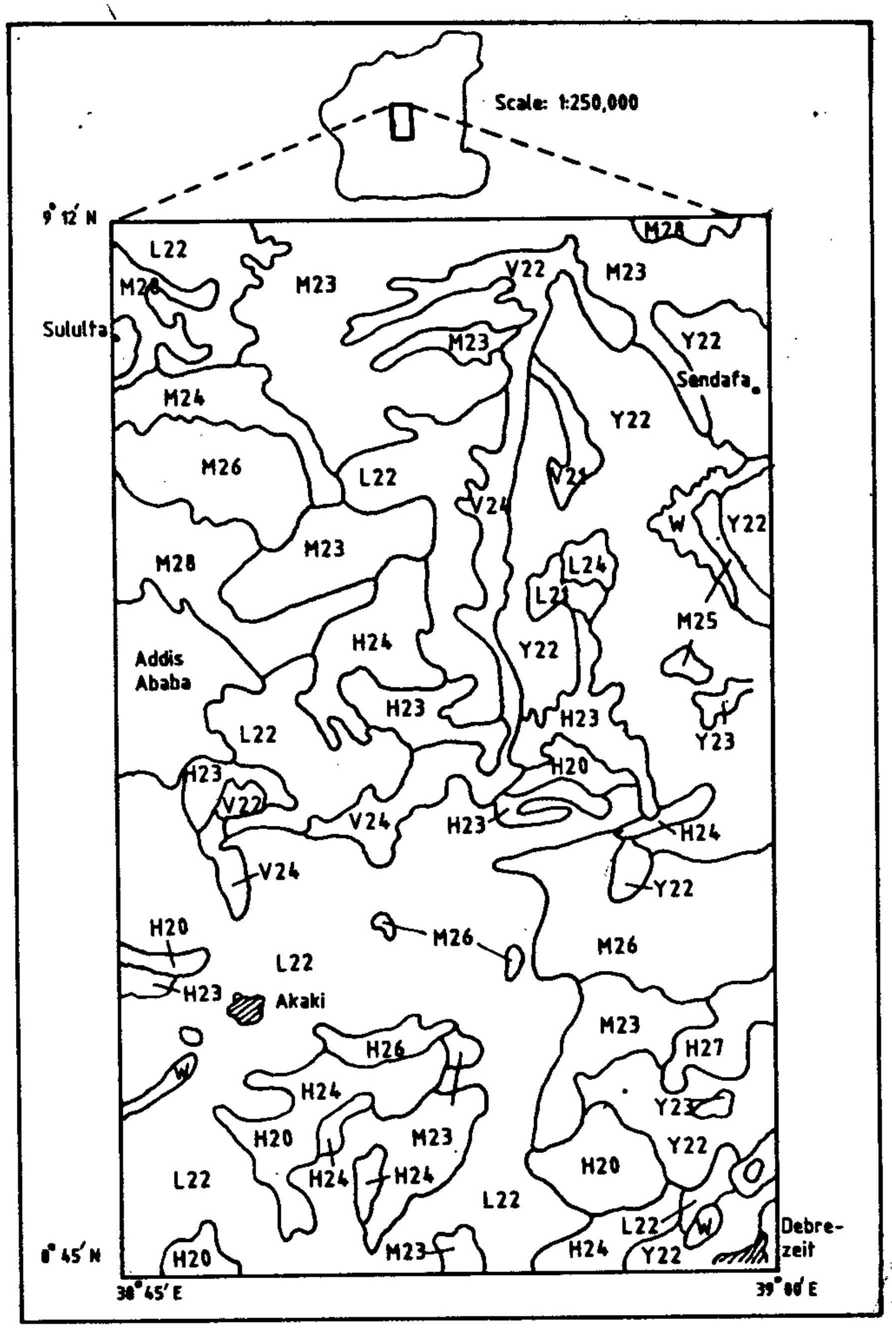

Fig. 2. Land units in pilot area one (PILOT1) (Adapted from Mitiku, 1987)

Key (adapted from LUPRD, 1989) for figure 2.

Code	Physiography
A	Alluvio-colluvial landforms
B	Rolling to steep isolated hills
C	Complex expolsion tuff craters and surrounding plains
H	Hilly redges and rises of central Rify Valley floor
L	Volcano-lacustrine terraces around major lakes
M	Stepfaulted mountains on felsitic pyroclastic material
R	Nearly leve to undulating benched Rift Valley floor
V	Felsitic volcanic landforms and lava floors
30	Moderately deep to deep; well drained; loam and silty loam Phaeozems on basaltic volcanic landforms; hilly ridges and faulted mountain slopes (<8%), pH 6.5-6.7
31	Deep; moderately well drained; silty loam; moderately sodic Andosols on hilly ridges and rises to the Rift Valley floor, pH > 7; slopes < 6%
32	Moderately deep; moderately well drained; loamy Andosols in the Rift Valley floor; pH > 7; with gullied land
33	Moderately deep to deep; moderately well drained; loamy Andosols and associated strongly alkaline Solonetz in the Rift Valley floor; pH > 7.6; slope < 6%
34	Moderately deep to deep; moderately well drained; loamy Fluvisols on hilly ridges and rises of the Rift Valley floor and alluvio-colluvial plains and valleys, with vertisols; pH 5-6; slopes < 2%
35	Deep; somewhat excessively drained; coarse loamy Andosols in the Rift Valley floor; slightly sodic, pH > 7 slope < 4%
36	Deep; somewhat excessively drained; loam to sandy loam Andosols in the Rift Valley floor and volcanic landforms; pH > 7.2; slope < 3%
37	Deep; somewhat excessively drained; coarse loamy, moderately sodic Andosols and Fluvisols in the Rift Valley floor (< 4%), on volcano-lacustrine landforms; pH 6.8-7.1
38	Deep to very deep; well drained; slight flooding; coarse loamy; strongly alkaline and saline Fluvisols on volcano-lacustrine terraces and alluvio-colluival landforms; pH 7.9; slope < 6%
39	Rockoutcrops, steep ridges andbadlands, very shallow Lithosols, with pockets of Nitosols and Cambislos
W	Water bodies

units have been identified (LUPRD 1989); alluvio- colluvial landforms (A), hills (B), complex explosion tuff craters (C), hilly ridges and rises of the Central Rift Valley floor (H), volcano-lacustrine terraces (L), mountains (M), Rift Valley floor (R) and felsitic volcanic landforms and lava flows (V). The major soil types are Lithosols, Phaeozems, Andosols and Fluvisols. Major physiographic units and soil types define land units, with specific land attributes (Fig. 3).

Expert Systems: A model can be built to satisfy local needs and to utilize locally available information. The simple computerized land evaluation system LEV-CET employed in this study (Teshome 1994) was developed

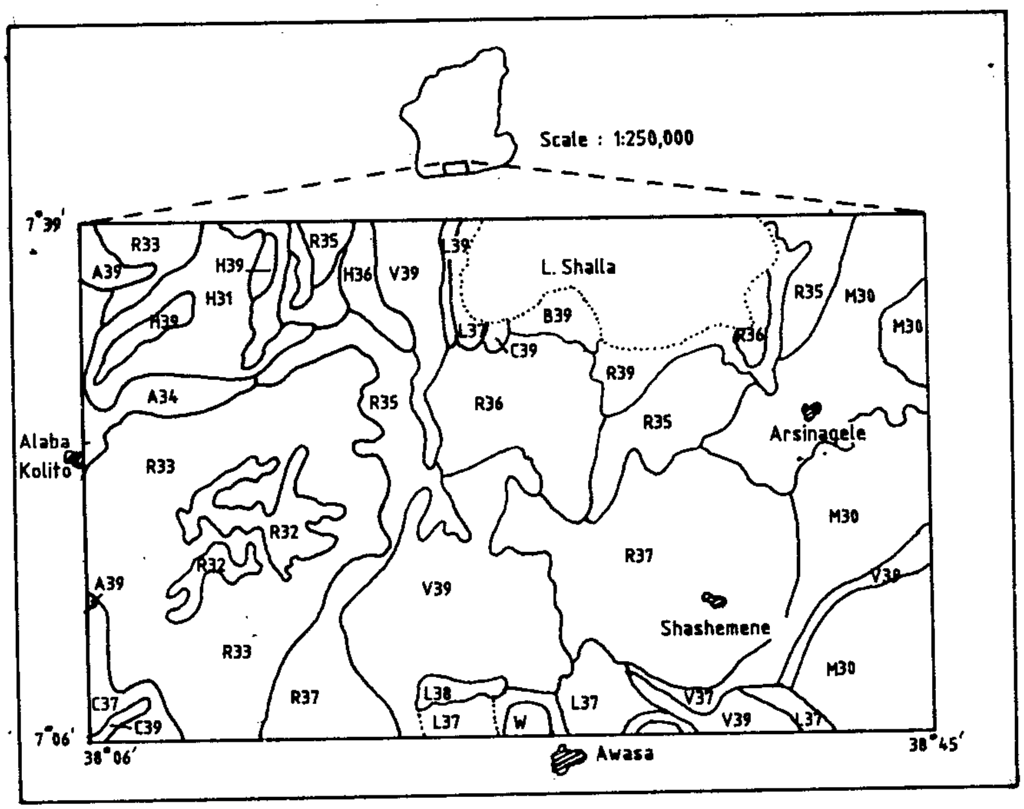

Fig. 3. Land units in pilot area 2 (PILOT2) (Adapted from LUPRD, 1987)

using the facilities of Automated land Evaluation System : ALES (Rossiter 1988; 1990; Rossiter & Van Wambeke, 1989; 1991). ALES is a microcomputer programme implementing the FAO (1976; 1983) land evaluation methodology. ALES provides the framework to create models in terms of attributes of land and bio-physical, as well as socio- economic requirements of specific uses.

An expert system, such as ALES, has four main components.

- Knowledge acquisition module : the database from a land resource inventory.
- Knowledge base : all specifications of land use types and factor ratings of selected attributes.
- Inference engine or analysis tool : user-defined reasoning keys or decision trees.
- User interface or an interactive dialogue that provides an explanation as to why the system arrived at its conclusions. It also provides the possibility to trace mistakes in decision trees, fine tune the model, and to generate reports. The general procedure followed to arrive at the overall suitability evaluation, as used by LEV-CET is given in Fig. 4.

Land use types (LUTs) considered in. LEV-CET are rainfed barley, maize and tef grown by farmers, who use sub-optimal inputs (fertilizers, improved seeds, improved implements, etc.). The LUT specification (Fig. 4) describes crops in terms of method of cultivation, produce, management and bio-physical requirements that are relevant for their functioning.

The land resources database (Fig. 4) comprises information on crops, climate, soils and landform. Based on requirements of the considered crops, specific diagnostic criteria are selected from the database to define attributes or land use requirements (LURs). Definition of each diagnostic criterion involves partitioning into classes and grouping into land use requirements.

The land use requirement (LUR) reference list specifies selected attributes, each of them being defined by a combination of relevant criteria (Table 2). For instance, temperature requirement is defined by frost occurrence, mean air temperature and mean minimum temperature during the growing period. The combination of these criteria with corresponding land use requirements is used in decision trees.

TABLE 2. Codes, descriptive names and relevant diagnostic criteria of land use requirements (LURs) employed in LEV-CET

Land use requiremnt code	Descriptive name	Relevant attributes (abbreviations and units of measurement)
moi	Moisture conditions	Length of growing period (gpl, days), rainfall during the growing period (rfg, mm)
tem	Temperature conditions	Frost occurrence (fros), growing period mean (gmt, °C) and minimum temperature (Tmin, °C)
rot	Rooting conditions	Effective depth (dep, cm), texture (texs), surface coarse fragments (scfv, %)
wet	Wetness conditions	Flooding (flo), drainage (dra), texture (texs)
fer	Fertility conditions	Organic matter (O.M., %), Cation exchange capacity (CEC, cmol(+)/100g soil), Sum of exchangeable bases, (SEB, cmol(+)/100g soil), pH (PHH)
sal	Excess salts conditions	Salinity (ECe, mmhos/cm, Alkalinity (ESP, %)
eas	Ease of cultivation conditions	Slope (slop, %), surface stoniness (ston, %), rock outcrops (rok, %)

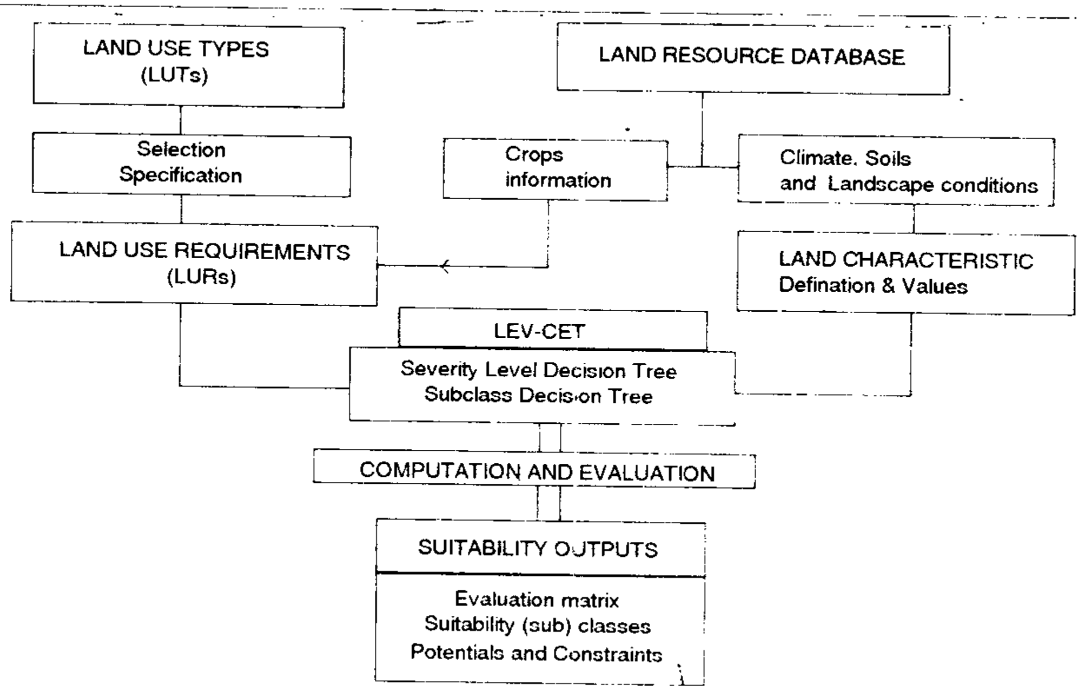

Fig. 4 Flow chart of the sequence of procedures of a physical suitability evaluation using LEV-CET (source: Teshmoe, 1994)

Factor ratings, referred to as severity levels, are assigned to relevant diagnostic criterion values. The number of factor ratings can vary. Four severity levels are used to rate selected land use requirements in this study. Severity levels correspond to increasing levels of physical limitations.

In practice, a farming operation involves a substantial number of vriables and constraints. Usually, however, only a small fraction of these variables and constraints truly dominates the behaviour of the system. Therefore, only those variables which have a significant influence to the functioning of the use and which vary from one land unit to another, need to be selected and included in a decision procedure.

The basic component of the model, i.e. inference engine, is a severity level decision tree (Fig. 4). The tree is a structural representation of a reasoning process, needed to reach decisions based on expert knowledge and judgements in the form of decision rules to place each land unit into one of the suitability classes.

Specific subclasses to any combination of severity levels of land attributes (LURs) are assigned by constructing a physical suitability subclass decision tree. Subclasses give information about the nature of constraints.

One severity level decision tree is built for each land use requirement in the LUT specification. Figures 5 and 6 illustrate decision trees of moisture conditions for barley, and temperature conditions for maize, respectively. Figure 7 shows a severity level decision tree for a tef to determine conditions of wetness. Moisture requirement is determined by the length of the growing period and by all the rainfall during this period (Fig. 5). Temperature conditions are determined by considering the occurrence of frost, mean and minimum temperatures during the crop growth cycle (Fig. 6). The evaluation of wetness conditions is derived from ratings of risk of flooding, drainage and soil texture (Table 2 & Fig. 7).

Severity classes of each attribute are expressed by a user defined number of ranges (a, b, ...) (Fig. 5, 6 & 7). A final decision is reached when a severity level (1, 2, 3 & 4) is preceded by an sterisk (*). An equality sign (=) indicates that the branch or

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Moisture conditions (moi)[1]
glp: a. <60       *4
     b. 60-90     >rfg -------------------------------------------------------- a. <200      *4
     c. 90-120    >rfg ------------------------------------ a. <200     *4      b. 200-300   *3
     d. 120-150   =c                                        b. 200-300  *3      c. 300-400   =b
     e. 150-180   >rfg --------- a. <200      *4            c. 300-400  *2      d. 400-700   =b
     f. 180-210   =b             b. 200-300   *3            d. 400-700  *1      e. 700-850   =b
     g. 210+      *4             c. 300-400   *2            e. 700-850  =d      f. 850+      *4
     h. ??                       d. 400-700   =c            f. 850+     *3      g. ??
                                 e. 700-850   =c            g. ??
                                 f. 850+      *3
                                 g. ??
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[1] Refer table 2 for abbreviations and decisions as : *1 - no or slight, *2- moderate, *3-severe, and *4- very severe limitations

Fig.5. Example of a severity level decision tree in LEV-CET for landuse type barley and LUR moisture conditions

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Temperature conditions (t) [1)]
Fros:a. no    >gmt --  a. <7.5      *4
     b. sl1   >gmt --| b. 7.5-10    *3
     c. sl2   =b     | c. 10.5-13   >T min ---------------------------------------- a. <6      *4
     d. any   *4     | d. 13-15.5   >Tmin ---------------------- a. <6      *4      b. 6-10    = a
     ??              | e. 15.5-18   >Tmin --- a. <6      *4      b. 6-10    =a      c. 10-14   *3
                     | f. 18-26.5   =e        b. 6-10    *3      c. 10-14   *3      d. 14+     =c
                     | g. 26.5+     *3        c. 10-12   *2      d. 14+     *2      ??
                     | ??                     d. 12+     *1      ??
                     |                        ??
                     |___ a. <7.5         *4
                          b. 7.5-10.5     =a
                          c. 10.5 - 26.5  >tmin ---------- a. <6     *4
                          ??                               b. 6-10   =a
                                                           c. 10-14  *3
                                                           d. 14+    =c
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[1)] Fros is occurrence of frost (sl1 slight from October to December, sl2 is slight from December to January, and any is occurrence of frost any time during the crop cycle), gmt is mean temperature during the crop cycle, and Tmin is mean minimum temperature during the crop cycle in degree C

Fig. 6. A severity level decision tree in LEV-CET for landuse type maize and landuse requirement temperature conditions.

severity level should be equated or be joined to a sub-tree, and then take the decision of the class to which it is equated. The greater-than sign (>) shows that the attached branch (sub-tree) should be followed. A double-question mark sign (??) indicates that either a decision has not yet been made, or that alternative criteria can be inserted in the case of incomplete data.

For instance in figure 5, when the length of growing period (gpl) is below 60 days, there is a very severe limitation (4) to barley. When gpl is above 60 days, one has to check rainfall during the growth cycle (rfg) before arriving at a decision. If gpl is 60-90 days and rfg is below 200 mm or above 850 mm, the final decision will be 4, and if rfg is between 200 mm and 850 mm, the final decision is *3 due mainly to the effect of a shorter growing period length (Fig. 5).

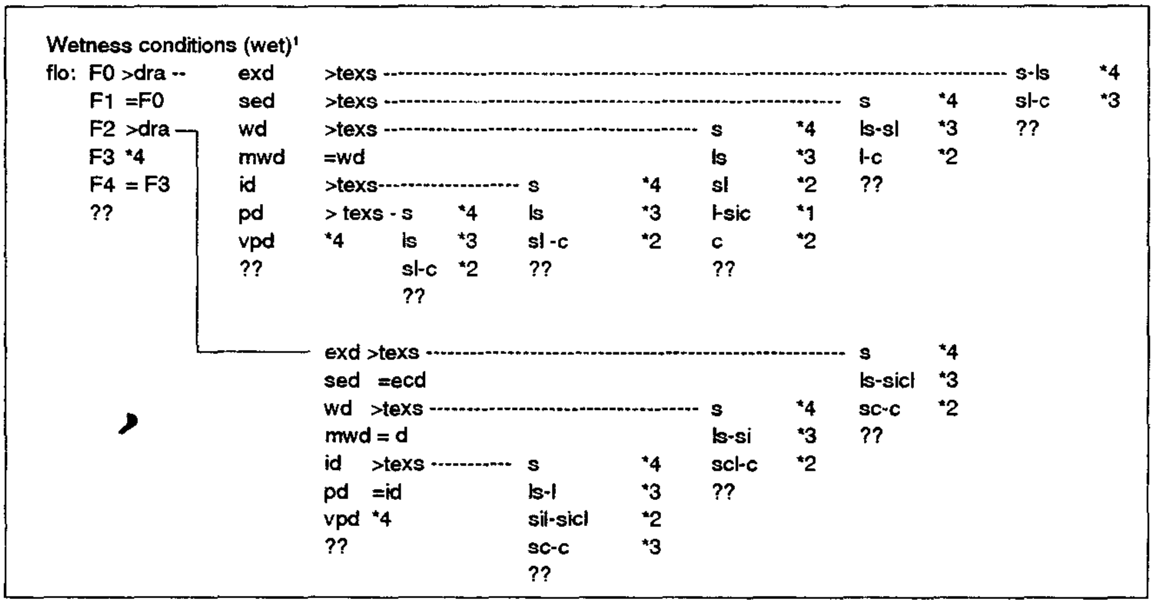
The ultimate evaluation is computed by selecting land use types and land units. Computation assesses how well the selected land unit is fitted for the considered LUTs. The LEV-CET model then analyses decision trees and compares the values of relevant criteria of each attribute (LUR) in the data base with the land use requirements. Evaluation outputs are presented in a matrix. The matrix helps to make comparisons among and within land units and land use types.

Application of Expert Systems and Evaluation Outputs

Agroclimatic suitability is derived by comparing the crop requirements with specific conditions of temperature and moisture during crop cycle. In PILOT1, areas around Akaki and Debrezeit are climatically highly suitable for barley and tef, and moderately suitable for maize. In the northern part (northwards from Addis Ababa to Sendafa), there are severe to very severe limitations to maize and severe limitation to tef due to too low temperatures (slight to severe frost hazard in areas of over 2400 m altitude and mean temperatures of below 16°C and mean minimum temperatures of below 10°C) during the growing period. Barley is better suited than the other crops due to its adaptability to cooler conditions.

In PILOT2, barley and tef are climatically moderately suitable, while maize is highly suitable. Moderate limitations to barley and tef are caused by too long growing periods and high rainfall amounts in the western and southern parts, and due to too short growing period length and little rainfall in the northeastern part of PILOT2. A too long growing period length (over 180 days) and much rainfall (over 900 mm during the growing period) cause lodging, damages harvestable crop, and encourages diseases and pests.

From the climatic point of view,



Flooding: F0 is that there is no flood risk or that the land surface is higher than the highest water table, F1 is occasional flood risks (1-2 months), F2 is when flood risk very often (5 out of 10 years) for a period of 2-3 months, F3 is that there is flood risk almost every year for a period of 2-4 months and F4 is that the land surface is flooded nearly every year. **Drainage**:exd is excessively drained, sed is somewhat excessively drained, wd is well drained , mwd is moderately well drained, pd is poorly drained land vpd is very poorly drained. **Texture;** s is sand, ls is loamy sand, sl is sandy loam, l is loam, sil is silty loam, si is silt, scl is sandy clay loam, cl is clay loam, sicl is silty clay loam, sc is sandy clay and c is clay.

Fig.7. Example of a severity level decision tree in LEV-CET for land use type Tef and LUR wetness conditions

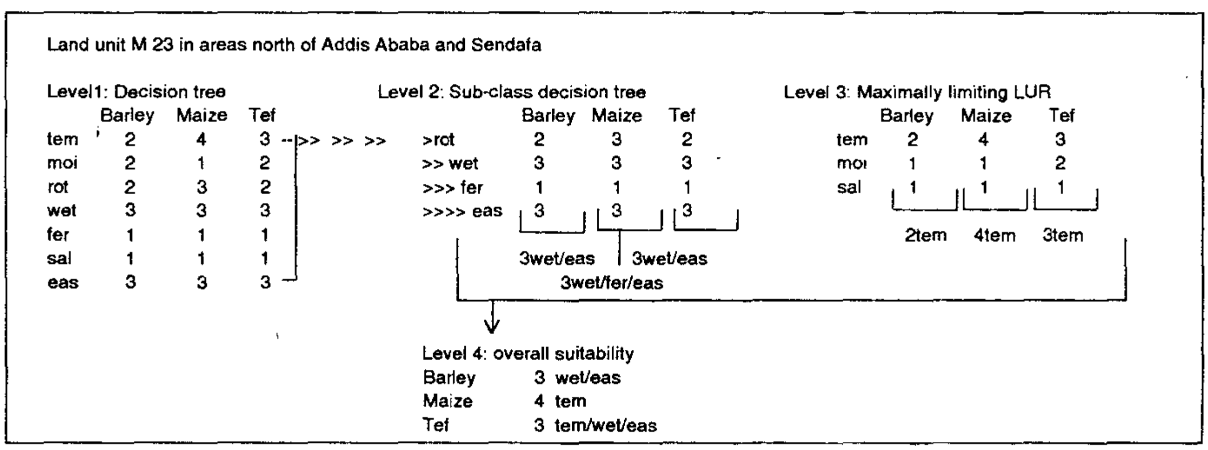


Fig.8. Levels of decision making using LEV-CET as a computer captured expert system in land suitability assessment.

the most suitable crop in the higher altitude, northern part of PILOT1 is barley, tef being highly suitable in the central and southern part of PILOT1. Maize is the most suitable crop in PILOT2.

Most land units in PILOT1 are moderately suitable to all three crops, the major limitations being wetness and rooting conditions (Table 3). The wetness limitations refer to imperfectly (and in some units excessively)drained and occasionally flooded situations. Severe constraints of imperfectly drained, occasionally flooded clayey soils on land units L22, Y22 for barley and maize, and excessively drained, shallow silty loam, stony and rocky soils on land unit M23 for all three crops are identified (Table 3).

Most land units in PILOT2 have moderate limitations from conditions of wetness, fertility and salinity/alkalinity (Table 4). Barley is severely constrained on land unit R35 due to wetness, on land unit R37 due to wetness and fertility and on land unit L38 due to wetness and rooting. Severe constraints for maize are identified on land units R33 and R36 due to salinity/alkalinity, on R35, R37 and L38 due to wetness, and on land units R33, R36 and L38 because of salinity/alkalinity conditions. Land unit 39 is unsuitable for all three crops mainly due to cultivation constraints and erosion risk. An explanation facility (WHY ?) provides an interactive dialogue in a top-down approach. The interface starts from results provided at level 4 (Fig. 8) and proceeds backward through intermediate steps (levels 3 to 1) to the basic data. It reviews the basis for results, basic data used, assumptions made and the logic and rules followed to reach the final decisions.

At level 4, (Fig. 8) the final suitability results from LEV- CET indicate that land unit M23 in the northern part of PILOT1 has severe limitations (*3) to both barley and tef, and a very severe limitation (*4 tem) to maize (Fig. 8 & Table 3). Investigating the reasoning behind these decisions, one can see that temperature conditions (Fig. 8) of the area: slight frost occurrence from December to January with mean growing period Temp. 15.5-18.0 °C and mean min. Temp. 6-10°C, have resulted in a very severe limitation to maize and a severe limitation to barley and tef. Severe limitations (*3 eas) for all three crops related to problems of cultivation and erosion

Table 3. Summary of the physical suitability evaluation of landunits in PILOT1.

Land unit	Barley	Maize	Tef
H20	S2wet *	S2rot/wet	S2rot/wet
Y21	S2wet/ fer/eas	S2rot/wet/ eas	S2rot/wet/ eas
Y22	S3wet	S3wet	S2rot/wet
[illegible]22	S3wet	S3wet	S2rot/wet
M23	S3wet/eas	S3rot/wet/ eas	S3wet/ eas
H24	S1	S1	S1
V24	S2wet	S2rot/wet	S2rot/wet
Y25	S2wet	S3wet	S2rot/wet
H26	S2wet	S3rot/wet	S2rot
Y27	S2wet	S2wet	S2rot/wet
M28	S3eas	S3eas	S2eas
P29	S2wet/fer	S2rot/wet	S2rot

* For explanations of abbreviations, refer Table 2.

Table 4. Summary of the physical suitability evaluation of land units in PILOT2.

Land unit	Barley	Maize	Tef
M30	S2wet/fer *	S2wet/fer/sal	S2sal
H31	S2wet	S2wet/fer/sal	S2sal
R32	S2wet	S2wet/fer/sal	S2sal
R33	S2wet/fer	S2wet/fer/sal	S2sal
A34	S2wet/fer	S2wet/fer/sal	S2sal
R35	S3wet	S3wet	S3wet
R36	S2rot/sal	S3sal	S3sal
R37	S3wet	S3wet	Sewet
V37	S3wet/fer	S3wet/fer	S3rot/ wet
L38	S3rot/wet	S3rot/wet/ sal	S3rot/ wet/sal
39	Neas	Neas	Neas

* For abbreviations refer Table 2.

risk on land unit M23 are due to slopes (16-30%), and to the occurrence of surface stoniness (3-15%) and rock outcrops (20-30%).

Decision problems include often complex sets of factors. Therefore, a repeated calibration and testing is necessary. This may be achieved by comparing suitability classes of the model with yields or with performance obtained on benchmark sites or by comparing the coincidence of actual land use with the results of model evlauation.

The present land use and crop yields in the studied areas correspond fairly well with the assessments given by LEV-CET. The major crop grown in the northern part of PILOT1 is barley, with few areas cultivated for tef. Areas around Akaki and Debrezeit are cultivated mainly for tef, followed by barley and occasionally maize. PILOT2 areas are mainly cultivated for maize, few areas being cultivated for tef.

Results also indicate that land is not always used according to its physical potentials outlined by LEV-CET. This is mainly because in the model only bio-physical attributes of land are considered, without any consideration to the socio-economic aspects of the farming in the area. Although yields are low (e.g. tef) or land has physical limitations (requirements are not strictly met) as indicated from the outputs, farmers may cultivate their land in ways that are objectively unsuitable. This is because farmers strike a compromise and look for comparative advantages between resource uses and family needs or goals in view of accepted level of risks, demand and price situations and other societal and economic aspects.

Taking the case of tef, farmers prefer to grow this crop because of several reasons other than the bio-physical conditions of the area which are considered in the model. These include high market demands and high income generated from tef, the tolerance of the crop to drought and waterlogging making it less risky and good storage property of tef seeds. The practical application of the model to decision making, therefore, requires a strong integration of bio-physical and socio-economic information.

CONCLUSIONS

The computer aided decision support system (LEV-CET) provides a simple, quick and reproducible analysis of physical land performance potentials and limitations.

LEV-CET, as an expert system, helps in evaluation of alternative land use types in a short time offering the possibility to respond without delay to inquiries from users, and provide awareness of the limitations of manual methods (avoid repetitive work and associated mistakes or non-reproducibility of results).

Expert systems express reasoning processes based on local experience (expert judgement), they can be constructed by local experts, and make efficient use of available knowledge and data.

LEV-CET provides a flexible and simplified system to evaluate land in central Ethiopia with a reasonable accuracy. The model, however, will be of a more practical significance when socio-economic information is included in the assessment to arrive at viable and more realistic decisions.

A computer aided decision support system (DSS) provides the basis to guide research priorities, to identify comparable environments, to assist in the interpretation and analysis of results from trials, and to advise inputs to optimize production opportunities. Computer aided DSS can help farmers, extension agents and planners, as well as researchers to reduce the level of uncertainty involved in decision making.

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