# ExET 3.2 - EXPERT SYSTEM FOR PHYSICAL AND ECONOMIC EVALUATION OF AGRICULTURAL LAND*

**Virgil Vlad[1], Ion Munteanu[1], Corneliu Vasile[2], Ulpia Ionescu[1], Ionut Vişan[1], Stan Piticu[1]**

## ABSTRACT

**The paper presents the expert system for physical and economic evaluation of agricultural land *ExET* ("sistem *EX*pert de *E*valuare *T*ehnică şi *E*conomică a *T*erenurilor agricole") - version 3.2. First, the objectives and reasons that have determined the system conception are outlined. The principle of re-using the existing data (generally very expensively obtained) have led to choose the land evaluation methodology ICPA-1978 (parametric multiplicative). This methodology was improved according to the methodology ICPA-1987 and other experiences. A new evaluation parameter - "soil pollution and other land degradations and deficiencies" was defined and three models for physical evaluation have been developed and implemented: natural evaluation, current evaluation (taking into account operational land improvement works) and potential (conditional) evaluation. The model for economic evaluation - based on estimation of gross margin (normalised per hectare/year, corresponding to defined reference technologies of medium input level) - and the user reports provided by the system are presented. The software implementation of system is based on a specialised expert system generator ("shell") - ALES. Finally, some conclusions on using the system, some possibilities of developing the existing evaluation models and some requirements for new functions for such systems are outlined.**

**Key words:** expert systems, agricultural land evaluation, expert systems for agricultural land evaluation, physical evaluation, natural evaluation, current evaluation, conditional evaluation, potential evaluation, economic evaluation, reference cropping technologies, land use planning, land management.

## INTRODUCTION

Land evaluation has an increasing importance in the world – and also in Romania – in the last time, for different reasons (Vlad, 1997a,b, 1998, 2000a,b). A Romanian methodology for physical land evaluation at the 1:10,000 scale (ICPA,1978; Teaci,1980) was implemented within an expert system on personal computer (ExET 3.2). The paper presents the main requirements and design decisions for the system, the physical and economic evaluation models that have been developed and implemented, some concluding remarks and some developments taken into consideration for the future.

## SYSTEM REQUIREMENTS AND DESIGN DECISIONS

The main aims taken into consideration to develop the system are:
- assistance in land use planning at local levels (farms, agricultural enterprises/associations);
- land evaluation for taxation, land expertise for bank loans, land tenancy agreements, etc.;
- assistance in agricultural decision making at different other levels, especially at subdistrict (commune) level.

---

* Published in: Romanian Agricultural Research, 2000, nr. 13-14, pp. 51-60.
[1] Research Institute for Soil Science and Agrochemistry (ICPA),
Bd. Mărăşti, nr.61, 71331 Bucharest, e-mail: vvlad@icpa.ro
[2] Institute of Agricultural Economics (IEA),
Bd. Mărăşti, nr.61, 71331 Bucharest.

Other aspects that have been taken into consideration for system development are:

- In the market economy context, an economic evaluation is needed;

- A land evaluation methodology for the 1:10,000 scale has been used with good results in Romania since 1978 (ICPA,1978;Teaci,1980). According to it, an important volume of good data on agricultural land at 1:10,000 scale has been collected by district soil survey offices (over 35% of agricultural land, respectively, over 40% of arable land) and has been computerised (Marian et al.,1997); Re-using these data is quite necessary because their very high obtaining costs;

- The system is to be used by different users: farmers, soil/land/farming specialists and soil/land/farming advisers (commune/district agricultural consulting centres, etc.); Consequently, an implementation of the system on personal computers and a friendly user interface are needed;

- Land evaluation is a dynamic subject: the economic aspects are very dynamic (especially in a transition economy like in present in Romania) and, also, new aspects are to be taken into consideration (especially concerning the environment protection and sustainable agriculture); Consequently, a flexibility of the system is needed to easily permit its development and, also, its "personalisation" to user specific requirements.

## PHYSICAL EVALUATION METHODOLOGY

The implemented model is provided by the land evaluation methodology of ICPA (1978) (Teaci,1980), which does not take into consideration economic aspects. It is for large scales (1:10,000) and uses a parametric multiplicative method. A land unit (estimated as ecologically homogenous), TEO, is evaluated by a suitability index (rating mark, $K$) for each crop (group of similar crops) or land use. It is obtained as a percentage by multiplying partial rating indices ($k_i$):

$$K = \left( \prod_i k_i \right) * 100$$

The partial indices $k_i$ are primarily given by tabular functions $f_{XXX}$ and are represented by yield-decreasing coefficients (sub-unitary values) corresponding to different value classes of land characteristics XXX (determined by soil, relief, climate and hydrology factors). The influence on yield of some land characteristics may be dependent by some other related characteristics, as in the example given in *Table 1*.

*Table 1.* Tabular function $f^{I}_{GWT}$ – Yield decreasing coefficients for groundwater table level influence on winter wheat growing in natural conditions (without drainage works) (ICPA,1978).

| Corrected Mean Annual Precipitation (PREC) | Texture in Profile (TXB) | GroundWater Table level (GWT) [classes] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 00 | 01 | 02 | 03 | 05 | 10 | 20 | 80 |
| < 600 mm/year | Coarse | 0.2 | 0.5 | 0.7 | 1 | 0.9 | 0.8 | 0.8 | 0.6 |
| | Medium-Fine | 0.1 | 0.4 | 0.6 | 0.9 | 1 | 0.8 | 0.8 | 0.5 |
| > 600 mm/year | Coarse | 0.1 | 0.4 | 0.6 | 1 | 0.9 | 0.9 | 0.9 | 0.5 |
| | Medium-Fine | 0.1 | 0.3 | 0.5 | 0.8 | 1 | 0.9 | 0.9 | 0.4 |

Similar tabular functions $p_{YY}$ establish yield-increasing coefficients (values > 1), which assess the effects of different land improvement (reclamation/amelioration) works YY on different land characteristics for each crop (land use). The resulting partial suitability indices are obtained by multiplying the yield-decreasing coefficients for natural conditions by these yield-increasing coefficients. The tabular function coefficients assess the degree of decrease/increase of yield due to influences of corresponding factors - related to the maximum yield (*Ym*) obtained in the best natural conditions in Romania. Consequently, the suitability index *K* represents the percent of this *Ym* obtained on a TEO. It is crop-specific.

The tabular functions have been established by a group of experts based on their experience and on statistical results obtained by different Romanian agricultural research units in their scientific (controlled) field experiments (Teaci,1980). They have been tuned according to different agricultural practice results.

## IMPLEMENTATION OF PHYSICAL EVALUATION METHODOLOGY

In ExET - version 3.2, 21 primary land characteristics (*Table 2*) and 10 land improvement works (*Table 3*) are used. The combination of these factors/parameters - the same for all crops and land uses - in order to obtain the partial indices and final suitability index is presented in *Figure 1*. The measured temperature and precipitation are corrected (TEMC/PREC in *Figure 1*). Tabular functions for 24 crops, groups of similar crops and land uses (winter wheat, barley, maize, sun flower, potato, sugar beet, soya-bean, pea/bean, oil flax, fibre flax, hemp, alfalfa, clover, vegetables, apple tree, pear tree, plum tree, sweet/sour sherry tree, apricot tree, peach tree, vineyard for wine, vineyard for eating grapes, pasture and hay-field) are implemented. An overall suitability for arable land use is calculated as an average of the highest four suitability indices among those of arable utilisation types.

*Table 2.* The Land Characteristics (LC) used by ExET 3.2.

| *No.* | *LC Symbol* | *ICPA (1978) LC Code* | *LC Description* | *Number of classes of values* |
|---|---|---|---|---|
| 1 | ALK | 33 | degree of soil ALKalisation | 8 |
| 2 | CAR | 55 | total content of calcium CARbonates ($CaCO_3$) | 10 |
| 3 | EXP | 7 | land EXPosure to sun | 6 |
| 4 | FLH | 52 | land FLooding Hazard (incl. by groundwater) | 10 |
| 5 | GLE | 30 | degree of soil GLEyisation | 8 |
| 6 | GWT | 15 | Ground-Water Table level | 8 |
| 7 | HUM | 47 | soil HUMus storage | 8 |
| 8 | LSL | 5 | Land SLides and micro-relief form | 16 |
| 9 | MRE | 4 | Minor RElief form | 26 |
| 10 | PDD | - | degree of soil Pollution and other land Degradations/Deficiencies | 11 |
| 11 | PER | 43 | soil PERmeability (sat. hydraulic conductivity) | 6 |
| 12 | PGL | 31 | dgr.soil Pseudo-GLeyisation (surface water gley) | 7 |
| 13 | PHA | 44 | PH in top-soil (A) | 11 |
| 14 | POR | 40 | total soil PORosity | 5 |
| 15 | PRE | 11 | mean annual PREcipitation | 11 |
| 16 | SAL | 32 | degree of soil SALinisation | 9 |
| 17 | SLO | 6 | land SLOpe gradient | 9 |
| 18 | TEM | 8 | mean annual air TEMperature | 11 |
| 19 | TXA | 25a | TeXture in top-soil (A) | 10 |
| 20 | TXB | 25b | TeXture in profile control section (B) | 10 |
| 21 | UEV | 38 | Useful Edaphical Volume | 6 |

*Table 3.* The Land Improvement Works (LIW) taken into account by ExET 3.2

| *No.* | *LIW Symbol* | *LIW Description* |
|---|---|---|
| 1. | AM | soil AMendment application (soil liming or gypsing) |
| 2. | CE | works for preventing and Controlling soil Erosion |
| 3. | CP | works for Controlling soil Pollution and other land degradations/deficiencies |
| 4. | CS | works for Controlling soil Salinisation and alkalisation |
| 5. | DR | pipe (deep) DRainage |
| 6. | DS | Drainage of Surface water |
| 7. | EB | EmBankment works |
| 8. | FE | intensive soil FErtilisation |
| 9. | LO | deep soil LOosening |
| 10. | TE | construction of TErraces |

Some ***improvements of the basic land evaluation methodology*** (ICPA,1978) have been carried out and implemented within ExET 3.2 models:

- Neglecting the influence of the contrast of texture within soil profile on soil performance (ICPA,1978) according to the ICPA (1987) methodology.

- Definition of a new compound characteristic of land - *"Degree of soil pollution and other land degradations and deficiencies" (PDD)* - with 11 classes of values (*Table 4*), instead of the old parameter "Degree of soil pollution" with 3 classes of values. The new parameter takes into consideration the average of the influence on different possible crops (land uses). The definition of 11 classes decreases the error to 5%, which corresponds to the accuracy level of the evaluation method. Anyhow, different types of pollution/degradation/deficiencies are possible and, consequently, it is very difficult to differentially assess their effect on different crops. For this a special expert system is needed. In exchange, PDD may globally take into account, in addition to soil pollution, other significant land problems not-taken into account by other evaluation characteristics (e.g. surface waterlogging not-taken into account by PGL, PRE and GWT; base saturation degree; contrast of soil texture; interrelated influence of soil texture and porosity; etc.).

*Table 4*. Definition of the Land Characteristic "Degree of Soil Pollution and other Land Degradations and Deficiencies" (PDD).

| *Class Code* | *Yield Decrease [%]* | *Severity Level* | *Decr. Coefficient* | *CP Effect (Resulting Coef.)* |
|---|---|---|---|---|
| 00 | 0 - 5 | 1 | 1 | 1 |
| 10 | 5 - 15 | 2 | 0.9 | 1 |
| 20 | 15 - 25 | 3 | 0.8 | 1 |
| 30 | 25 - 35 | 4 | 0.7 | 1 |
| 40 | 35 - 45 | 5 | 0.6 | 1 |
| 50 | 45 - 55 | 6 | 0.5 | 1 |
| 60 | 55 - 65 | 7 | 0.4 | 1 |
| 70 | 65 - 75 | 8 | 0.2 | 0.9 |
| 80 | 75 - 85 | | | |
| 90 | 85 - 95 | 9 | 0 | 0.8 |
| 99 | 95 - 100 | | | |

- Taking into consideration of soil gypsing (as soil amendment).

- Tuning the existing tabular functions $f_{XXX}$ and $p_{YY}$ (yield-decreasing/increasing coefficients) and adding new ones - $f^{I}_{PDD}$ (*Table 5*), $f^{II}_{GLE}$, $f^{II}_{HUM}$ (*Table 6*), $f^{III}_{GWT}$, $f^{II}_{PDD}$ (*Table 7*) - according to the ICPA (1987) methodology and latest experiences on model application.

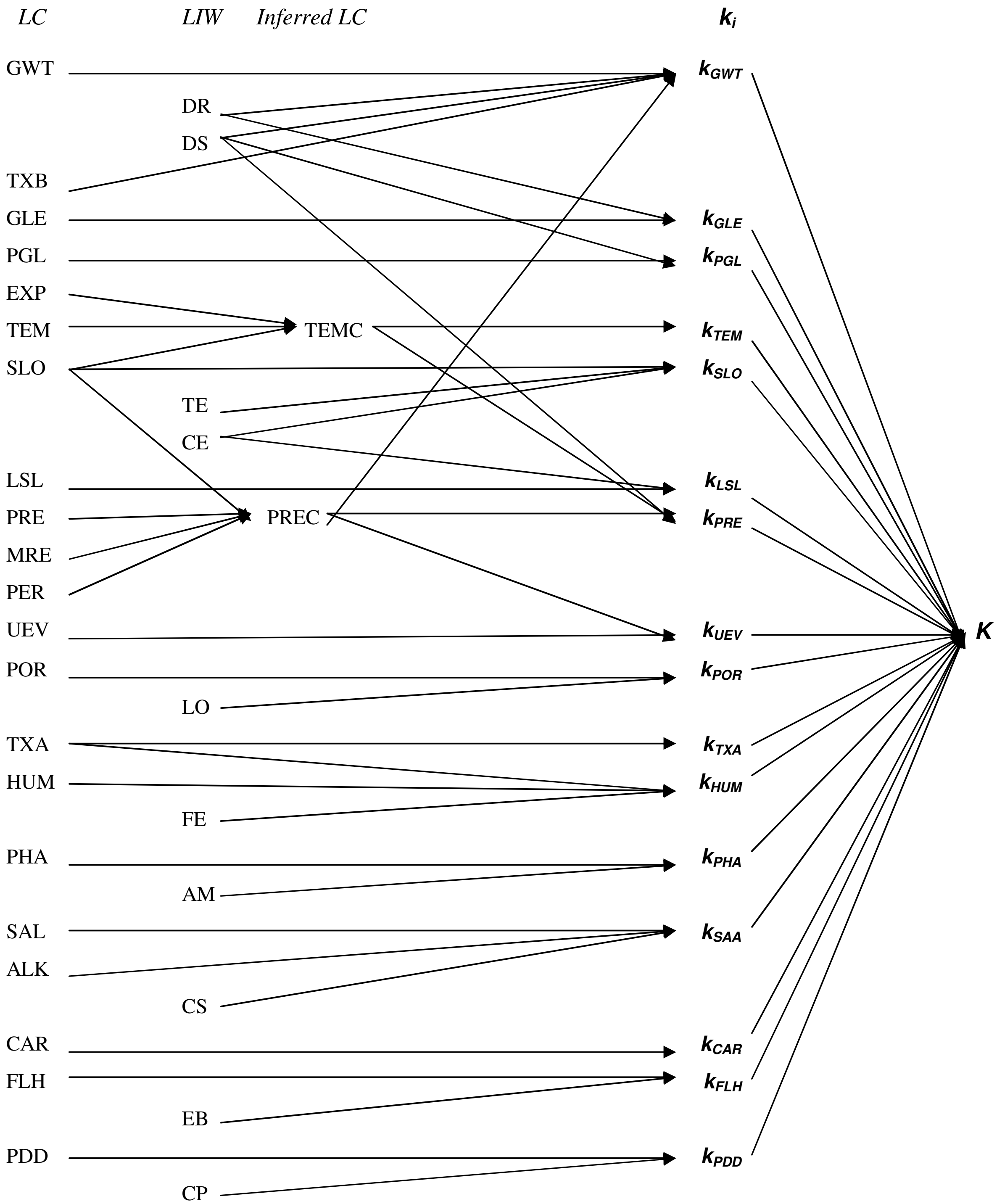


*Figure 1.* ExET 3.2 - Schema of the Physical Land Evaluation Model

Three models for physical land evaluation have been defined and implemented:

(i) ***ExET 3.2n - Natural Land Evaluation:*** refers to the natural conditions of land, assuming there is no operational land improvement (LI) works (that is it takes into account the values of land characteristics which were before execution of eventual such works). The list of the tabular functions used in this case is given in *Table 5.*

*Table 5.* Tabular functions for Natural Land Evaluation ExET 3.1n

| *No.* | *Partial Index* | *Tabular function* |
|---|---|---|
| 1. | $k^N_{GWT}$ | $f^I_{GWT}$ (GWT, TXB, PREC) |
| 2. | $k^N_{GLE}$ | $f^I_{GLE}$ (GLE) |
| 3. | $k^N_{PGL}$ | $f_{PGL}$ (PGL) |
| 4. | $k^N_{TEM}$ | $f_{TEM}$ (TEMC) |
| 5. | $k^N_{SLO}$ | $f_{SLO}$ (SLO) |
| 6. | $k^N_{LSL}$ | $f_{LSL}$ (LSL) |
| 7. | $k^N_{PRE}$ | $f_{PRE}$ (PREC, TEMC) |
| 8. | $k^N_{UEV}$ | $f_{UEV}$ (UEV, PREC) |
| 9. | $k^N_{POR}$ | $f_{POR}$ (POR) |
| 10. | $k^N_{TXA}$ | $f_{TXA}$ (TXA) |
| 11. | $k^N_{HUM}$ | $f_{HUM}$ (HUM, TXA) |
| 12. | $k^N_{PHA}$ | $f_{PHA}$ (PHA) |
| 13. | $k^N_{SAA}$ | $f_{SAA}$ (SAL, ALK) |
| 14. | $k^N_{CAR}$ | $f_{CAR}$ (CAR) |
| 15. | $k^N_{FLH}$ | $f_{FLH}$ (FLH) |
| 16. | $k^N_{PDD}$ | $f_{PDD}$ (PDD) |

(ii) ***ExET 3.2c - Current Land Evaluation:*** takes into account the effects of the existing operational LI works (except irrigation):

- the values of the land characteristics PGL, PHA, SAL/ALK, FLH and PDD are modified by the corresponding LI works (*Figure 1*) and, consequently, in these cases the same tabular functions as for natural evaluation are applied to the new values of land characteristics;
- the value of GWT is modified after the DR or DS works became operational, but the corresponding partial index ($k^C_{GWT}$) is obtained by another tabular function, $f^{II}_{GWT}$, (*Table 6*);
- it is considered that the values of the land characteristics GLE, SLO, LSL, PRE, POR and HUM are not modified by the corresponding LI works (*Figure 1*) and in their cases the corresponding partial indices are obtained by other tabular functions (*Table 6*);

*Table 6.* Partial indices for Current Land Evaluation ExET 3.2c (LCs not-modified by LI works)

| *No.* | *Partial Index* | *Tabular Function* | *Condition* |
|---|---|---|---|
| 1. | $k^C_{GWT}$ | $f^{II}_{GWT}$ (GWT, TXB, PREC) | DR = 1 or DS = 1 |
| 2. | $k^C_{GLE}$ | $f^{II}_{GLE} = k^N_{GLE} * p^{II}_{DR}$ (GLE) | DR = 1 |
| 3. | $k^C_{SLO}$ | $f^{II}_{SLO} = k^N_{SLO} * p^I_{CE}$ (SLO)<br>$f^{III}_{SLO} = k^N_{SLO} * p_{TE}$ (SLO) | CE = 1<br>TE = 1 |
| 4. | $k^C_{LSL}$ | $f^{II}_{LSL} = k^N_{LSL} * p^{II}_{CE}$ (LSL) | CE = 1 |
| 5. | $k^C_{PRE}$ | $f^{II}_{PRE} = k^N_{PRE} * p^I_{DS}$ (PREC, TEMC) | DS = 1 |
| 6. | $k^C_{POR}$ | $f^{II}_{POR} = k^N_{POR} * p_{LO}$ (POR) | LO = 1 |
| 7. | $k^C_{HUM}$ | $f^{II}_{HUM} = k^N_{HUM} * p_{FE}$ (HUM, TXA) | FE = 1 |

(YY = 1: YY is operational; CE and TE are mutually exclusive)

(iii) ***ExET 3.2p - Potential Land Evaluation:*** considers the ideal situation when all ten LI works (*Table 3*) are operational (if necessary):

- because it is considered that the values of the land characteristics GLE, SLO, LSL, PRE, POR and HUM are not modified by the corresponding LI works, the corresponding partial indices are obtained by the tabular functions given in *Table 6* - indifferently whether the corresponding LI works are or are not operating; in the case of SLO, the effect of works TE is taken into account because it is more than the effect of works CE;

- in other cases, the influences of the existing operational LI works are evaluated as in the case of current evaluation and for the land characteristics GWT, PGL, PHA, SAL/ALK, FLH and PDD, whether their corresponding LI works are not operational, the corresponding partial indices are obtained by other tabular functions than for natural/current evaluation (*Table 7*); it is considered that the works EB eliminate completely the land flooding hazard.

*Table 7.* Partial indices for Potential Land Evaluation ExET 3.2p
(LCs modified by LI works - The case of non-existence of LI works)

| *No.* | *Partial Index* | *Tabular Function* | *Condition* |
|---|---|---|---|
| 1. | $k^P_{GWT}$ | $f^{III}_{GWT} = k^N_{GWT} * p^I_{DR}$ (GWT, TXB, PREC) | DR = 0 |
| 2. | $k^P_{PGL}$ | $f^{II}_{PGL} = k^N_{PGL} * p^{II}_{DS}$ (PGL) | DS = 0 |
| 3. | $k^P_{PHA}$ | $f^{II}_{PHA} = k^N_{PHA} * p_{AM}$ (PHA) | AM = 0 |
| 4. | $k^P_{SAA}$ | $f^{II}_{SAA} = k^N_{SAA} * p_{CS}$ (SAL, ALK) | CS = 0 |
| 5. | $k^P_{FLH}$ | $f^{II}_{FLH} = 1$ | EB = 0 |
| 6. | $k^P_{PDD}$ | $f^{II}_{PDD} = k^N_{PDD} * p_{CP}$ (PDD) | CP = 0 |

(YY = 0: YY is not operational)

## ECONOMIC EVALUATION MODEL

The economic model implemented is based on gross margin (Rossiter & Wambeke, 1989). The economic suitability classes are defined as classes of values of gross margin ($GM$), normalised per hectare-year, obtained by using a reference technology for each crop (land use):

$GM = R - C$ [ROL/ha/year], where: $R$ = Total Return, $C$ = Total Cost;

$R = Y * p$, where $Y$ = actual yield [Kg/ha/year]
$p$ = reference selling price of output [ROL/Kg]

$Y = Ym * K / 100$, where $Ym$ = maximum yield obtained in the best natural conditions in Romania using the reference technology
$K$ = crop (land use) suitability index of land unit;

$C = CY + CO$, where $CY$ = Yearly Cost, $CO$ = One-Time Cost;

$CY = \sum_i (cy_i * pcy_i)$, where: $cy_i$ = yearly input $i$, $pcy_i$ = price of $cy_i$

$CO = \sum_j (co_j * rco_j)$ , where: $co_j$ = one-time cost $j$, $rco_j$ = interest rate of $co_j$.

The reference technologies specify well-established technological inputs/operations and their related quantities/prices. They are land independent and meet the medium-current management level in Romania. The parameter values of the reference technologies for the specified 24 crops (land uses) and the maximum yields have been established based on expert knowledge, technical reports from research units and publications (*Table 8*). The economic parameters (especially the input and selling prices) must be updated as they change. An example of period 1996-1997 is given in *Table 8.*

The economic suitability classes adopted are those recommended by FAO (FAO, 1976) and an example is presented in *Table 9.*

*Table 8.* ExET 3.2 - Example of reference technologies (prices of 1996-1997 period)

| *Technology Parameter* | *winter wheat* | *barley* | *maize* | *sun flower* | *potato* | *sugar beet* | *vegeta bles (onion* | *soya-bean* | *pea/ /bean* | *oil-flax* | *fibre-flax* | *hemp* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seed kg/ha<br>Lei/kg[3] | 250<br>700 | 200<br>700 | 25<br>3600 | 6<br>11900 | 3300<br>2300 | 6<br>2300 | 55000<br>p/ha<br>65le/p | 110<br>1900 | 120<br>5400 | 100<br>3600 | 140<br>2900 | 90<br>3400 |
| N Fert. kgsa/ha<br>1700 Lei/kgsa[3]<br>3700 Lei/kgsa[3] | 25[1]<br>45 | 25[1]<br>55 | -<br>70[1] | -<br>85[1] | -<br>60[1] | -<br>100[1] | -<br>60[1] | -<br>55[1] | -<br>- | -<br>50[1] | -<br>50[1] | -<br>90[1] |
| P Fert. kgsa/ha<br>2000 Lei/kgsa[3]<br>3700 Lei/kgsa[3] | 60[1]<br>- | 70[1]<br>- | -<br>55[1] | 75[1]<br>- | -<br>80[1] | 45[1]<br>30 | 15[1]<br>15 | 75[1]<br>- | 45[1]<br>- | 70[1]<br>- | 70[1]<br>- | 60[1]<br>- |
| K Fert. kgsa/ha<br>1400 Lei/kgsa[3]<br>2900 Lei/kgsa[3] | 50[1]<br>- | 60[1]<br>- | -<br>50[1] | 80[1]<br>- | -<br>60[1] | 45[1]<br>15 | 50[1]<br>25 | 45[1]<br>- | 45[1]<br>- | -<br>50[1] | -<br>70[1] | 50[1]<br>- |
| Org.Fert. t/ha<br>8000 Lei/t[3] | 5 | 5,5 | 6 | 6,5 | 8 | 8 | 40 | 5 | 5 | 6,5 | 6,5 | 6,5 |
| Pesticides<br>miiLei/ha[2,3] | 360 | 360 | 360 | 300 | 2495 | 1360 | 1600 | 690 | 275 | 235 | 235 | 100 |
| Other Materials<br>miiLei/ha[3] | - | - | - | - | - | - | - | - | - | - | 406 | 200 |
| Mech.Works[4]<br>miiLei/ha[3] | 765 | 790 | 835 | 940 | 930 | 755 | 910 | 780 | 805 | 605 | 695 | 890 |
| Man-Pwr h/ha<br>1400 Lei/h<br>3200 Lei/h | -<br>8 | -<br>12 | -<br>44 | -<br>56 | -<br>481 | -<br>386 | 45<br>2340 | -<br>56 | -<br>64 | -<br>8 | -<br>96 | -<br>512 |
| Loan Interest<br>miiLei/ha | 480 | 485 | 710 | 695 | 5000 | 1490 | 5500 | 795 | 620 | 540 | 750 | 1310 |
| Interest Rate of one-time costs[5]<br>miiLei/ha | - | - | - | - | - | - | - | - | - | - | - | - |
| Other Costs[6]<br>miiLei/ha | 120 | 130 | 145 | 150 | 500 | 300 | 500 | 160 | 150 | 120 | 165 | 260 |
| **Total Cost**<br>miiLei/ha | 2365 | 2457 | 2936 | 2964 | 18810 | 5895 | 20406 | 3270 | 2896 | 2408 | 3278 | 5279 |
| **Max. Yield**<br>kg/ha | 5500 | 6000 | 6500 | 2500 | 35000 | 45000 | 45000 | 2500 | 2500 | 1800 | 7000 | 9000 |
| Selling Price<br>Lei/kg | 1200 | 1000 | 1100 | 2100 | 1400 | 270 | 1200 | 2500 | 3000 | 2500 | 800 | 1000 |
| **Max. Return**<br>miiLei/ha | 6600 | 6000 | 7150 | 5250 | 49000 | 12150 | 54000 | 6250 | 7500 | 4500 | 5600 | 9000 |
| **Max. Gross Margin**<br>[miiLei/ha] | 4235 | 3543 | 4214 | 2286 | 30190 | 6255 | 33594 | 2980 | 4604 | 2092 | 2322 | 3721 |

*Table 8.* ExET 3.2 - Example of reference technologies (prices of 1996-1997 period) (cont.)

1 + 20 kgsa/ha as government subsidies
2 + 75 miiLei/ha as government subsidies
3 including supplying costs
4 including the cost of fuel, wages, spare parts, interest rates, etc.
5 land improvement works are considered as supported by government
6 insurance cost and taxes are not included

| *Technology Parameter* | *alfalfa* | *clover* | *past--ure* | *hay--field* | *apple--tree* | *pear--tree* | *plum--tree* | *sherry-tree* | *apric.-tree* | *peach-tree* | *viney.-wine* | *viney. grapes* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seed kg/ha<br>Lei/kg[3] | 20<br>12500 | 20<br>6400 | 26<br>3800 | -<br> | - | - | - | - | - | - | - | - |
| N Fert. kgsa/ha<br>1700 Lei/kgsa[3]<br>3700 Lei/kgsa[3] | 50[1]<br>135 | 55[1]<br>150 | -<br>45[1] | -<br>45[1] | 35[1]<br>75 | 30[1]<br>80 | -<br>70[1] | 50[1]<br>60 | 50[1]<br>65 | 35[1]<br>75 | 30[1]<br>40 | 30[1]<br>60 |
| P Fert. kgsa/ha<br>2000 Lei/kgsa[3]<br>3700 Lei/kgsa[3] | 80[1]<br>- | 55[1]<br>- | 40[1]<br>- | 30[1]<br>- | 65[1]<br>- | 75[1]<br>- | 50[1]<br>- | 70[1]<br>- | 65[1]<br>- | 60[1]<br>- | 80[1]<br>- | 100[1]<br>- |
| K Fert. kgsa/ha<br>1400 Lei/kgsa[3]<br>2900 Lei/kgsa[3] | 80[1]<br>- | 55[1]<br>- | 25[1]<br>- | 25[1]<br>- | 65[1]<br>60 | 75[1]<br>50 | -<br>50[1] | 90[1]<br>- | 85[1]<br>- | 80[1]<br>- | 50[1]<br>40 | 60[1]<br>60 |
| Org.Fert. t/ha<br>8000 Lei/t[3] | 25 | 25 | 5 | - | 8 | 13 | 5 | 11 | 10 | 7 | 10 | 9 |
| Pesticides<br>miiLei/ha[2,3] | 110 | 85 | 30 | 30 | 2830 | 2420 | 1810 | 1350 | 3075 | 2915 | 1700 | 2340 |
| Other Materials<br>miiLei/ha[3] | - | - | - | - | - | - | - | - | - | - | 1000 | 660 |
| Mech.Works[4]<br>miiLei/ha[3] | 825 | 985 | 405 | 260 | 1680 | 1680 | 960 | 1125 | 1170 | 1200 | 790 | 1070 |
| Man-Pwr h/ha<br>1400 Lei/h<br>3200 Lei/h | -<br>6 | -<br>8 | 34<br>230 | 14<br>20 | -<br>1938 | -<br>2280 | -<br>1488 | -<br>3272 | -<br>1600 | -<br>1744 | 448<br>1296 | 448<br>1680 |
| Loan Interest<br>miiLei/ha | 510 | 510 | 500 | 190 | 4200 | 4400 | 2900 | 5000 | 3600 | 3400 | 3100 | 3800 |
| Interest Rate of one-time costs[5]<br>miiLei/ha | - | - | - | - | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Other Costs[6]<br>miiLei/ha | 155 | 155 | 100 | 100 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| **Total Cost**<br>miiLei/ha | 2926 | 2924 | 2239 | 925 | 17208 | 18147 | 12476 | 20106 | 15119 | 15221 | 13489 | 16176 |
| **Max. Yield**<br>kg/ha | 35000 | 40000 | 35000 | 25000 | 20000 | 20000 | 12000 | 9000 | 12000 | 16000 | 10000 | 13000 |
| Selling Price<br>Lei/kg | 140 | 140 | 100 | 100 | 1200 | 1250 | 1400 | 3000 | 1900 | 1600 | 1800 | 1700 |
| **Max. Return**<br>miiLei/ha | 4900 | 5600 | 3500 | 2500 | 24000 | 25000 | 16800 | 27000 | 22800 | 25600 | 18000 | 22100 |
| **Max. Gross Margin**<br>[miiLei/ha] | 1974 | 2676 | 1261 | 1575 | 6792 | 6853 | 4324 | 6894 | 7681 | 10379 | 4511 | 5924 |

*Table 9.* ExET 3.2 - Example of definition of the economic suitability classes

| FAO Class | Description | GM [million ROL/ha/year] |
|---|---|---|
| S1 | Highly suitable | > 5 |
| S2 | Suitable | 2,5 - 5 |
| S3 | Marginally Suitable | 1 - 2,5 |
| N1 | Economically Unsuitable | < 1 |
| N2 | Physically Unsuitable | - |

## COMPUTER IMPLEMENTATION

The evaluation models and the system requirements have been implemented on personal computer by using the expert system generator (shell) ALES (Rossiter & Wambeke, 1989; Rossiter, 1990). It is specialised software providing many appropriate functions for building expert systems for land evaluation. The inference mechanism that performs the evaluation is based on decision trees. A unitary definition of nine severity levels of land characteristic influences for all crops (land uses) was defined - like that presented for PDD (*Table 4*). Auxiliary programs (C++ language) have been developed to process ALES outputs for obtaining other required information than those provided by ALES (e.g. suitability indices according to Romanian methodology and estimated yields). The main steps to develop the expert system are presented by Vlad et.al.,(1997c).

The user reports provided by ExET 3.2 are:
- tables with crop (land use) suitability indices for each defined land unit (for the complex-compound TEOs and parcels, weighting suitability indices are computed);
- sheets for each TEO/parcel with suitability indices and estimated yields (long term average) of all crops (land uses), ordered alphabetically or by suitability index;
- lists of ordered crops (land uses) for each TEO/parcel and lists of ordered TEOs/parcels for each crop or land uses (ordering by gross margin, return, economic suitability class or FAO physical suitability class).

## CONCLUDING REMARKS

1. The system and implemented models have proved to be good enough and useful as land decision support at farm/local and other levels: choosing the most productive and the most efficient crop (land use) for a land, choosing the most productive and the most efficient land for a crop (land use), assessing the long term physical and economic performances of a land when is used for different crops (land uses), establishing the possible (physically and economicly) crops and land uses for a land, establishing the land limitations and their level when the land is used for different crops (land uses), choosing the appropriate agriculture land to be transferred to other uses, appropriately establishing land taxes, bank loans, land tenancy agreements, land exchange value/compensation, etc.

2. The differentiation between natural, current and potential land evaluation is necessary in practice for different purposes.

3. The suitability indices of the parametric method used by the Romanian methodology are more relevant, as physical evaluation, than physical suitability subclasses (FAO definition), but the last have the advantage of providing, besides the degree (1-9), also the type of limitations.

4. The errors induced by the multiplicative parametric evaluation methods like that of Romanian methodology are greater when two or more land characteristics have extreme values, or too many land characteristics determine relatively-high severity levels.

5. The new-defined land parameter PDD permits to take into account more accurately the soil pollution and to add the influence of the land degradations and deficiencies not-taken into consideration by other parameters.

6. Although physical evaluation has the advantage of time stability, it does not provide enough information for land use planning or as decision support in different other cases (land leasing, bank loans, etc.). Using physical land evaluation, different land units can be compared in terms of performance for a given crop (land use), but the comparison between the performance of a land unit for two or more crops (land uses) cannot really be done using only physical evaluation. Further, the majority of the decisions on land are based on economic criteria (profit, cost/benefit ratio, etc.). For these reasons, economic evaluation is necessary. It takes into account both land

physical characteristics and economic conditions and it can establish realistic suitability classes for practice. Also, it can assess the influence of some negative land use aspects that do not determine a reduction of yield (e.g. soil degradation). Some examples to compare the relevance of the two types of evaluation are presented in *Table 10*. The same suitability index (80[*],64-68[#]) correspond to very different gross margins (between -622 and +8,517 and, respectively, between -1,372 and +6,117 thousand ROL /ha /year) and, conversely, almost the same gross margin (-1,372 / -1,281)[@] are obtained by land units with very different suitability index (11 and 68).

*Table 10.* Economic Evaluation "versus" Physical Evaluation

suitability index
gross margin [thousand ROL/ha/year]

| Land Unit | Crops / Land Uses | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | wint. wheat | maize | sun-flowr | potato | sugar beet | vegetab (onion) | soya-bean | alf-alfa | past-ure | apple-tree | vineyard grapes |
| Bz17 | 61<br>33 | 54<br>-212 | 61<br>500 | 38<br>662 | 43<br>-31 | 49<br>3,807 | 55<br>230 | 68<br>839 | 47<br>-34 | 38<br>-1,228 | 68[#]<br>-1,372[@] |
| Bz22 | 17<br>-540 | 20<br>-740 | 23<br>-452 | 16<br>-3,131 | 11<br>-1,281[@] | 25<br>297 | 15<br>-572 | 22<br>-607 | 22<br>-416 | 25<br>-2,515 | 26<br>-3,867 |
| Cj20 | 52<br>-84 | 47<br>-326 | 42<br>31 | 41<br>1,191 | 40<br>-119 | 45<br>3,237 | 47<br>70 | 65<br>754 | 65<br>229 | 47<br>-390 | 16<br>-4,489 |
| Ct07 | 64<br>76 | 56<br>-180 | 64<br>581 | 26<br>-1,416 | 32<br>-436 | 64[#]<br>6,117 | 58<br>289 | 64<br>729 | 29<br>-311 | 23<br>-2,752 | 36<br>-3,262 |
| Db01 | 80<br>287 | 80<br>194 | 80<br>981 | 65<br>5,387 | 72<br>1,148 | 80[*]<br>8,517 | 80<br>737 | 80<br>1,233 | 58<br>121 | 65<br>1,425 | 80[*]<br>-622 |
| Db41 | 37<br>-282 | 37<br>-479 | 32<br>-213 | 29<br>-873 | 25<br>-716 | 25<br>221 | 28<br>-299 | 22<br>-610 | 37<br>-183 | 47<br>-390 | 28<br>-3,729 |
| Tr08 | 72<br>182 | 72<br>69 | 65<br>601 | 52<br>3,232 | 52<br>341 | 64<br>6,117 | 72<br>577 | 58<br>527 | 58<br>121 | 65<br>1,424 | 72<br>-1,102 |

(Prices 1996/1997)

7. Some necessities and possibilities for developing the system have been identified:

a) Improving the existing evaluation models: tabular functions, economic evaluation parameters, better calibration of the maximum yields, defining more accurately the land improvement works, establishing more accurately the modifications of land characteristics due to operational land improvement works (e.g. gleyisation, surface water gley, groundwater table level, etc.), etc.;

b) Reconsidering the inter-relations between different land characteristics: grouping land characteristics, application of multiple limitation and heuristic combinations methods (Vlad,1997a,2000a), reducing the number of multiplying terms, etc.;

c) Taking into consideration other land utilisation types: rotations, other crops/cultivars, irrigated agriculture, ecological agriculture, different reference technologies (different management levels: subsistence, medium, high), etc.;

d) Taking into consideration other aspects: other natural factors (e.g. monthly temperature and precipitation, length of plant growing period), site related criteria (e.g. accessibility by roads and railways; distance to urban/rural centres, support services, farmhouses, water sources; parcel size and configuration; rural development programs), other economic criteria, two levels in economic evaluation (land owner/tenant and government/society), other sustainability aspects (e.g. protection/risks vulnerability, respectively pollution/degradation of soil and water, production risks, economic viability, social acceptability), quality of land utilisation types outputs, etc.;

e) Taking into consideration other land evaluation methods, e.g. parametric non multiplicative and quantitative land evaluation using simulation models for soil processes and crop growing

(Vlad, 1994,1997a,2000a); Differentiation of evaluation models according to evaluation aims (e.g. different potential yields), etc.;

f) Evolution towards a decision support system (Vlad,1998,1999,2000c); interfacing with GIS;

8. To develop land evaluation models and expert systems, collaborations of experts of different specialisation are necessary: soil science, agroclimatology, agronomy, farming, economics, systems analysis, information technology, etc.

9. Using ALES to implement land evaluation systems has many advantages: short time of implementation, user-friendly interface, interactivity based on rich menu system and help facilities, data management, standard user reports, advanced explanation facility for evaluation results, flexibility for improving/tuning the evaluation models and for system development.

10. To implement some more complex evaluation models/submodels and components (algorithmic, other rules than those defined by decision trees, Windows type interface), other software engineering tools are necessary: visual programming, object oriented techniques, integrating expert systems tools with object oriented tools and GIS tools, etc.

## REFERENCES

*FAO. (1976). A framework for land evaluation.* FAO Soils Bulletin 32, Rome, 72 pp.

*ICPA (1978). Guidelines for Land Evaluation - scale 1:10000.* Research Institute for Soil Science and Agrochemistry (ICPA), Bucharest, 143 p. (in Romanian).

*Marian A., V. Vlad, Mariana Tapalagă, P. Ghinea (1997). Software for management and processing of the data on land units at 1:10.000 scale.* Curierul ASAS, "Informatics offers in the agr. domains" p.II/19-22. (in Rom.)

*Rossiter D. G. and van Wambeke A. R. (1989). ALES Version 2.2 User's Manual.* Department of Agronomy, Cornell University, Ithaca, NY, USA, 188 pp.

*Rossiter D.G.(1990). ALES:A framework for land evaluation using a microcomputer.* Soil Use & Manag.,6,p.7-20.

*Teaci D. (1980). Agricultural land evaluation. Ed.* Ceres, Bucharest, 296 pp. (in Romanian).

*Vlad V. (1994). Integration of an Expert System in a GIS for Agriculture.* Research Inst. for Soil Sci. and Agrochemistry Bucharest, Inst. for Remote Sensing Applications - Joint Research Centre of the E.C. Ispra, Commission of the EC, Report CIPA-CT-93-2350, 103p.

*Vlad V. (1997a). The state of the art of the agricultural land evaluation methods.* Academy of Agricultural & Forestry Sciences, Internal doctoral report, Bucharest, 94 p. (in Romanian).

*Vlad, V. (1997b). Evolution of land evaluation towards decision support systems for land management.* Proc. of the 15th Nat. Conf. of Soil Science (Aug.1997, Bucharest), Publ.of the SNRSS, vol.29D, p.166-174, (in Rom.).

*Vlad V., I.Munteanu, C.Vasile. (1997c). Expert system for land suitability evaluation for main crops (ExET 1.4).* Curierul ASAS, "Informatics offers in the agricultural domains ", Bucharest, p.II/47-52. (in Romanian).

*Vlad V. (1998). A decision support system for sustainable land management: Structure and functions.* Proceedings of the 16th World Congress of Soil Science, WCSS on CD-ROM, Cirad (France), Symp.36, Sci.Reg.870, 8p.

*Vlad, V.(1999). General structure of a decision support system concerning evaluation and use of agricultural land.* Academy of Agricultural & Forestry Sciences, Internal doctoral report, Bucharest, 58p. (in Romanian).

*Vlad V. (2000a). An outline of systematisation of the domain of land evaluation.* Ştiinţa Solului (Soil Science), Bucharest, vol.XXXIV, nr.2, 19 p. (in Romanian, in press).

*Vlad V. (2000b). Requirements for a decision support system for sustainable land management.* Soil Use and Management, 14 p. (in press).

*Vlad V. (2000c). Considerations on a decision support system for agricultural land and the database of the Romanian agricultural qualitative cadastre.* Proc.of the 16th Nat.Conf.of Soil Sci. (Suceava),11p. (in Rom.).