The implementation of agricultural land evaluation process using Geographic Information Systems

Ph. D. Thesis - Summary

This research assumes that is necessary and possible the transition of national agricultural land evaluation methodology ICPA (1987) in computerized environment, specifically in GIS environment, to achieve objective, spatialized and automated quantifications of indicators, coefficients and evaluation notes (evaluation marks).

The present work is a methodological one, for its creation was consulted national and international bibliography with specialized papers in the field of land evaluation and GIS. Its practical side is given by the thoroughly documentation of the implementation stages of the national methodology for agricultural land evaluation as well as SQL functions created during implementation and available in this work.

Land evaluation refers to "the process of corroboration and interpretation of the study of soil, vegetation, climate and other aspects of the land in order to identify and make a first comparison of promising alternatives of land use in socio-economic terms" (Brinkman 1972).

Land evaluation being a "border activity between pedology and agricultural economy, with many implications in all natural sciences, agricultural technology and in general economy. Agricultural land evaluation is a complex operation of research, assessment and appreciation of lands technical quality and their production capacity, through a system of techniques indices and notations of evaluation notes” (Teaci 1970).

Suitability refers to a process of "evaluation with more general character and is relevant to a range of uses" (Patriche 2003) so "the suitability of a land for a particular use" (Țărău 2006). Favorability refers to "the extent to which agricultural land satisfy growth requirements and formation of crops for various agricultural plants or cultivated species, in normal weather conditions and in a medium agrotechnical environment" (Țărău 2006).

The purpose of the present research is the successful implementation of the methodology for calculating the parameters and evaluation indicators and the calculation of the coefficients and evaluation scores (evaluation notes) in accordance with the ICPA (1987), in GIS.

The core objective of this paper is to create a framework for implementation (a functional model) in a open source GIS. Secondary objectives are: creating a relational
database, creating the model for agricultural land evaluation process in GIS (input-information flow-output) and creating a local SIS.

Literature mentions as promoters in developing knowledge of agricultural land evaluation based on a standardized methodology, three "schools" respectively the German (Thaer, 1820; Birnbaum, 1820; Knop, 1871; Detmer, 1876; Krafft, 1877; Arens, 1960), Russian (Dokuchaev and Sibirțev, 1881-1895) and American (Storie, 1932; Klingebiel and Montgomery, 1961; Soil Conservation Service, 1981), but major contributions were made across Europe as well as overseas.

At the end of the 1970s, FAO has funded a working group in land evaluation field, the research was completed with the publication of the first edition of A Framework for Land Evaluation work in 1976, which was the basis of land evaluation methodologies, further developed.

Agricultural lands evaluation issues in Romania, was approached simultaneously by geographers, pedologists and agronomists, since the eighteenth-century. Important contributions in literature, were made by the agronomist Ionescu de la Brad, Vasiliu (1933), Oprea (1939-1946), Ionescu - Sisești (1939), Chiriță and Cernescu (1959), Crișan (1959), Georgescu (1964), Cârstea (1964), Maxim (1972).

However, the first methodology developed in order to evaluate agricultural lands was made by Dumitru Teaci, who initiated the Romanian agricultural land evaluation system in the early 70s, this research has been founded in the work published in 1970 Agricultural lands evaluation. The methodology proposed by Teaci (1980) is included in the synthesis work Drafting Methodology of Soil Survey published in 1987, this work consists of three volumes and edited by the staff of the Soil Science and Agrochemistry Research Institute (ICPA), coordinated by Florea, Bălăceanu, Răuță and Canarache.

At the institutional level, land evaluation research was supported by the Soil Science and Agrochemical Research Institute of Bucharest, founded in 1970, and in 1975 arise County Offices for Soil and Agrochemical Studies O.J.S.P.A.

What is GIS? In Encyclopedia of Geographic Information Science, the concept of GIS "incorporate the following: a software product, bought to make a well-defined set of functions (GIS software) digital representations of various aspects of geographical area (GIS data), a community of people using these tools for different purposes (GIS community) activities to use GIS to solve problems or in advanced science (GIScience) "(Longley 2008).

History of the concept and domain of GIS is short, more exactly 51 years, but it has raised significant interest and implicitly received a surprisingly fast evolution. This evolution depended on the development of related fields respectively cartography, photogrammetry and remote sensing, the emergence and evolution of computers and all modern recording, data acquisition and processing equipment (peripheral devices).

A first approach in the GIS field was initiated by the Canadian government in the mid-1960s, through the project Canada Geographic Information System. In the early 1970s, GIS entered into the attention of university research laboratories and government agencies, this meant practically the beginning of GIS development. Gradually, to the 1980s it started the development of digital mapping and remote sensing (which offers both new sources of data and technology), and shortly military needs were responsible for the development of Global Positioning System (GPS).

After 1990 the general public had access to increasingly more efficient computers and peripherals, to advanced software, to communications networks, to Internet and Web, which facilitated worldwide data acquisition and exchange, and raised the interest of common users and researchers in all areas.

Michael F. Goodchild introduced in 1992 for the first time in literature, the concept of GIScience, the author talks about "science behind systems", raising the question whether GIScience is the research about GIS? or the research using GIS? identifying the main issues of GIS that must be debated and continuously investigated and concluding that "GIS is a tool of GIScience, which will generate further development thereof" (Goodchild 1992). A recent and concise definition mentions that "GIScience addresses fundamental issues underlying Geographic Information Systems as well as GIS use in scientific progress" (Goodchild 2008).
GIS remarks as a system whose components are interconnected and we distinguish among them: hardware equipment (the one providing working tools), software component (the one that provides data manipulation functions), geospatial data (in different formats to be analyzed or interpreted), rules and working methods (mandatory and standardized for each component) and GIS community (represented by users and developers that manipulate the data through software and hardware components or implement new methods of analysis).

Depending on the domain implementation and its users GIS has the aim: to inform the general public, to perform operations and handling data, to produce accurate information, to solve geographic problems, to analyze and to inventory spatial data.

In applying in digital environment, the methods of land evaluation, GIS has several key points:

- automation of evaluation through analytical functions specific to IT environment;
- objectivization, achieved through strict criteria of delimitation of land map units and the input data for the evaluation system;
- spatialization of land evaluation, which is obtained by spatial organization of the input parameters in the evaluation process as well as the results.

*Soil Information Systems* (SIS) are special GIS, whose purpose is to analyze and interpret data on soil and land in order to solve different requirements of specialists in soil science and related fields. SIS has the same components as GIS, but their applicability is well defined, and serve as inventory of soil-land resources, analysis and modeling. Specific to SIS is that geospatial data (original or derived) refer mainly to soil, GIS rules and methods are added and some specific rules in the analysis and modeling of soil-land resources, and the community is represented only by specialists in the field. One of the finalities of the research, materializes in creating a local SIS.

According to soil studies classification schema described in the methodology in force, the evaluation of land is classified as *"special pedological study, a inventory of soil resource and land favorability for different cultures"* (ICPA, 1987).

National land evaluation system has its origins in three other methodologies, this are referring to establish lands suitability (was taken as model *Land Capability Classification* methodology, developed in 1961 by USDA and the classification developed by Cârstea in 1964) and land favorability for uses and crops (was taken as model the methodology developed by D. Teaci in 1970/1980). In Romania, land evaluation is performed on TEO's,
considering 4 types of land use and 22 types of crops, resulting 24 possible situations in the methodology.

According to the methodology, evaluation of land is for both natural conditions (reflecting the natural productive capacity of the land) and the conditions of improved evaluation notes (reflecting the land productive capacity under the influence of improvement works).

To quantify the evaluation notes (in natural conditions) were considered the following eco-pedological indicators: average annual temperature - corrected values, average annual rainfall - values corrected, gleyzation, pseudogleyzation, salinity or alkalinity, texture in Ap or in the top 20 cm, pollution, slopes, landslides, groundwater depth, inundability, total porosity in restrictive horizon, CaCO₃ total content on 0-50 cm, the pH in Ap or in the top 20 cm, edaphic volume, humus reserve in layer 0-50 cm, the surface humidity excess.

The 17 indicators receive a factor of evaluation, which can have values from 0 (unfavorable) to 1 (maximum favorability). Multiplying the coefficients product of the 17 eco-pedological indicators by 100, is obtain the evaluation note for land use and crops. The evaluation note for natural conditions can have a maximum of 100 points. Evaluation points obtained are ranked, settling 10 favorability classes (class I is the best, with score of 91-100, and class X is the lowest scoring 1-10).

It is known that, some negative features of the terrain can be corrected by developing improvement works. The operation, that subject the evaluation score (note of evaluation) to a re-evaluation is called potentiation.

Once implemented these works are deleted the penalties introduced to coefficients of evaluation, achieving in this way potentiation of evaluation notes. Raising the value of the coefficients is done by multiplying with higher coefficients the evaluation notes obtained under natural conditions.

First national proposal of a model for agricultural land evaluation in computerised environment, is done by Vlad V., in his Proposal for an integrated expert system for land evaluation in Romania, published in 1996. Currently to calculate evaluation notes it is used BDUST (application developed by the ICPA staff), which is fully functional in the context of the objectives and the purpose for which it was created (store and update data, calculate, estimate and determine classification), however GIS component is missing from BDUST application.
Primary data on which the present research is based are represented by: soil survey studies conducted by OJSPA Iasi, soil profiles made and characterized by OJSPA Iasi and national methodology for agricultural land evaluation (ICPA, 1987 - Volume I - II - III).

For the study area, which covers 13 neighboring municipalities (Bălțați, Brăești, Dumești, Erbiceni, Horlești, Lețcani, Lungani, Miroslava, Podu Iloaiei, Popești, Rediu, Românești and Sinești) located in Iasi county, were available soil survey studies of 1:10000 scale and 620 soil profiles set in the period 1989-2005. Physical and chemical analyzes of studies have been conducted by the Iasi County Office for Pedology and Agrochemical Studies, according to the methodology.

The study area covers 68,085 hectares, of which 59,681 hectares belonging to land taken in study, the remaining 8,404 hectares belonging to built areas, lake, forest and deep forms of erosion. In terms of location in the physical-geographic context, study area occupies the southern part of the Hill Plain Jijia at the contact with Iasi Coast.

In terms of soil, according to data for the 13 soil survey studies and recent taxonomic classification of soils in Romanian System of Soil Taxonomy (SRTS-2012), in the study area were identified six classes of soil in which distinguished 10 types of soil. Soil types identified are: Cernoziom și Faeoziom (Class CERNISOLURI) Preluvosol and Luvosol (Class LUVISOLURI), Gleiosol (Class HIDRISOLURI) Solonetz and Soloceac (Class SALSODISOLURI), Aluviosol and Regosol (Class PROTISOLURI) and Antrosol (Class ANTRISOLURI).

To these soil types and subtypes are added soil complexes, within which the composition and contribution percentage led to the identification of 110 complex types. As mentioned, soil taxonomic level is assigned according to the new SRTS-2012, but to reach this form, soils were originally listed from Romanian System of Soil Classification SRCS-1980 in SRTS-2003 (as a part of soil studies were classified into the 1980 soils taxonomy), later realizing the transition from SRTS-2003 in SRTS-2012.

To implement in GIS the model for agricultural land evaluation, were selected open source software, compatible with the requirements of our model. Main platform on which is based the implementation of agricultural land evaluation, is the open source applications complex: QuantumGIS - PostgreSQL.

As I mentioned from the beginning of the scientific approach of this paper, the purpose of research will be: implementing the national methodology for agricultural land
The implementation of agricultural land evaluation process using Geographic Information Systems

Ph. D. Thesis – Summary

Iuliana Cornelia Niculită

evaluation in GIS, which once completed will result in the creation and development of a SIS. This local SIS includes a soil database linked to a land database, through a mapping units database. From relationing and querying these databases, will be created the agricultural land evaluation database (this will give the results of our research).

Soil Database called DBSOIL includes all quantitative and qualitative information about soil properties. It was created by two databases on soil attributes aggregating. These two databases are in different formats and have different sources of information, namely Soil Units Database called SUD and Analytical Database of Soil Profiles, called DBSP.

Mapping Units Database with its acronym MUDB provides graphical support for viewing information created and Terrain Database - TDB covers all of quantitative and/or qualitative land aspects relevant to soil (hypsometry, slope, exposition).

To implement the process of agricultural land evaluation were needed SIG operations, as follows: spatial data acquisition operations, where were discussed spatial data sources (topographic maps with scale 1:25,000 and 1:5.000, the maps developed by ISPIF Bucharest 1:50.000 scale maps, soil studies with scale 1:10.000, MNA climate data, CMRM, GSODAM) and their formats (vector, raster, and database); spatial data storage operations; spatial data manipulation operations (SQL query); spatial data analysis operations (where were discussed MNAST interpolation and slope and exposition variables as well as geostatistical modeling of climatic factors) and visualization techniques.

Were determined separately each of the 17 eco-podological indicator by SQL functions in DBSOIL. Where eco-pedological main indicators (the 17), depended on secondary indicators to be determined (enrolled in classes of values indicated by methodology), they were latter quantified in DBSOIL.

Because the author has proposed that the model implemented in GIS to be used and applied in the evaluation of agricultural land on other geographical areas in Romania, were taken into account all the circumstances of environmental indicators listed in the national methodology for agricultural land evaluation. Thus, although the results of the implementation of agricultural land evaluation methodology will refer in this paper only to the territory in the study, the structure of DBSOIL and SQL functions refer to the whole range of environmental indicators situations identified in Romania, so the calculation model presented in this paper can be successfully applied whenever to a new national territory.
After calculate indicators under natural conditions it have been quantified the evaluation indicators under potentiated conditions (surface drainage works, irrigation works and works to prevent and combat soil erosion). Once estimated the values of the indicators, was developed the computation mode of coefficients evaluation (evaluation marks) in SIG, for each eco-pedological indicator participating in the evaluation of land under natural and potentiated conditions.

The final part of the research was to implement the calculation of evaluation scoring (evaluation marks) under natural and potentiated conditions according to ICPA, middle notes of evaluation for land use and crops and estimation of potential crop productivity. The elaboration of cartographic material according to quality classes (agricultural uses) and favorability (crops) was achieved by ICPA standards.

In conclusion, agricultural land evaluation provides a response to decision factor regarding the potential of land for current use and some proposed uses. Within the current Romanian system of agriculture and agricultural land evaluation, we consider opportune to implement agricultural land evaluation methodology in GIS, approach that can simplify the process and is a fundamental premise in shaping natural potential of land for sustainable agriculture.

As we reviewed, research on land evaluation started from simple considerations of economic and productive potential of land, increasing to standardization of methodologies and evaluation methods for quantifying parameters and provides accurate data for hierarchy, up to implement methods in GIS and using modern technology, approach that had been successfully achieved in the present study.

I think that GIS environment, in terms of implementation of national methodology ICPA, should stop using value classes (where possible) and replace them with calculated values of the indicators, especially when the calculated values are correct and accurate in GIS environment, leaving no room for interpretation. These "forced" classifications of indicator values, often resulting in final evaluation scores favoring the inclusion of land in higher graded or penalizing the land, often falling to the lower classes, ideal would be to create a model that assume direct relationship between factors and coefficients and no current assignment based on classes (which leaves room for subjectivity in classification).

Taking opportune the encoding of parameter values made by ICPA, the author has implemented in its turn the numerical coding of values and value classes, to simplify and
facilitate calculations and estimates made in the SQL language and for a "clean" data storage, which has resulted in efficient processing of information.

The presented implementation of agricultural land evaluation in GIS can integrate soil data from different sources, analyze them in order to evaluate the land and can offer a multitude of results, these may support a correct interpretation of farmland assessment.

Soil Information Systems easily solve specialized user requirements in this domain, as evidenced by this paper (can analyze in detail the indicators of evaluation of land and is made available cartographic sources for any parameter or indicator).

Relational databases are the best choice in structuring information and manipulate an impressive amount of data, they are efficient and allow full access through SQL for the user to make better decisions.

The benefits of the system proposed in this paper are:

1. smooth integration of information from different data sources (as scale, spread, type of information, file format);
2. create structures and rank information in databases;
3. transform table information into graphical information (spatialized) through spatial database;
4. calculation of all indicators, coefficients of evaluation and scoring of evaluation is done in a very short time - just a click of the mouse;
5. editing maps is easy, regardless of its type and scale and the colors used in making maps are part of the official web safe palette colors, which standardizes their printing;
6. provides standardized color palette and hatches for all soil types and subtypes defined by STRS 2012 and proposes an intuitive model to display the components of the soil complex (for any composition and percentage of participation);
7. using open source applications, knowledge is transferred and can be accessed by the entire scientific community, which is a key factor in the future development of national methodology;
8. open source methodology ensures transparency, the user can learn how to calculate the parameters and decide in choosing the correct ones;
9. integration with GIS offers different possibilities in spatial analysis and allows the results to be displayed in maps, graphs, reports, etc.
10. creating a database of spatial information paves the way for integration in prediction models and land use planning.

Major differences between the model proposed in this paper, the implementation of national methodology for agricultural land evaluation in GIS platform *QuantumGIS* - *PostgreSQL* and the computerised application *BDUST* (currently used in the evaluation scoring at OJSPA) were identified and are presented in what follows.

- *QuantumGIS-PostgreSQL* - Is an open source application - can be used without a need to purchase a license by all interested users (research centers, universities, and so on).
- *BDUST* -'s proprietary application - used only OJSPA service is not available outside the institution (by others users interested in land valuation, researcher centers, universities).
- *QuantumGIS-PostgreSQL* - Provides proper support in data modeling and spatialization of source data, this leads to a fair and objective quantification of parameter values participating in land valuation.
- *BDUST* - do not offer support in modeling the source data.
- *QuantumGIS-PostgreSQL* - Allows access anytime to database and formulate new requirements / queries, functions, order by users via SQL.
- *BDUST* -do not allows users to interact with information in the database, functions are standard and can not be applied other functions / calculations.
- *QuantumGIS-PostgreSQL* - Edit maps related to all information from the database, creates graphics, creates symbologies, reports.
- *BDUST* - Do not create maps, symbols, graphs, reports only provide tabular information.
- *QuantumGIS-PostgreSQL* - database is spatial (space correspondent is based on geographic coordinates between the information in the database and maps).
- *BDUST* - Database is non-spatial (there is no spatial correspondence between information in the database and maps that are intended to be made).
- *QuantumGIS-PostgreSQL* - Allows through specific GIS functions the translation of information from one source to another, without having the user enter information from the keyboard.
- *BDUST* - Do not allow translating data from other formats to default format, is input only from the keyboard.
- *QuantumGIS-PostgreSQL* - Allows import of many file types, import is possible on two levels, with vector or raster files (graphics information bring spatialized database
attributes) or by .bd file type (table information with attributes brings graphics information using geographic coordinates).

- **BDUST** - Do not allow the import.
- **QuantumGIS-PostgreSQL** - Is compatible with a variety of formats for the export operation, which makes the whole information "open" to other GIS software and thus available for integration into other systems.

- **BDUST** - Export data is only in a tabular form as reports.

Presenting the advantages of the model proposed in the paper and analyzing the differences between the proposed model and computed software currently used in the calculation evaluation notes (BDUST) we concluded that the work has managed to implement national ICPA model for agricultural land evaluation and the model developed in GIS platform QuantumGIS - PostgreSQL is certainly functional and useful in agricultural land evaluation.