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# BDUST – THE DATABASE OF THE AGRICULTURAL SOIL-LAND UNITS AT LARGE SCALE OF ROMANIA: BASIC CONCEPTS

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## Abstract

BDUST aims at the management - at the national, district and commune (sub-district) level - of the data that characterize at large-scale the agricultural soil/land of Romania. It is hierarchically organized on soil survey works, communes and districts. The data content is determined by use requirements at different levels (national, district, commune, farm) and by European compatibility. There were taken into account the data requirements of the land suitability and capability evaluation models, but also of some simulation models of soil processes and crop yields. The soil/land characteristics are defined according to the existing Romanian soil survey methodologies which are completed with some specifications, extensions and new concepts. The elementary spatial entity is the land mapping unit (UT), yielded from the superposition of three spatial layers/entities: climatically homogeneous area (ACO) – a subdivision of a pedo-geo-climatic microzone area, soil unit (US) and "ecologically" homogeneous territory (TEO), so that a UT is completely characterized by the triplet ACO-US-TEO. There were defined also complex spatial units (associations of simple units that can not be represented on maps): complex USs and complex UTs (pseudo-complex, simple-complex, associative double-complex and dissociative double-complex), which are compounds of simple USs and/or TEOs – either possibly "actual" or "fictive". The existing soil profiles are pointed to the corresponding UTs (USs). Primary (input) data are validated and some of possible lost data and other necessary data are determined from primary data. A large set of user-reports (processing's) are provided: land evaluations at UT-level (land rating marks, quality/suitability/capability classes, requirements of land improvement and agro-pedo-ameliorative works), descriptive formulae of US's and capability units, decoding of formulae, and a set of synthetic data of land evaluation and characterization at commune level.

**Key words:** agricultural land characterization, land databases, spatial data structures, climatically homogeneous area, soil unit, land unit, complex land unit, agricultural land evaluation, agricultural land capability, agricultural land improvement requirements.

## Introduction

The present management of agricultural land raises a great diversity of problems: land use planning, crop technologies, land improvement/ reclamation works, soil conservation, environmental impacts, application of land legislation etc. The decisions in such problems need a great diversity of land/soil characterisation data, appropriately organized in databases. For this reason in Romania the Law nr. 144/2002 established the updating of soil surveys and building of the Database of agricultural soil-land units at large scale (BDUST) to store the obtained data.

This database continues the previous related achievements in Romania (Vlad et al., 1997; Marian et al., 1997; Tapalagă et al., 1997; Răuţă et al., 1998; Vintilă et al., 2004) and, in the same time, it is resonant with the recent increasing international undertakings for updating and extending of soil/land databases (JRC, 2010; EC, 2010; USDA, 2010; ISRIC, 2010; Keay et al., 2008; etc.).

The paper presents the objectives and requirements of the BDUST database, its data content and the criteria used to establish this content, the necessary extensions of existing soil methodologies, the data structures, the functions provided by database software and the future development.

## OBJECTIVES AND REQUIREMENTS OF BDUST

Firstly, the objectives of the database were established: to manage the data at national, district and commune level (data entry, validation and retrieval) and to process the data for supporting the soil survey report elaboration (detailed characterisation of land at the 1:10000 – 1:5000 scales) and for providing with syntheses at different levels; to respond to the present user requirements, including European Union initiatives, and to be easily adapted to the future requirements; to be user-friendly, not-requesting special IT knowledge and not-requesting other software acquisition.

Then, the general requirements of the database were identified: requirements of the Ministry of Agriculture, Food and Forests (MAAP), which were included into the Order nr. 223/2002 of the MAAP (MAAP, 2002); requirements of Ministry of Environment, National Statistics Institute and European Commission; other present and future requirements (e.g. farm requirements); application of existing methodologies (Florea et al., 1987; Florea and Munteanu, 2003; Munteanu and Florea, 2009).

The analysis of requirements concluded the necessity to extend the existing methodologies, establishing three documents that were elaborated: Unitary Methodology of BDUST, Data Content Specifications of BDUST and Data Input Forms of BDUST.

Also, the database was divided into two sections: BDUST-B (Basic data, characteristics at soil-land unit level) and BDUST-S (Synthetic data at commune, district and national levels).

## CRITERIA FOR ESTABLISHING THE BDUST DATA CONTENT AND DATA FORMAT

To establish the data content of the BDUST database, three basic requirements were taken into account:

(1) the data requested by the methods/models and algorithms used for data processing and interpretation to respond to the user current requirements (Florea et al., 1987; Vlad, 2001; MAAP, 2002): evaluation of land suitability for the main crops and agricultural land-uses, evaluation of land capability for the main agricultural land-uses and elaboration of the different specific reports requested by the soil survey regulations;

(2) the data requested by other future possible data processing's for different users, especially based on some simulation models of soil processes and crop yields (Vlad, 2001): ROIMPEL (Audsley et al., 2006), STICS, WOFOST (Supit et al., 1994), EPIC and others;

(3) other data requested by different decision support systems for sustainable land management (Vlad, 2001, 2002, 2003, 2004, 2005).

Regarding establishing the data format, some principles were used:

(a) utilization of numbers as codes for different soil/land characteristics and indicators, in order to decrease the risk of user operating error and to increase the storage/processing efficiency;

(b) utilization, where possible, the values of data instead of classes of values, in order to easily and more accurately use of data when different (existing or future) methodologies are applied, or in the cases of model modifications, as well as in order to eliminate the codifying work and the error risks of class setting;

(c) utilization of pedo-transfer functions to determine the possible derived data, in order to minimize the number of primary data that are to be prepared by soil surveyors and to eliminate the work and error risks of user calculations and estimations;

(d) including some redundant data, especially if they are possibly easily measured and more accurately obtained than by using pedo-transfer functions, as well as for use in the cases of some missing data;

(e) introducing new indicators (not used in the existing methodologies), considered necessary for future database use;

(f) storing of some derived data (calculated by definitions or estimated by pedo-transfer functions), important or frequently used, in order to increase the processing efficiency.

## BDUST DATA STRUCTURES

A hierarchy of four territorial levels are used to refer or aggregate the data: (i) national, (ii) district, (iii) commune (commune, town, municipality) and (iv) soil survey work (may be one or more soil survey works in a commune, each referring to the whole or a part of commune territory). The data are basically referred and managed at the commune level.

The basic spatial structures of soil-land characterisation data used in the BDUST-B database are designed to be properly used in a future GIS containing the digitized soil survey maps, where these spatial structures are identified by the same unique keys. Five hierarchical nested spatial/ mapping structures, seen as GIS layers, are used (Florea et al., 1987, 1999; Vlad, 2001): (1) UT (Land Unit; elementary spatial/mapping unit for land characterization and management), (2) US (Soil Unit), (3) ACO (Climatically Homogenous Areal, a new defined spatial object for BDUST), (4) MzPC (Pedo-Geo-Climatic Microzone) and (5) AMzPC (Areal of MzPC).

It is to note that the "land" is seen as a larger concept - it includes soil, but also climate, relief and hydrology (groundwater and surface water) – and the "soil" concept refers only to soil/sub-soil parameters in the strict sense (Vlad, 2001). Consequently, a UT is informationally seen as resulting from the superposing of three information layers: ACO (climatic characteristics), US (soil/sub-soil characteristics) and TEO (Ecologically Homogenous Territory - "ecologically" means in this paper that regards the terrain/relief/ landform and hydrology characteristics). So, by definition, a UT is completely characterized by the triplet TEO-US-ACO. Also, a TEO is, by definition, entirely included (spatially) into a single US and into a single ACO, so that the resulting UT is identical as spatial object with the TEO component and they both are referred by the same unique key (code).

The UTs/TEOs and USs are defined (identified by sequential numbers) at commune level and ACOs at district level. The MzPCs/AMzPCs are defined at national level and are used for medium-small scale applications (Florea et al., 1999). The TEOs, USs and ACOs (and, consequently, the UT) are considered homogenous (with an acceptable variation) regarding the considered characteristics, at the detail level to be used in land evaluation (suitability/capability) at large scale (> 1:10000).

An ACO or an AMzPC is each a single zone/area spatially contiguous ("areals"). A UT/TEO or a US refers each to all the same areals (with the same land, respectively soil characteristics) possibly existing into that respective commune. An MzPC refers to all the same (as pedo-geo-climatic characteristics) possibly existing AMzPCs in the country.

The climatic data (ACO) are defined as multi-annual (minimum 30 years) average values of climatic parameters. An ACO is entirely included (spatially) into an AMzPC and an AMzPC may contain one or more different ACOs. The coordinates of longitude and latitude at second (base 60) level of the ACO median centre are given, in order to have the possibility to estimate the amount of local radiation.

The land and soil units, in some cases, may be so complex that even at larger scales this complexity can not be represented on maps. For these cases in BDUST it is possible to define "Complex UT" (UTC) – containing "Complex US" (USC) or/and "Complex TEO" (TEOC). A USC is defined as a structure/association of maximum four simple USs which have distinct characteristics and that are not delineated on map and, similarly, a TEOC is defined as a structure/association of maximum four simple TEOs which have distinct characteristics and that are not delineated on map.

The simple USs or TEOs, components of USCs, respectively TEOCs, may be or not-be delineated on map in other commune's zones. In first cases the simple USs/TEOs are actual mapping units in those zones and in the last cases they are called "fictive". In both cases, the respective USCs and UTC (TEOC) are actual mapping units represented on map. For each complex unit (USC or TEOC) the total area of each component simple unit is specified as percent of the whole area of the complex unit.

In a US (simple or complex) one or more TEOs (simple or complex) may be defined and a TEOC may belong to a single US (simple or complex) and to a single ACO (which, by definition, may be simple only).

By combining simple or complex USs with simple or complex TEOs five types and sub-types of land mapping units (UT) may result:

- "Simple" UT – formed by a simple TEO placed in a simple US;
- "Pseudo-Complex" UT – formed by a simple TEO placed in a complex US;
- "Simple-Complex" UT – formed by a complex TEO placed in a simple US;
- "Double-Complex" UT – formed by a complex TEO placed in a complex US; A double-complex UT may be:
  - "Associative Double-Complex" UT – when to each simple TEO (component of the TEOC) a certain simple US (component of the USC) is associated, and the number of the simple USs components of the USC is equal with the number of the simple TEOs components of the TEOC;
  - "Dissociative Double-Complex" UT – when there is no regular association between the simple USs components of the USC and the simple TEOs components of the TEOC (the number of the simple USs components of the USC must not necessarily be equal with the number of the simple TEOs components of the TEOC).

The BDUST-B database is linked with the Database of soil profiles PROFISOL (Vlad et al., 1997) by the soil profile codes (sequential numbers in commune). The soil profile is referred to the UT it belongs and its coordinates of longitude and latitude at centi-second (base 60) level are given also. There is specified the type of soil profile: with/without analyses, (non-) representative for US/TEO, (not-) belonging to the soil monitoring network of level 1 or 2.

## DATA CONTENT OF THE BDUST DATABASE

The main data of the BDUST-B section (Basic data) are organized into eight data sets (tables of spatial unit/structure attributes):

(1) 14 data on soil survey works (surveyed area, UT sequence, survey type, survey period, scale, responsible);

(2) 26 data on ACOs (MzPC/AMzPC links, meteorological station link, annual averages of main climatic parameters, latitude/longitude coordinates of the ACO median centre);

(3) 67 data on USs (area, soil types/subtypes, physical and chemical characteristics of the top-soil horizon and sub-soil section, parent material, anthropogenic impacts);

(4) 66 data on UTs/TEOs (US/ACO links, areas by land uses, relief/landform and hydrology characteristics, special land cover indicators, land improvement/amelioration works, soil survey work);

(5) 10 data on soil profiles (PROFISOL link, TEO link, soil profile type, latitude/longitude coordinates);

(6) 13 data on complex soil units (area, structure of USCs);

(7) 23 data on UTCs/TEOCs (US/ACO links, areas by land uses, UTC type, structure of TEOCs);

(8) 46 synthetic (computer aggregated) data at commune level: areas by land uses and quality classes and mean (weighting) natural suitability rating marks and classes for the main land uses and for overall agricultural use.

The basic spatial unit (ACO, US, TEO) characteristics and soil types/subtypes are mainly defined according to the existing methodologies: Soil survey methodology (Florea et al., 1987), Romanian Soil Taxonomy System (Florea and Munteanu, 2003), Soil survey content (MAAP, 2002) and Guide for soil-land description in field (Munteanu and Florea, 2009).

Some new statements and extensions to these methodologies – especially regarding the data format, missing statements and option selection - and some new characteristics/indicators were necessary to be defined, such as:

- potential evapo-transpiration (annually cumulative, not-corrected and corrected by soil permeability and land slope and exposure to sun);
- variability risk of annual hydro-climatic balance (average of percent of standard deviation of the last minimum 30 years surveyed period);
- probability of negative meteorological events (percent of number of years with major negative meteorological events - that cause yield decrease to more than half - of the last minimum 30 years surveyed period);
- degree of land cover with different land use obstacles, such as stones and reeds;
- existence/ non-existence of each of 11 main well-defined land improvement and agro-pedo-amelioration works;
- degree of accuracy of data, regarding each basic spatial unit (ACO, US, TEO; five classes depending on how the data are measured or estimated);
- "memo" field for each instance of the database spatial units or entities, where the soil surveyor may store different useful notes.

The data of the BDUST-S section (Synthetic data) are organized into data sets (tables) containing synthetic data regarding the four main land uses - arable, orchards, vineyards and grasslands (pastures and hay-fields) - at the commune level:

- general data (total agricultural area, land use areas, date of soil survey, soil surveyor);
- mean (weighting) quality classes and mean (weighting) natural suitability rating marks for the main land uses and for overall agricultural use;
- land areas of the land quality classes and land capability classes for the main land uses and for overall agricultural use;
- land areas of the soil types, main landforms, AMzPC and protected natural zones;
- land areas of the classes of the main land degradations/deficiencies (landslides, flood hazard, groundwater and surface water gleying, wind and water soil erosion, gully soil erosion, anthropogenic land covering);
- land areas of soil pollution types and of classes of agro-chemical soil qualities/deficiencies (acidity/sodicity, humus content, N-index, available P content, available K content);
- description nomenclators for soil pollution types, pedo-geo-climatic microzones and protected natural zones.

## DATA PROCESSING. THE "EXPERT" SYSTEM FOR SOIL SURVEY SUPPORT

The software developed for the BDUST database provides soil surveyors with all the functions necessary to elaborate the soil survey documentation, thus becoming a true soil-land "expert" system:

- user friendly interface with soil surveyors;
- primary data entry/updating and storing;
- retrieval and visual presentation of primary and stored data;
- validation and correlation of primary data and providing user with error messages (real-time message display and print of overall error list); three types of data validation are implemented: format/value validation at individual data item (field) level, correlations at data set (spatial unit) level and correlations at the whole database level;
- calculating (by definition) and estimation (by pedo-transfer functions) of many derived data and possibly missing data;
- determining of natural suitability rating marks for the 24 crops and the four main land uses and of capability classes for the four main land uses at UT/UTC level;

- database saving;
- other data processing;
- elaboration and presentation (visual and printing) of the 46 user reports:
  - listing of primary data;
  - map legend with US formulae at US level and evaluation indicators at UT level, and their decoding table;
  - natural suitability rating marks for the 24 crops and the four main land uses, quality classes (five degrees) for the five main land uses (arable, orchards, vineyards, pastures and hay-fields) and suitability classes (10 degrees) for the 14 crops and five main land uses, at UT/UTC level;
  - capability classes (six degrees), formulae of capability units and requirements of land improvements and agro-pedo-ameliorations for the four main land uses at UT/UTC level, and formulae decoding table;
  - determining of synthetic data aggregated at commune level - above mentioned as data content of the BDUST-S section - and almost all of them at district and national level.

The main data processing's were implemented according to the models and algorithms described by Florea et al. (1987) and Vlad (2001). Many of these were developed with some new statements and extensions to be improved, to solve some missing decisions or to respond to new requirements. They mainly refer to primary data validation and correlation, land suitability and capability evaluation, establishing of requirements of land improvements and agro-pedo-ameliorations for the four main land uses, extension of soil unit and capability unit formulae, processing of complex soil unit (USC) and complex land unit (UTC/TEOC) data etc.

The US/USC formula (Florea and Munteanu, 2003) was extended as a mathematical fraction having as "numerator" the soil types/subtypes and value classes of soil characteristics (in two rows to accommodate to the print space in the case of long formulae) and as "denominator" the characteristic value classes of the TEOs/TEOCs belonging to the US/USC, according to Florea et al. (1987). Each US/USC/TEO/TEOC characteristic is identified by a symbol letter. A generic example of such a formula for a simple soil unit (US) is the following:

CZpsvska
XcaX42XvmG3W2S2A1k5d6-lq2/tq3-Temq/KM-PsNtqmE23Pcds3
-------------------------------------------------------------------------------
M:L-OO:SJ-vf:ca P01:99-1:5 Z1:8-X1:8 r11:92 f11:63 Q1:8 I1:3

where the symbol ":" is used to specify an interval of values (existing in the cases of more TEOs/TEOCs that belong to the US/USC). In the cases of complex soil units (USC), all existing soil types/subtypes of the component simple USs are given sequentially in the first row of the "numerator" and, the same, the intervals of values are specified using the symbol ":".

The land capability classes for the complex land units (UTC) are determined by the maximum limitation given by anyone of the characteristics of the ACO, simple USs and simple TEOs – components of the USC, respective TEOC, that define the UTC.

Also, in the cases of complex land units (UTC), in the capability unit formulae all soil types (if more) are sequentially given, as well as the intervals of values (using the symbol ":") of limitations defining the capability groups and of indicators defining capability subgroups – determined by the corresponding characteristics of the ACO, simple USs and simple TEOs – components of the USC, respective TEOC, that define the UTC.

A generic example of such a formula for a complex land unit (UTC) is the following:

IV - TS1, TS2, ... - L1G 3:4 L2G 2:3 ... _ I1sg 2:6 I2sg 1:4 ...

where:

IV is the capability class of the UTC;

TS1, TS2, ... are the soil types of the simple USs – components of the USC / UTC;

L1G 3:4, L2G 2:3, ... are intervals of ranks of capability groups defined by the limitations L1G, L2G etc.

I1sg 2:6, I2sg 1:4, ... are intervals of ranks of capability subgroups defined by the indicators I1sg, I2sg etc.,

where L1G, L2G, ..., l1sg, l2sg ... are symbol letters for group limitations (in capitals), respective for subgroup indicators (in small letters).

To establish the requirements of land improvements and agro-pedo-ameliorations for the four main land uses for a complex land unit (UTC), the same rules are applied: all requirements determined by all characteristics of the ACO, simple USs and simple TEOs – components of the USC, respective TEOC, that define the UTC – are specified.

For determination of different synthetic data by value classes in the cases of complex land units (UTC), the percent areas of the simple USs and simple TEOs – components of the USC, respective TEOC, that define the UTC – are taken into account.

Regarding the algorithms for establishing of requirements of land improvements and agro-pedo-ameliorations for the four main land uses, two examples of improvements are noted hereafter:

- the requirement of irrigation is recommended if the following conditions are simultaneously accomplished: the soil moisture deficit class is ≥ 3 and the land slope class is < 5% and the sheet erosion hazard (water and wind) is ≤ 8 t/ha/an and the landform is different than mountain;
- the requirement of soil deep loosening is recommended if the following conditions are simultaneously accomplished: the soil compaction degree (above 75 cm) is > 0 and the groundwater level depth is > 150 cm and the land slope class is ≤ 10% and the surface waterlogging hazard class is ≤ 3.

## CONCLUDING REMARKS

- It is advantageous for analysis and design of complex soil-land databases to use a hybrid system approach (top-down approach together with bottom-up approach); A database conception based on a nested hierarchical structure is useful also; The land mapping units may advantageously be seen as three informational layers: climate, soil-subsoil and terrain-hydrology; A system of complex soil units and complex land/terrain units (soils/terrain/land typological unit associations) carefully designed are necessary even for soil-land databases at larger scales;

- It is advantageous for development and implementation of a complex soil-land database to use an adaptive-evolutionary (prototype) approach: firstly a basic prototype of system is build as an "open-flexible system" (easily to be modified) having the most important functions implemented and made operational and then it is progressively tested and validated by end-users and "on going" modified and developed by adding new functions. Consequently, it is rapidly adapted to user requirements and the initial uncertainties and use emergencies are more easily solved;

- In an adaptive-evolutionary approach it is important to carefully manage (keep under control) the evolution of modifications and extensions from a system version to another, especially by frequent documentation revisions and updating notes (newsletters) disseminated to users;

- The present status of the BDUST database implementation provides soil surveyors with all functions necessary to elaborate a complete soil survey documentation, thus becoming a true soil-land “expert” system;

- Some new functions are seen to be implemented in the near future to develop the BDUST database: improving of the existing decision algorithms for present land use change, elaboration of syntheses of land improvement/amelioration work requirements and of present land use change requirements at commune level, elaboration of recommendations at land parcel level, elaboration of syntheses al farm level, "help" and explanation functions for users, functions for synthetic data "export" (transfer) from BDUST-B section to BDUST-S section, digitising of soil survey maps and upgrading of the BDUST database to a geographical information system of soil-land at large scale in compliance with the INSPIRE methodology (EC, 2010; Keay et al., 2008).


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# BDUST – BAZA DE DATE A UNITĂŢILOR DE SOL-TEREN AGRICOL LA SCARĂ MARE DIN ROMÂNIA: CONCEPTE DE BAZĂ


## Rezumat

BDUST este destinată gestiunii la nivel naţional, judeţean şi comunal a datelor de caracterizare la scară mare a solului/terenului agricol din România, fiind organizată ierarhic pe lucrări de cartare, comune şi judeţe. Conţinutul de date a fost impus de cerinţele de utilizare la diferite niveluri (naţional, judeţean, comunal, fermă) şi de compatibilitate la nivel european. S-au avut în vedere cerinţele de date ale modelelor de bonitare şi de evaluare a pretabilităţii terenurilor agricole, dar şi ale unor modele de simulare a proceselor din sol şi a formării recoltelor. Caracteristicile solului/terenului sunt definite de metodologiile existente completate cu unele precizări, extensii şi concepte noi. Entitatea elementară este unitatea de teren (UT), rezultată din suprapunerea a trei straturi/entităţi spaţiale: arealul climatic omogen (ACO) – o subdiviziune a arealului de microzonă pedoclimatică, unitatea de sol (US) şi teritoriul "ecologic" omogen (TEO), astfel că o UT este caracterizată complet de tripleta ACO-US-TEO. Au fost definite şi unităţi complexe (asociaţii de unităţi simple nereprezentabile pe hartă): US complexe şi UT complexe (pseudo-complexe, simplu-complexe, dublu-complexe asociate şi dublu-complexe disociate), având în componenţă US şi/sau TEO simple – ambele "reale" sau "fictive". Profilele de sol executate sunt localizate în UT (indirect în US) corespunzătoare. Datele primare sunt validate şi unele date posibil lipsă şi alte date necesare se determină din cele primare. Un set larg de prelucrări/rapoarte pentru utilizator sunt furnizate: evaluări la nivel de UT (note de bonitare, clase de calitate, favorabilitate şi pretabilitate, cerinţe de lucrări agropedoameliorative şi de îmbunătăţiri funciare), formule de descriere a US şi a unităţilor de pretabilitate, decodificarea formulelor, precum şi o serie de date sintetice de evaluare şi caracterizare la nivel de comună.


**Cuvinte cheie:** caracterizarea terenurilor agricole, baze de date pedologice, structuri de date spaţiale, areale climatic omogene, unităţi de sol, unităţi de teren, unităţi de teren complexe, bonitarea terenurilor agricole, pretabilitatea terenurilor agricole, cerinţe de ameliorare a terenurilor agricole.