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PROPOSAL FOR AN INTEGRATED EXPERT SYSTEM FOR LAND EVALUATION IN ROMANIA[1]

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Summary

The present land evaluation methodology (for 1:10,000 scale), its computer implementations and the available data sets for land evaluation in Romania are briefly presented. As a result of the analysis of these above, the general requirements for a new (computerized) land evaluation system in Romania - from the functional point of view (what the system must do) and operational point of view (how the system must function) are given. Finally, a general structure of the system is proposed. It is based on a new approach - an "integrated expert system" using "models base" - which permits integration of different land evaluation methods (models), different computer implementation technics and different data sets. General principles for computer implementation are also outlined.

Key words: *land evaluation methodology, expert systems, models base, integrated expert system for land evaluation, computer implementation.*

1. Introduction

The Research Institute for Soil Science and Agrochemistry - ICPA Bucharest - is the Romanian national scientific organisation which have in responsibility and deal with basic and applied research concerning inventory and management of national soil/land resources for sustainable agricultural and forestry development and environmental protection. In this respect, it has collected up to now many different soil/land data and has developed two national methodologies for land evaluation (rating), one for 1:50,000 scale (ICPA,1975; Teaci,1980) and the second for 1:10,000 scale (ICPA,1978,1987; Teaci,1980). There are established also different specialized methodologies for land evaluation (ICPA,1987).

Developments in information technology and in soil and crop sciences and, on the other hand, the changes in Romanian agriculture (land property and socio-economic context) make possible and necessary a development of a new land evaluation system in Romania. This paper presents requirements for a such system and proposes a general structure and computer implementation principles for it. As a preliminary of these, a brief analysis of available land/soil data and current methodology for land evaluation in Romania are presented.

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2. Available Land/Soil Data for land evaluation in Romania

According to the methodology for 1:50,000 scale, the data for the whole Romanian agricultural land were collected and computerized as a data base (Vlad et al., SC[2]/1991, TR[3]/1993-1994). For each of about 150,000 land units, over 110 parameters are stored: soil, climate, landform, hydrology, technological characterisation, current and potential land suitability indices for 25 crops and land use categories. Stored areas of land units refer to land use categories and owner categories in each sub-district (commune).

According to the methodology for 1:10,000 scale the data for cca. 35% of Romanian agricultural land (cca. 40% of arable land) have been collected and computerized up to now (Marian et al.,TR/1990; Vlad et al.,TR/1993-1994). About 35 parameters regarding soil, climate, landform, hydrology are stored for each land unit. Also, the areas of land use categories are stored for each land mapping unit (corresponding to land units in a cadastral plot). Data are validated and three types of land suitability indices (current, current-potential and ideal-potential) for 25 crops and land uses and 8 technological parameters are obtained at different levels of aggregation. Other data are collecting and computerizing now.

A data base of soil profiles was established (Vlad et al.,TR/1987-1989, TR/1993-1994). It can store over 30 general data fields (identification, location etc.), about 75 land characteristics, about 60 morphological data, 40 physical data and 34 chemical data for a soil horizon/subhorizon (of 10 possible) and 13 chemical parameters for groundwater. Data for about 4000 soil profiles have been stored up to now including general/land data and physical parameters (200 on an average). Over 450 soil profiles are characterised by chemical parameters (cca. 125), and over 150 soil profiles have all types of parameters (cca. 1000). Different processing functions are available: data validation, derived parameters calculation, missing or non-available data estimation using pedotransfer functions, statistical parameters estimation for groups of profiles, reports printing, etc. Other data are collecting and computerizing now.

Many other computerized or non-computerized data sets of different specialized definitions exist for different regions of Romania at ICPA and at the 37 territorial (district) soil survey offices.

The existent data bases contain non-spatial information about land/soil units or soil profiles. A geographical information system for agricultural land/soil in Romania was started to be developed (Vlad et al.,SC/1991; Vintilå et al.,TR/1991; Munteanu et al.,SC/1993; Vlad,1994).

3. Romanian Land Evaluation Methodology for 1:10,000 scale.

The land evaluation methodology for 1:10,000 scale was computerized and is used at present. It uses a *multiplicative parametric method* and was developed for *physical land evaluation* at a *large scale*. As land utilization types *twenty-four crops, crop groups and land uses* are considered: *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.* An overall suitability for *arable land use* is calculated as an average of the highest four suitability indices among those of arable land utilization types (crops or groups of crops).

For rainfed agriculture *twenty-three land characteristics* are taken into account: minor relief form, land slides and micro relief, slope, exposure to sun, mean annual air temperature, mean annual precipitation, ground-water table level, flooding hazard, texture in topsoil, texture in profile, contrast of texture, total porosity, permeability, useful edaphical volume, gleyzation,

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[2] Scientific Communication (Research Inst. for Soil Sci. and Agrochemistry, Bucharest)
[3] Technical Report (Research Inst. for Soil Sci. and Agrochemistry, Bucharest)

pseudogleyzation, salinization, alkalinisation, humus storage, pH in topsoil, total content of $CaCO_3$, land reclamation, soil pollution. They are established/estimated for land units with usual land/soil survey procedures using 5 - 11 (26) classes of values.

The land characteristics are combined using tabular functions to obtain yield decreasing indices for each land utilization type. *Seventeen yield decreasing indices* (each of them corresponding to a land characteristic or to a combination of related land characteristics) - the same for each land utilization type - are established. An yield decreasing index estimates the proportion of the yield decreasing due to the influence of a given land characteristic or group of land characteristics using a number between 0 and 1. These indices are multiplied to obtain the sub-unitary suitability index, which is multiplied with 100 to obtain the percentage suitability index (between 0 and 100).

This is the *current land suitability* because all the methodology procedures assume a *medium (current) level of technology/management* in Romania and are based on the actual values of land characteristics. The tabular functions for decreasing indices are established with reference to *the best land conditions that are found in Romania* and were established by a group of *experts* based on their experience and, also, on *statistical* results obtained by different Romanian agricultural research units in their scientific (controlled) field experiments.

The methodology establishes, also, the evaluation procedures for the situations of land improvement (land reclamation or ameliorative technology). Yield increasing indices (> 1) are used for these cases. In this way, two conditional land suitabilities are calculated: *current-potential suitability* - for the situation of implementation of the current-possible improvements for the given land unit - and *ideal-potential suitability* - for the situation of implementation of all ideally-possible improvements for the given land unit. These conditional land suitabilities take into account the residual influence of the factors for which land improvements are made.

The methodology was computer implemented in two ways:

- batch processing way on a DEC PDP-11 compatible minicomputer (CORAL 4021/4030), for centralised evaluations (Marian et al.,TR/1990; Vlad et al,TR/1993-1994);
- expert system way on personal computer for six rainfed crops (Vlad,1994; Vlad et al.,TR/1994), using the ALES expert system shell (Rossiter,1990).

The expert system implementation, ***ExET,*** was carried out to test the possibility/feasibility to extend the methodology for economic land evaluation, to meet the requirements for an interactive user-friendly interface and to use expert system shells. For economic land evaluation, the well-defined inputs (and their related costs/prices) corresponding to the current (medium) technology/management level in Romania were established. Consequently, for each crop the Maximum Current Yield (P_{cm}) was established. It corresponds to the yield obtained in the best land conditions in Romania (all yield decreasing indexes have the value 1) using the current (medium) technology/management. The actual yield (P_c) for a land unit is obtained by multiplying P_{cm} with the sub-unitary suitability index, and the return is obtained by multiplying P_c with a reference sale price. The economic suitability, represented by gross margin, is calculated as the difference between the return and total cost. This implementation pointed out the necessity of Economic Land Evaluation, the advantages of using an expert system shell (great flexibility, user-friendly interface, explanations about evaluation reasoning, etc.) and some disadvantages (difficulties of implementing of complex algorithmic procedures).

4. Requirements for a new computerized Land Evaluation System in Romania

As a result of the last changes in Romanian agriculture and progresses in soil and crop sciences (Bouma,1989; Bouma & Bregt,1989; Burrough,1989; DeMers,1989; Driessen & Konijn,1992; Dumanski & Onofrei,1989; Jones & Biagi,1989; Lein,1990; Rossiter,1990; Smit et al.,1984; Toselli & Meyer-Roux,1990; van Diepen et al.,1991; van Keulen & Wolf,1986; van Lanen & Bregt,1989; van Lanen,1991; Varcoe,1990; Verheye,1991,1992; Vossen,1992,1994), a new - multifunctional and more accurate - computerised Land Evaluation System is requested in Romania to be used for:

- establishing the agricultural policy at the national and zone (district) levels;
- land use planning at local level (farms, agricultural production enterprises/companies);
- taxes establishing (by the government authorities);
- making other kinds of decisions (e.g. evaluations for bank loans, statement establishing for land leasing, arbitration between different interests etc.

All these must be assured taking into account the new realities in Romania concerning land property (a great number of land owners) and the farms characteristics (very small - spatially separated - land parcels).

As consequences of the above purposes, the system must assure the following objectives (requirements):

From the Functional point of view (What the system must do):

- *Small scale and Large scale land evaluation* (from farm level to national level).

- *Physical and Economic land evaluation*.

Well-defined reference economic parameters are necessary for economic land evaluation (including the influence of the present high inflation rate, the transport distances etc.). Also, well-defined economic models are to be established for different special economic evaluations (e.g. flexibility in land use, relative importance of land units for different land utilization types, sensitivity of evaluation to the physical and socio-economic changes etc.).

- *General and Detailed land evaluation*

(regarding land utilization types corresponding to national, zone or local decision-making).

For the national and zone levels, the crops taken into account by the present land evaluation Romanian Methodology seem to be sufficient as land utilization types for the future system. For local (farm) level more detailed land utilization types must be defined. At least the following characteristics must be established for each crop (the same to that considered for national level):

. the most used/recommended cultivars (varieties) in Romania,

. three levels of technological input/management (low, medium, high).

Also, some defined multiple-cropping systems (intercroppings, rotations) must be taken into account. For all levels - national, zone, local (farm) - Potential, Current-Potential, Water-Limited and Current suitabilities are necessary.

- *Quantitative* (good evaluation accuracy), *semi-quantitative and qualitative methods* are requested. The available soil water flow and crop growing simulation models have to be used and for the remaining factors (not taken into account by the simulation models) appropriate expert rules or algorithms (simple models) must be reviewed/established to be used in qualitative and semi-quantitative methods. Some new land characteristics are to be considered: mean monthly temperature and rainfall, length of plant growing period, position (distances/accessibility), parcel size/configuration etc.

- Considering the *aspects concerning environment (land/soil/water) degradation*, respectively *conservation (protection).*

At least, the following degradation/pollution types may be taken into account:

. For Soil: erosion, physical structure degradation;
. For Soil and GroundWater: nitrogen content, phosphate content, fluorine content, heavy metals content, pesticides content, oil and brine content, soluble organic content, acidification, salinity, alkalinity, groundwater level (artificial rising) and waterlogging.

In connection with these land characteristics, the corresponding characteristics of land utilization types and their relations must be established. Also, the influence of other land characteristics on environment degradation has to be established. The change degree of degrading characteristics and the costs to maintain these characteristics unchanged after a land use cycle must be established, in order to be taken into account in physical and economic land evaluation.

- Considering *other aspects of land utilization types* like the quality of outputs (e.g. flavours, tastes, protein/fibber/sugar content etc.).

- *Use of the existing data sets* (different methodologies, different availability for different territories) as much as possible, respectively *requests for few new data*.

- *Compatibility with other systems* (European Union, FAO, USDA etc.).

- Elaboration of *technological recommendations* concerning reclamation (improvement) and conservation (protection) of land (soil).

From the Operational point of view (How the system must function):

- *Easiness of system use*, so that it could be used by different people without special knowledge in soil science, plant physiology, computing, modelling etc.
As consequences, the following needs are requested:
. *user-friendly interface* of the system,
. *directly usable results* of the system (no other calculations/interpretations to be necessary),
. *explanations* of evaluation reasoning,
. *facilities for system tuning* according to user requirements (local condition),
. *different levels of user access* to system functions
(to protect the system against misusing and alteration).

- *Easiness of functional configuration* for different levels (user categories).

- *Easiness of system development* (implementation of new versions).

5. General Structure of the proposed computerized Land Evaluation System

The conception of the proposed system, that must meet the requirements presented above, has resulted primarily from the particularities of the necessary data (at national level) for land evaluation: large volumes of data, that request high costs (10-50 times higher then the corresponding software (Bill et al.,1993)) and very long time to be collected (10-30 years, that is 3-10 times longer than the corresponding software). On the other hand, in this long duration of data collection, different changes (improvements) in the used methodology may be introduced and this leads to data sets of different definitions and qualities. More, there are available different data sets for different agricultural territories.

As a consequence of these facts, it is more advantageous to *accommodate the processing to data,* not inversely - data to processing (as usually). In this respect, the basic idea is to implement different models and algorithms, which will form together a *"models base"* (Vlad et al.,1986), as a balance to data that are organised in data base. The appropriate model/algorithm may be chosen and used for a given data set. This permits, also, to use entirely the existing data sets (the losses of data and their quality by unifying are avoided).

On the other hand, this method is requested by the necessity to implement a mixture of different land evaluation methods and implementation technics to meet the system requirements. In this way it is possible to use the best available knowledge for different land utilization types, factors, requirements and data sets. This knowledge is formed by simulation models, specific algorithms (including the pedotransfer functions), expert-type rules, regression functions, etc. These will be generically called *"models"*.

Knowledge accumulated in Romania concerning soil/plant simulation models (Simota, TR/1986, TR/1990, 1993?, 1994?; Simota & Canarache, 1986, 1988; Vlad, 1994, 1995?; Florea, 1983), pedotransfer functions (Canarache,1986,1987,1990; Canarache & Simota,1993), using land survey data with deterministic models (Vlad,1994,1995?), soil protection (Rauta & Cârstea,1994; Rauta et al.,TR/1986-1994,1994?; Dumitru et al.,TR/1986-1994; Lacatusu et al.,TR/1986-1994 Florea et al.,1991), expert type systems (Vlad et al.,TR/1991-1994, Canarache & Cojocaru,TR/1993) and soil/land information system development (Vlad et al.,TR/1988, SC/1992, TR/1991-1994, 1994) is a good premise to develop this approach.

The proposed general structure for the Land Evaluation System is presented in *Figure 1*. The system is called *"Integrated Expert System"* because it is “integrated” from three points of view: it integrates (1) different land evaluation methods ("models"), (2) different data sets, and (3) different implementation technics (including expert system type). The system works under the control of an expert system type module (*"Expert Control Module"*) which implements the general procedure for land evaluation. This control module "chooses" from "Models Base", in different phases of land evaluation procedure, the best "model" for the given situation (available data set, group of evaluation factors, evaluation type/level, etc.).

The following types of "models" are necessary:
- *Soil water flow and crop growth simulation models* (like WOFOST, SIBIL, EPIC etc.), for different user requests, different land utilization types, different available data etc.;
- *Pedo-Transfer Functions*, for different "models" and for different availability situations of the primary land characteristics;
- *Indirect Estimation Algorithms* for the estimation of the primary land characteristics that are not available (including the interpolation algorithms for weather data);
- *Land Evaluation (LE) Expert Sub-systems*, for different land evaluation kinds (levels), for factors and land utilization types that are not taken into account by simulation models, and for specific parts of land evaluation procedure;
- *Technological Recommendation (TR) Expert Sub-systems,* for different user requests;
- *Data Converters,* for conversion of different formats (structures) of data, according to different "models" requirements;
- *Data Generators*, for computer generation of data (e.g. climatic data);
- *Data Presentation*, according to different user requests;
- *Data Entry/Modification*, according to different situations.

For the communication between modules, some specialised data structures are used:
- *Control Tables* ("status" information about each module),
- *Module-Interface Files* (for larger volumes of data for module communication),
- *Meta DataBase* (structure information about General Data Base).

It is noted that this structure provides for a very good modularity of the system, which can assure the flexibility requirements for system development and configuration.

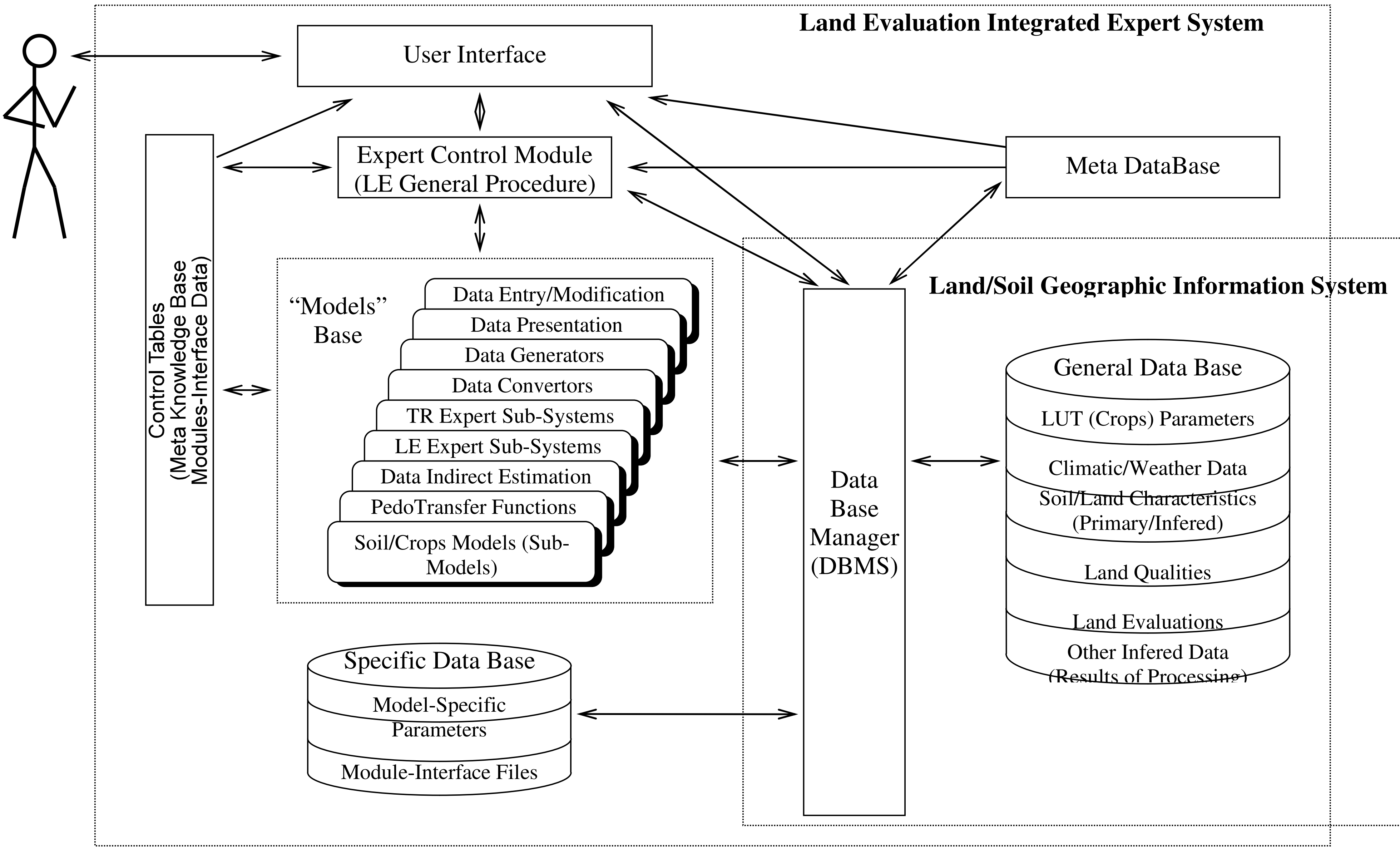

Figure 1: General structure of the Land Evaluation Integrated Expert System

6. Computer Implementation of the Integrated Expert System for Land Evaluation

The development of the system must be carried out gradually, in successive stages:
- Development of a prototype of the system, implementing few functions, according to an established priority;
- Testing/calibration/validation of the prior implementations and development of new functions, according to the established priority; This stage will be repeated for different functions.

The system (variants of the system) must be implemented on two different computers types:
- personal computer, to be used in agricultural farms and in consulting/extension centres,
- workstation, for national level evaluations, based on Land/Soil GIS.

According to this requirement, the development tools must permit a good portability on the two platforms. In the case of workstation implementation, the system uses the Descriptive Data Base of the Land/Soil GIS and in the case of personal computer implementation, the system will have its own data base (*Figure 1*).

Easiness of system development (testing, calibration, validation, maintenance, etc.) is needed.

Classical technics (for implementing the algorithmic procedures) and artificial intelligence type techniques (for implementing the expert-type procedures) must be used and must be integrated.

To meet these implementation requirements, the following options are recommended:
- strong modularity (functional and at programming level),
- table driven algorithms,
- object-oriented programming (which permits flexibility, modularity, easy modelling the real world).

In this respect, the following development tools (available on both workstations and personal computers) are proposed:
- C++ and FORTRAN 77 (90) programming languages,
- NEXPERT OBJECT, as software tool for expert system type procedures implementation (it is object-oriented and has a natural interface with C++),
- ORACLE, for data base management functions.

7. Conclusions

It is proposed a new land evaluation system which permits to use the appropriate land evaluation models to user-specified requests and to available data. Requirements for this system are outlined.

For system requirements analysis and system conception a top-down approach was used (Vlad, 1994a). Following this approach, further requirements analysis and system conception must be carried out gradually on more detailed levels by a multi-disciplinary research team (soil/land, agroclimatology, agronomy/farming, economics, sociology, information technology):

- establishing the project requirements and planning;
- establishing the working standards and procedures for the project team;
- more detailed analysis on the requested utilizations of the system and on the available data; corresponding to the analysis results, the detailed functions of the systems can be established (land utilization types, land suitability types, etc.);
- choosing the simulation models to be used for land evaluation; appropriate experiments are needed for this;
- establishing the pedotransfer functions, indirect data estimation algorithms, data converters and data generators necessary for the chosen simulation models;

- establishing methods and carrying out experiments necessary for obtaining of unavailable pedotransfer functions and indirect data estimation algorithms;
- establishing methods and carrying out experiments necessary to calibrate and validate the chosen simulation models;
- establishing expert rules necessary for land evaluation and technological recommendations;
- establishing data presentation features.

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