

# EXPERT SYSTEM FOR PHYSICAL AND ECONOMIC EVALUATION OF AGRICULTURAL LAND

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## ABSTRACT

The paper presents the expert system for physical and economic evaluation of agricultural land ExET, 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 specialized 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, physical evaluation, natural evaluation, current evaluation, conditional evaluation, potential evaluation, economic evaluation, 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, 2000 a, 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, and expertise for bank loans, land tenancy agreements etc.;
- assistance in agricultural decision making at different other levels, especially at subdistrict (commune) level.

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 due to 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

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flexibility of the system is needed to easily permit its development and, also, its “personalization” 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 homogeneous), 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 ( $k_i$ ):

$$K = (\prod k_i) * 100$$

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 on some

other related characteristics, as in the example given in table 1.

Similar tabular function  $\rho_{YY}$  establish yield increasing coefficients (value > 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 ( $Y_m$ ) obtained under the best natural conditions in Romania. Consequently, the suitability index K represents the percent of this  $Y_m$  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 field experiments. They have been tuned according to different agricultural practice results.

Table 1. Tabular function  $f_{GWT}^d$  - Yield decreasing coefficient for groundwater table level influence on winter wheat growing under 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

Table 2. The land characteristics (LC) used by ExET 3.2

LC symbol	ICPA (1978) LC code	LC Description	Number of classes of values
ALK	33	Degree of soil ALKalisation	8
CAR	55	Total content of calcium CARbonates ( $CaCO_3$ )	10
EXP	7	Land EXPosure to sun	6
FLH	52	Land Flooding Hazard (inclusive by groundwater)	10
GLE	30	Degree of soil GLEyisation	8
GWT	15	Ground-Water Table level	8
HUM	47	Soil HUMus storage	8
LSL	5	Land Slides and micro-relief form	16
MRE	4	Minor RELief form	26
PDD	-	Degree of soil Pollution and other land Degradations/Deficiencies	11
PER	43	Soil PERmeability (sat. hydraulic conductivity)	6
PGL	31	Dgr. soil Pseudo-GLEyisation (surface water gley)	7
PHA	44	pH in top-soil (A)	11
POR	40	Total soil PORosity	5
PRE	11	Mean annual PREcipation	11
SAL	32	Degree of soil SALinisation	9
SLO	6	Land SLOpe gradient	9
TEM	8	Mean annual air TEMperature	11
TXA	25a	TeXture in top-soil (A)	10
TXB	25b	TeXture in profile control section (B)	10
UEV	38	Useful Edaphical Volume	6

Table 3. The land improvement works (LIW) taken into account by ExET 3.2

LIW symbol	LIW Description
AM	Soil AMendment application (soil liming or gypsing)
CE	Works for preventing and Controlling soil Erosion
CP	Works for Controlling soil Pollution and other land degradations / deficiencies
CS	Works for Controlling soil Salinisation and alkalisation
DR	Pipe (deep) DRainage
DS	Drainage of Surface water
EB	EmBankment works
FE	Intensive soil Fertilization
LO	Deep soil LO osening
TE	Construction of TErraces

### 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 (TEMPC/PREC in Figure 1). Tabular functions for 24 crops, groups of similar crops and land uses (winter wheat, barley, maize, sunflower, potato, sugarbeet, 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 utilization types.

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 (1978) 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.

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	8	0.2	0.9
90	85 - 95	9	0	0.8
99	95 - 100	9	0	0.8

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.).

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

- Tuning the existing tabular functions  $f_{XXX}$  and  $\rho_{YY}$  (yield-decreasing/increasing coefficients) and adding new ones -  $f_{PDD}^I$  (Table 5),  $f_{GLE}^I$ ,  $f_{HUM}^I$  (Table 6),  $f_{GWT}^{III}$ ,  $f_{PDD}^I$

(Table 7) - according to the ICPA (1987) methodology and latest experiences on model application.

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.

(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;

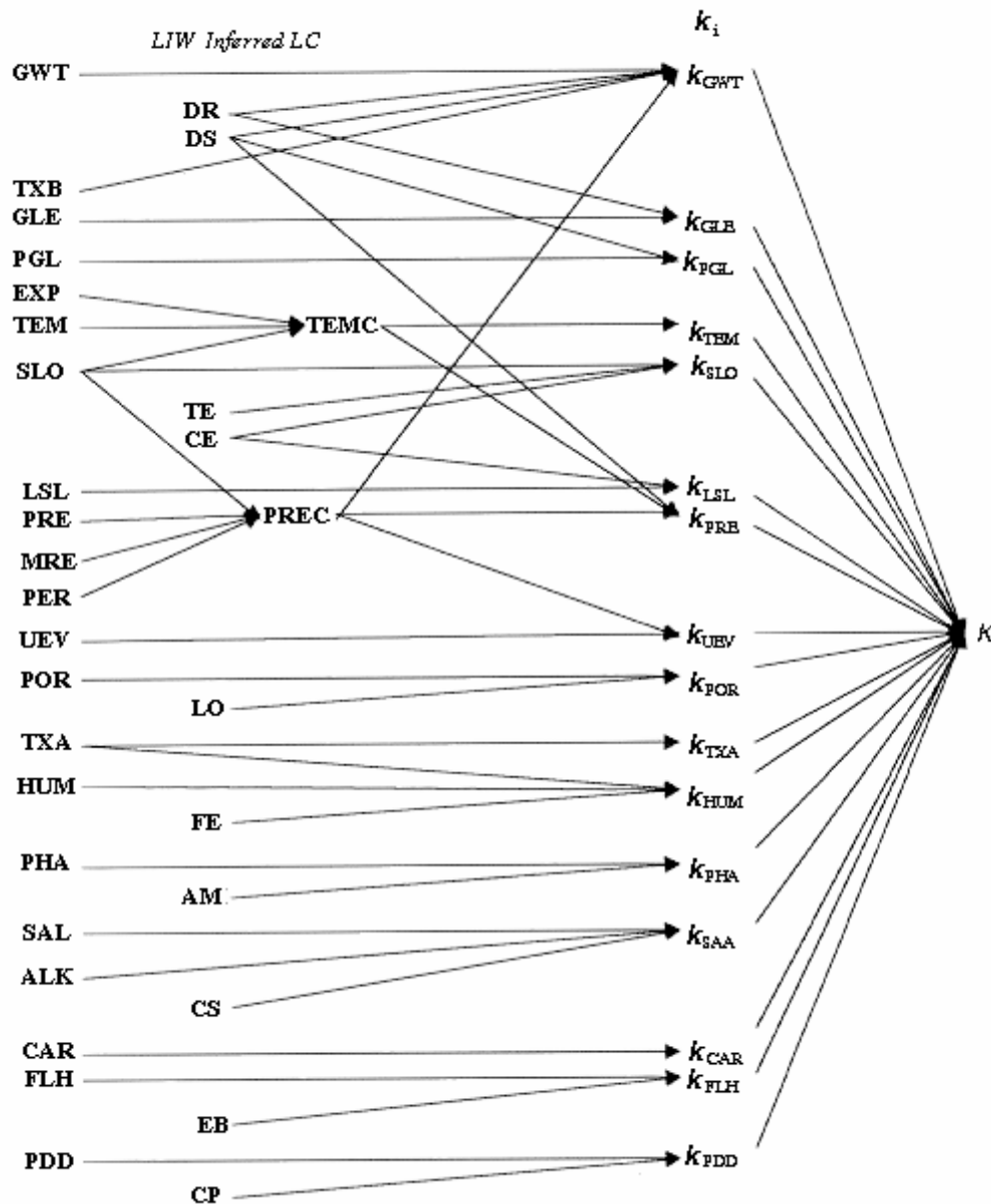


Figure 1. ExET 3.2 – Scheme of the physical land evaluation model

Table 5. Tabular functions for natural land evaluation  
ExET 3.1n

Partial index	Tabular function
$k_{GWT}^N$	$f_{GWT}^I$ (GWT, TXB, PREC)
$k_{GLE}^N$	$f_{GLE}^I$ (GLE)
$k_{PGL}^N$	$f_{PGL}^I$ (PGL)
$k_{TEM}^N$	$f_{TEM}^I$ (TEMC)
$k_{SLO}^N$	$f_{SLO}^I$ (SLO)
$k_{LSL}^N$	$f_{LSL}^I$ (LSL)
$k_{PRE}^N$	$f_{PRE}^I$ (PREC, TEMC)
$k_{UEV}^N$	$f_{UEV}^I$ (UEV, PREC)
$k_{POR}^N$	$f_{POR}^I$ (POR)
$k_{TXA}^N$	$f_{TXA}^I$ (TXA)
$k_{HUM}^N$	$f_{HUM}^I$ (HUM, TXA)
$k_{PHA}^N$	$f_{PHA}^I$ (PHA)
$k_{SAA}^N$	$f_{SAA}^I$ (SAL, ALK)
$k_{CAR}^C$	$f_{CAR}^I$ (CAR)
$k_{FLH}^N$	$f_{FLH}^I$ (FLH)
$k_{PDD}^N$	$f_{PDD}^I$ (PDD)

- the value of GWT is modified after the DR or DS works became operational, but the corresponding partial index ( $k_{GWT}^C$ ) is obtained by another tabular function,  $f_{GWT}^{II}$  (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)

Partial index	Tabular function	Condition
$k_{GWT}^C$	$f_{GWT}^{II}$ (GWT, TXB, PREC)	DR = 1 or DS = 1
$k_{GLE}^C$	$f_{GLE}^{II} = k_{GLE}^N * p_{DR}^{II}$ (GLE)	DR = 1
$k_{SLO}^C$	$f_{SLO}^{II} = k_{SLO}^N * p_{CE}^I$ (SLO)	CE = 1
	$f_{SLO}^{III} = k_{SLO}^N * p_{TE}^I$ (SLO)	TE = 1
$k_{LSL}^C$	$f_{LSL}^{II} = k_{LSL}^N * p_{CE}^{II}$ (LSL)	CE = 1
$k_{PRE}^C$	$f_{PRE}^{II} = k_{PRE}^N * p_{DS}^I$ (PREC, TEMC)	DS = 1
$k_{POR}^C$	$f_{POR}^{II} = k_{POR}^N * p_{LO}$ (POR)	LO = 1
$k_{HUM}^C$	$f_{HUM}^{II} = k_{HUM}^N * p_{FE}$ (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)

Partial index	Tabular function	Condition
$k_{GWT}^P$	$f_{GWT}^{III} = k_{GWT}^N * p_{DR}^I$ (GWT, TXB, PREC)	DR = 0
$k_{PGL}^P$	$f_{PGL}^{III} = k_{PGL}^N * p_{DS}^{II}$ (PGL)	DS = 0
$k_{PHA}^P$	$f_{PHA}^{III} = k_{PHA}^N * p_{AM}$ (PHA)	AM = 0
$k_{SAA}^P$	$f_{SAA}^{III} = k_{SAA}^N * p_{CS}$ (SAL, ALK)	CS = 0
$k_{FLH}^P$	$f_{FLH}^{III} = 1$	EB = 0
$k_{PDD}^P$	$f_{PDD}^{III} = k_{PDD}^N * p_{CP}$ (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).

$Y = Y_m * K/100$ , where  $Y_m$  = maximum yield obtained under 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,  $pcy_i$ =price of  $cy_i$ ;

$CO = \sum_i (co_j * rco_j)$ , where  $co_j =$  One-Time Cost,  $rco_j =$  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).

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

Technology Parameter	Winter wheat	Barley	Maize	Sunflower	Potato	Sugarbeet	Vegetables (onion)	Soya bean	Pea/bean	Oil-flax	Fibre-flax	Hemp
Seed kg/ha	250	200	25	6	3300	6	55000	110	120	100	140	90
Lei/kg <sup>2</sup>	700	700	3600	11900	2300	2300	65lei/p	1900	5400	3600	2900	3400
N fert.kg a.i./ha												
1700 lei/kg a.i. <sup>3</sup>	25 <sup>1</sup>	25 <sup>1</sup>	-	-	-	-	-	-	-	-	-	-
3700 lei/kg a.i. <sup>3</sup>	45	55	70 <sup>1</sup>	85 <sup>1</sup>	60 <sup>1</sup>	100 <sup>1</sup>	60 <sup>1</sup>	55 <sup>1</sup>	-	50 <sup>1</sup>	50 <sup>1</sup>	90 <sup>1</sup>
P fert.kg a.i./ha												
2000 lei/kg a.i. <sup>3</sup>	60 <sup>1</sup>	70 <sup>1</sup>	-	75 <sup>1</sup>	-	45 <sup>1</sup>	15 <sup>1</sup>	75 <sup>1</sup>	45 <sup>1</sup>	70 <sup>1</sup>	70 <sup>1</sup>	60 <sup>1</sup>
3700 lei/kg a.i. <sup>3</sup>	-	-	55 <sup>1</sup>	-	80 <sup>1</sup>	30	15	-	-	-	-	-
K fert.kg a.i./ha												
1400 lei/kg a.i. <sup>3</sup>	50 <sup>1</sup>	60 <sup>1</sup>	-	80 <sup>1</sup>	-	45 <sup>1</sup>	50 <sup>1</sup>	45 <sup>1</sup>	45 <sup>1</sup>	-	-	50 <sup>1</sup>
2900 lei/kg a.i. <sup>3</sup>	-	-	50 <sup>1</sup>	-	60 <sup>1</sup>	15	25	-	-	50 <sup>1</sup>	70 <sup>1</sup>	-
Org.fert.t/ha												
8000 lei/t	5	5.5	6	6.5	8	8	40	5	5	6.5	6.5	6.5
Pesticides thous lei/ha <sup>2,3</sup>	360	360	360	300	2495	1360	1600	690	275	235	235	100
Other materials thous lei/ha <sup>3</sup>	-	-	-	-	-	-	-	-	-	-	406	200
Mech.works <sup>4</sup> thous lei/ha <sup>3</sup>	765	790	835	940	930	755	910	780	805	605	695	890
Man-Pwr h/ha												
1400 lei/h	-	-	-	-	-	-	45	-	-	-	-	-
3200 lei/h	8	12	44	56	481	386	2340	56	64	8	96	512
Loan interest thous. lei/ha	480	485	710	695	5000	1490	5500	795	620	540	750	1310
Interest rate of one-times costs <sup>5</sup> thous. lei/ha	-	-	-	-	-	-	-	-	-	-	-	-
Other costs <sup>6</sup> thous. lei/ha	120	130	145	150	500	300	500	160	150	120	165	260
Total cost thous. lei/ha	2365	2457	2936	2964	18810	5895	20406	3270	2896	2408	3278	5279
Max. yield kg/ha	5500	6000	6500	2500	35000	45000	45000	2500	2500	1800	7000	9000
Selling price lei/kg	1200	1000	1100	2100	1400	270	1200	2500	3000	2500	800	1000
Max. return thous. lei/ha	6600	6000	7150	5250	49000	12150	54000	6250	7500	4500	5600	9000
Max.gross mar- gin thous. lei/ha	4235	3543	4214	2286	30190	6255	33594	2980	4604	2092	2322	3721

<sup>1</sup> + 20 kg a.i./ha government subsidies

<sup>2</sup> + 75 thous lei/ha as government subsidies

<sup>3</sup> including supplying costs

<sup>4</sup> including the cost of fuel, wages, spare parts, interest rates etc.

<sup>5</sup> land improvement works are considered as supported by government

<sup>6</sup> insurance cost and taxes are not included

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

Technology parameter	Alfalfa	Clover	Pasture	Hay field	Apple-tree	Pear-tree	Plum-tree	Sherry-tree	Apric.-tree	Peach-tree	Vineyard-tree	Vineyard-grapes
Seed kg/ha	20	20	26									
lei/ha	12500	6400	3800	-	-	-	-	-	-	-	-	-
N fert. kg a.i./ha												
1700 lei/kg a.i. <sup>3</sup>	50 <sup>1</sup>	55 <sup>1</sup>	-	-	35 <sup>1</sup>	30 <sup>1</sup>	-	50 <sup>1</sup>	50 <sup>1</sup>	35 <sup>1</sup>	30 <sup>1</sup>	30 <sup>1</sup>
3700 lei/kg a.i. <sup>3</sup>	135	150	45 <sup>1</sup>	45 <sup>1</sup>	75	80	70 <sup>1</sup>	60	65	75	40	60
P fert. kg a.i./ha												
2000 lei/kg a.i. <sup>3</sup>	80 <sup>1</sup>	55 <sup>1</sup>	40 <sup>1</sup>	30 <sup>1</sup>	65 <sup>1</sup>	75 <sup>1</sup>	50 <sup>1</sup>	70 <sup>1</sup>	65 <sup>1</sup>	60 <sup>1</sup>	80 <sup>1</sup>	100 <sup>1</sup>
3700 lei/kg a.i. <sup>3</sup>	-	-	-	-	-	-	-	-	-	-	-	-
K fert. kg a.i./ha												
1400 lei/kg a.i. <sup>3</sup>	80 <sup>1</sup>	55 <sup>1</sup>	25 <sup>1</sup>	25 <sup>1</sup>	65 <sup>1</sup>	75 <sup>1</sup>	-	90 <sup>1</sup>	85 <sup>1</sup>	80 <sup>1</sup>	50 <sup>1</sup>	60 <sup>1</sup>
2900 lei/kg a.i. <sup>3</sup>	-	-	-	-	60	50	50 <sup>1</sup>	-	-	-	40	60
Org fert. t/ha												
8000 lei/t <sup>3</sup>	25	25	5	-	8	13	5	11	10	7	10	9
Pesticides												
thous. lei/ha <sup>2-3</sup>	110	85	30	30	2830	2420	1810	1350	3075	2915	1700	2340
Other materials												
thous. lei/ha <sup>3</sup>	-	-	-	-	-	-	-	-	-	-	1000	660
Mech.works <sup>4</sup>												
thous. lei/ha <sup>3</sup>	825	985	405	260	1680	1680	960	1125	1170	1200	790	1070
Man - Pwr h/ha												
1400 lei/h	-	-	34	14	-	-	-	-	-	-	448	448
3200 lei/h	6	8	230	20	1938	2280	1488	3272	1600	1744	1296	1680
Loan interest												
thous. lei/ha	510	510	500	190	4200	4400	2900	5000	3600	3400	3100	3800
Interest rate of one-time costs <sup>5</sup>												
thous. lei/ha	-	-	-	-	1000	1000	1000	1000	1000	1000	1000	1000
Other costs <sup>6</sup>												
thous. lei/ha	155	155	100	100	500	500	500	500	500	500	500	500
Total cost												
thous. lei/ha	2926	2924	2239	925	17208	18147	12476	20106	15119	15221	13489	16176
Max. yield												
kg/ha	35000	40000	35000	25000	20000	20000	12000	9000	12000	16000	10000	13000
Selling price												
lei/kg	140	140	100	100	1200	1250	1400	3000	1900	1600	1800	1700
Max. return												
thous. lei/ha	4900	5600	3500	2500	24000	25000	16800	27000	22800	25600	18000	22100
Max. gross margin												
[thous. lei/ha]	1974	2676	1261	1575	6792	6853	4324	6894	7681	10379	4511	5924

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.

### Computer implementation

The evaluation models and the system requirements have been implemented on personal computer by using the expert system generator (shell) ALES (Rossiter & Wam-

beke, 1989; Rossiter, 1990). It is specialized 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 characteristics 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 informations than those provided by ALES (e.g. suitability indices accord-

ing 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).

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	-

## 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 economically) 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

Table 10. Economic evaluation "versus" physical evaluation  
suitability index  
gross margin [thousand ROL/ha/year]

Land unit	Crops / Land uses										
	winter wheat	maize	sun-flower	potato	sugar-beet	vegetable (onion)	soya-been	alfalfa	pasture	apple-tree	vineyard grapes
Bz 17	61	54	61	38	43	49	55	68	47	38	68 <sup>#</sup>
	33	-212	500	662	-31	3807	230	839	-34	-1228	-1372 <sup>@</sup>
Bz 22	17	20	23	16	11	25	15	22	22	25	26
	-540	-740	-452	-3131	-1281 <sup>@</sup>	297	-572	-607	-416	-2515	-3867
Cj 20	52	47	42	41	40	45	47	65	65	47	16
	-84	-326	31	1191	-119	3237	70	754	229	-390	-4489
Ct 07	64	56	64	26	32	64 <sup>*</sup>	58	64	29	23	36
	76	-180	581	-1416	-436	6117	289	729	-311	-2752	-3262
Db 01	80	80	80	65	72	80 <sup>*</sup>	80	80	58	65	80 <sup>*</sup>
	287	194	981	5387	1148	8517	737	1233	121	1425	-622
Db 41	37	37	32	29	25	25	28	22	37	47	28
	-282	-479	-213	-873	-716	221	-299	-610	-183	-390	-3729
Tr 08	72	72	65	52	52	64	72	58	58	65	72
	182	69	601	3232	341	6117	577	527	121	1424	-1102

(Prices 1996 / 1997)



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<sup>#</sup>) correspond to very different gross margins (between -622 and + 8517 and, respectively, between -1372 and +6117 thousand ROL/ha/year) and, conversely, almost the same gross margin (-1372 /-1281)<sup>@</sup> are obtained by land units with very different suitability index (11 and 68).

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 the land characteristics due to operational land improvement works (e.g. gleysation, 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.

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Table 1. Tabular function  $f^1_{GWT}$  - Yield decreasing coefficient for groundwater table level influence on winter wheat growing under 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

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 <sub>3</sub> )	10
3	EXP	7	land EXPosure to sun	6
4	FLH	52	land Flooding Hazard (include. 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 FERtilization
9.	LO	deep soil LOosening
10.	TE	construction of TERRaces

**Table 4. Definition of the land characteristic “Degree of soil pollution and other land degradations and deficiencies**

Class code	Yield decrease [%]	Se-verity level	Decr. coefficient	CP Effect (re-sult-ing 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	8	0.2	0.9
90	85 - 95	9	0	0.8
99	95 - 100	9	0	0.8

Table 5. Tabular functions for natural land evaluation ExET 3.1n

No	Partial index	Tabular function
1.	$k_{GWT}^N$	$f_{GWT}^I$ (GWT, TXB, PREC)
2.	$k_{GLE}^N$	$f_{GLE}^I$ (GLE)
3.	$k_{PGL}^N$	$f_{PGL}^I$ (PGL)
4.	$k_{TEM}^N$	$f_{TEM}^I$ (TEMC)
5.	$k_{SLO}^N$	$f_{SLO}^I$ (SLO)
6.	$k_{LSL}^N$	$F_{LSL}$ (LSL)
7.	$k_{PRE}^N$	$f_{PRE}^I$ (PREC, TEMC)
8.	$k_{UEV}^N$	$f_{UEV}^I$ (UEV, PREC)
9.	$k_{POR}^N$	$f_{POR}^I$ (POR)
10.	$k_{TXA}^N$	$f_{TXA}^I$ (TXA)
11.	$k_{HUM}^N$	$f_{HUM}^I$ (HUM, TXA)
12.	$k_{PHA}^N$	$f_{PHA}^I$ (PHA)
13.	$k_{SAA}^N$	$f_{SAA}^I$ (SAL, ALK)
14.	$k_{CAR}^N$	$f_{CAR}^I$ (CAR)
15.	$k_{FLH}^N$	$f_{FLH}^I$ (FLH)
16.	$k_{PDD}^N$	$f_{PDD}^I$ (PDD)

Table 6. Partial indices for current land evaluation ExET 3.2c (LCs not-modified by LI works)

No	Partial index	Tabular function	Condition
1.	$k_{GWT}^C$	$f_{GWT}^{II}$ (GWT, TXB, PREC)	DR = 1 or DS = 1







## ROMANIAN AGRICULTURAL RESEARCH

	wheat										
Bz 17	61	54	61	38	43	49	55	68	47	38	68 <sup>#</sup>
	33	-212	500	662	-31	3.807	230	839	-34	-1.228	-1.372 <sup>@</sup>
Bz 22	17	20	23	16	11	25	15	22	22	25	26
	-540	-740	-452	-3.131	-1.281 <sup>@</sup>	297	-572	-607	-416	-2.515	-3.867
Cj 20	52	47	42	41	40	45	47	65	65	47	16
	-84	-326	31	1.191	-119	3.237	70	754	229	-390	-4.489
Ct 07	64	56	64	26	32	64 <sup>#</sup>	58	64	29	23	36
	76	-180	581	-1.416	-436	6.117	289	729	-311	-2.752	-3.262
Db 01	80	80	80	65	72	80 <sup>#</sup>	80	80	58	65	80 <sup>#</sup>
	287	194	981	5.387	1.148	8.517	737	1.233	121	1.425	-622
Db 41	37	37	32	29	25	25	28	22	37	47	28
	-282	-479	-213	-873	-716	221	-299	-610	-183	-390	-3.729
Tr 08	72	72	65	52	52	64	72	58	58	65	72
	182	69	601	3.232	341	6.117	577	527	121	1.424	-1.102

(Prices 1996 / 1997)