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ROMANIAN'S FOREST SOILS GIS MAP AND DATABASE AND THEIR ECOLOGICAL IMPLICATIONS

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Abstract: Designing digital maps concerning forest soils constitutes a necessity both worldwide as well as at a national level. Presently there are many maps of these kind and geographic informatics systems (SOTER, EUSIS, LUCC). Among these can be found SIGSTAR 200, a system realized by the Pedological Research and Studies Institute ICPA Bucharest. The GIS forest soil map was realized starting from this system (by demarcating the soils that appear in the national forest fund). The soil variants were grouped in a number of 32 soil types and subtypes in accordance with Romania's Soil Taxonomy System (SRTS 2003). Improvements were brought to the map by using the pedological database of the Forest Research and Management Institute (ICAS) (2665 soil profiles realized in the last 5 years within the National Forest Inventory) and the GIS maps of Romania's geology and ecosystems. The superposition of the limits of forest districts and the production unities over the soil map allows a geographical disposition of soils within the administrative borders of our forest fund. Based on their repartition, the most important forest soils are the following: dystric cambosol, haplic luvosol and eutric cambosol, followed by entic podzol, preluvosol and dystric fluvisol. Significant differences were registered between the national soil distribution and the one from the forest fund: larger distributions at the national level for haplic phaeozem, chernozem and dystric fluvisols than in forests and the other way around, larger participation repartitions for forest dystric cambosol and haplic luvosol in comparison with the country's average. The utility of this map, together with the afferent databases, can be observed in the forest management activity, for different national or international reports, in realizing other maps and databases, or in other economical or scientific activities.

Keywords: Forest soils, GIS map, soil database, erosion, forest management.

1.INTRODUCTION

Pedology, as the science of soil, is officially attested in the year 1906, when, within the Geological Institute administered by the renowned geologist Ludovic Mrazec, an agro-geological section is founded and administered by the young geologist and pedologist Gheorghe Munteanu Murgoci. In the establishment law from the Agricultural, Industry and Commerce Ministry of Romania's Geological Institute, which appeared in 1906, it is mentioned that "the purpose of the Geological Institution is the study of Romania's soil and subsoil. The Institute will realize the geological and agro-geological map of Romania (pedological map, in today's terms) by taking into consideration all the country's economical requests. In the study of the soil, the agricultural and silvicultural requests are primarily taken into consideration. The agro-geological findings will allow a rational classification of the arable fields and of their lengthiness." (Munteanu, 2006).

Starting from these requests imposed through law, Gheorghe Munteanu Murgoci, together with Emanoil Protopopescu Pache and Petre Enculescu accomplished, in only 3 years, the map of Romania's Kingdom soils at a scale of 1: 2500500 (Munteanu, 2008). The map was presented at the Agro-geological Conference in Budapest in the year 1909. Subsequently, in 1927, another map of Romania's soils is realized at a scale of 1: 500000. For many decades, this map constituted the only source of information concerning Romania's soils (Munteanu, 2008).

A new stage in the development of the soil science is reached in 1970 through the establishment of the Pedological Research and Studies Institute. Nowadays, Romania is among the few countries that have a general map of soils at a scale of 1: 200000, a task that started in 1963 and was finalized in 1994.

The Geographical Informatic System of Romania's Soil Resources, known as SIGSTAR-200 (Vintilă, et al., 2004), was elaborated at Pedological Research and Studies Institute Bucharest based on the information contained in the 50 pages of maps that constitute "Romania's Soils map at the scale of 1:200000". This map was published in the period 1963-1994 and the legend's structure reflects the evolution of the pedological taxonomy (ICPA-Metadata afferent to SIGSTAR-2000 data set).

From an informatic point of view, SIGSTAR-200 was realized with the help of Arc/Info (ESRI, 1995) and GRASS (1999) software. Nowadays, the database is sustained both in a SIG Arc/Info vector graphic format as well as in a standard exchange format (named „e00"), so that they can be compatible with other types of SIG. The hardware configurations on which SIGSTAR-200 was developed consisted of a network of high performance computers and different peripheral equipments: digitizer, scanner, plotter and printer. Starting with the year 2000, this configuration was improved with GPS devices that are compulsive in field placement within the cartographic studies. The cartographic information was transformed in Gauss-Krüger coordinates and stereo `70, on Krasovsky 1940 ellipsoid, datum Pulkovo 1942. (Vintilă et al., 2004).

If the study of agricultural soils is the purpose of the Pedological Research and Studies Institute, through County Offices of Pedological Studies, the study and monitoring of forest soils is accomplished by the Forest Research and Management Institute (ICAS). Until now, ICAS has realized the GIS map of Romania's forest ecosystems (2008).

In Romania, Dincă et al., (2012) have realized a GIS map of the organic carbon stock from forest soils and Muraru et al., (2009) made maps of agricultural soil properties based on data collected in real time from the ground, by using geo-spatial coordinates provided by the Global Positioning System (GPS).

The demand for relevant and updated soil information is increasing. Soil science researchers are being demanded to produce information in different spatial resolutions with associated quality in what is being called Digital Soil Mapping (DSM) (Caten, et al., 2012). In recent decades the soil science community has made great efforts to develop regional and global soil and terrain databases (Mulder et al., 2011).

Some examples of soil databases with a continental scale are: the Harmonized World Soil Database at a scale of 1:5 M (million) developed by FAO-UNESCO (FAO et al., 2008); The European Soil Database at a scale of 1:1 M, which is part of the European Soil Information System — EUSIS (Le Bas et al., 1998). The latter is the product of a collaborative project involving the European Union and neighbouring countries, and has been active for the past 20 years (King et al., 1994). Furthermore, the latest version of the European Soil Database (v2.0), which includes an extended geometric component 'The Soil Geographical Database of Eurasia' (Lambert et al., 2002), also covers the Russian Federation, Belarus, Moldova and Ukraine (Morvan et al., 2008); The Soil and Terrain Digital Database (SOTER), which incorporates quantitative information on soils and terrain at scales of 1:1 M and 1:5 M (Oldeman & van Engelen, 1993); SOTER database for different parts of Africa, at a scale of 1:2 M (Dijkshoorn, 2003 and van Engelen et al., 2006) and the SOTER database for Latin America and the Caribbean at a scale of 1:5 M (Dijkshoorn et al., 2005).

There are many national soil databases such as the American Web Soil Survey (WSS) (Soil Survey Staff, 2010a) and the Soil Survey Geographic Data Base (SSURGO) from the Natural Resources Conservation Service (NRCS) (Soil Survey Staff, 2010b); the Australian Soil Resource Information System (ASRIS) from CSIRO Australia (CSIRO, 2010); Available from the Agriculture and Agri-Food Canada: the Canadian Soil Information System (CANSIS) and the National Soil Database (NSDB) of Canada (AAFC, 2010); and the Russian Soil map at a scale of 1:2.5 M (Stolbovoi & McCallum, 2002). For an extended inventory of available soil databases see Rossiter, 2004 and Nachtergaele, 1999.

The Geographical Informatics Systems (SIG) harvests, memorizes, proves, integrates, manages, analyzes and displays information concerning different areas from Earth. In such systems, information is processed through specific spatial analysis methods (Worboys, 1995) in order to produce statistic information necessary for the decision process (Vintilă et al., 2004).

In present times, three essential SIG's exist at an international level in the area of soil and fields (Vintilă et al., 2004):

- „SOTER – Global and National Soils and Terrain Digital Databases" (Van Engelen & Wen, 1995) was initiated in 1986 by the International Society for the Science of Soils and was methodologically conducted by the International Soil Reference and Information Centre (ISRIC). The system, nowadays finalized, had two main objectives: (1) creating a global SIG with information about soils and fields; (2) creating an information service about soils and fields, for the global and regional management of these resources.

- „EUSIS – European Soil Information System” (SAI, 1999) is a project still in process, coordinated by EU’s European Soil Bureau (ESB). This system is composed of: (1) a geographical database of Europe’s soils, at a scale of 1:1000000 („SGDBE”), as well as at a scale of 1:250000, still in process in some countries; (2) an analytical database of Europe’s soil profiles („SPADE”); (3) a database of Europe’s soils hydraulic properties („HYPRES”); (4) the knowledge base with pedo-transfer rules.

- „LUCC – Land Use and Land Cover Change” (IGBP/HDP, 1999) is a joint project of „International Geosphere-Biosphere Programme” (IGBP) and „International Human Dimensions Programme” (IHDP). LUCC has as main objective the thorough ongoing study of the effects produced by the changes of field covering and usage, including the relations with the global changes produced in the environment.

In Germany, based on the geomorphologic conditions, the relief is a major driving force in soil genesis. This is expressed by the digital-soil mapping research which highlights the great importance of digital terrain attributes in combination with information on parent material in soil prediction (Behrens & Scholten, 1996).

In Ecuador (Liess, et al., 2009) researchers have established that the major soil types of the researched area are Histosols associated with Stagnosols, Cambisols and Regosols. Umbrisols and Leptosols are present to a lesser degree. Stagnosols gains importance with an increasing altitude and with a decreasing slope angle. Umbrisols are to be found only on slopes <30 degrees. Cambisols occurrence might be related to landslides.

Many authors describe the application of modern technology and its role in soil mapping: computer science, geographic information systems, digital remote sensing, database management, and statistics (Kuhsla, 2006); geophysical tools such as global positioning systems (GPS), radar, electromagnetic induction, etc. (DeAnn, 2007); the generic framework, which we call the scorpan-SSPF method (soil spatial prediction function with spatially auto correlated errors)is particularly relevant for those places where soil resource information is limited (McBratneyet al., 2003); a method to update conventional soil maps using digital soil mapping techniques without additional field work (Yang et al., 2011); a methodology based on artificial neural networks (ANN) that is able to spatially predict soil units (Behrens et al., 2005); a cost-efficient methodology for digital soil mapping in poorly-accessible areas (Cambule et al., 2013); geostatistics descriptive tools such as semi-variograms to characterize the spatial pattern of continuous and categorical soil attributes (El-Sayed, 2012); diffuse reflectance spectroscopy as a tool for digital soil mapping (Brodsky, et al., 2011); single stage classification methods (Multiple Multinomial Logistic Regression and Bayes) and multiple stage classification methods (Classification and Regression Trees (CART), J48 and Logistic Model Trees (LMT) using geographic information system and terrain parameters (Coelho & Giasson, 2010); a geographical information system (GIS) or expert knowledge-based fuzzy soil inference scheme (soil-land inference model, SoLIM) (Zhu et al., 2001).

2. MATERIALS AND METHODS

The following steps were followed in order to realize Romania’s forest soils GIS map:

1. Romania’s soils GIS map realized by the Pedological Research and Studies Institute in the year 1994 was used as a starting point. This map was chosen because it was realized and periodically brought to date (the last version, from the year 2012 was used); the scale of the map is 1/200 000.

Over this map, the map of forest ecosystems realized by ICAS in the year 2008 was overlapped; the scale of this map is of 1/250000. Only the forest soils were demarcated by taking into consideration the forest’s outlines.

Over this last map, were overlapped the limits of forest districts and production unities that corresponded to the year 1989.

In this way, an initial map of Romania’s forest soils at a scale of 1/200000 was obtained. This map has a list of the name of soils from Romania’s System of Soil Classification (SRCS 1980).

2. The types, subtypes and varieties of soil were merged in types of soil corresponding to Romania’s Soil Taxonomy System (SRTS 2003).

Also, the soil names were transformed from SRCS to SRTS. From an initial number of 424 soil variants, only 32 have remained.

Specific colours were assigned to each type of soil; for example: black for andosol (the name of this soil comes from the Japanese language where „ando” means “soil that has a dark colour”), brown for chernozem, dark green for dystric cambosols, light green for eutric cambosol, dark blue for gleiosol, light blue for dystric fluvisol, red colours for red luvosol and yellow for dystric arenosol (Fig. 1).

3. A comparison was realised between the soil types identified during the National Conferences for the Science of Soil (Iași 2009, Craiova 2012) and the ones from the National Forest Inventory (2665soil profiles) with the ones from the GIS map. The soil types from the map were identified by knowing the coordinates of the places from where the soil profiles were extracted, through methods specific of ArcView programme.

In case of differences between the two identifications, Romania's geological GIS map (http://earth.unibuc.ro/download/harta-geologica-a-romaniei-scara-1-200-000) and the GIS forest ecosystem maps were consulted. The correct soil type was chosen based on the lithological substratum and the type of vegetation.

3. RESULTS

Based on the occupied surface, the most spread forest soils are dystric cambosol (2292385 ha), haplic luvosol (1440052 ha) and eutric cambosol (869909 ha), followed by entic podzol (447657 ha), preluvosol (335050 ha) and dystric fluvisol (330564 ha).

The solidification factors from the mountain forest area are represented by predominantly acid rocks, an uneven relief with altitudes that vary between 1000 m and 1700 m, a cold and humid climate and forest vegetation comprised of Norway spruce stands and mixtures of resinous with common beech. In these solidification conditions, the dominant type of soil is dystric cambosol, which occupies 35% from the forest fund surface, followed by entic podzols with 7%.

At hills, the solidification factors are represented by clays and loams, difficult permeable rocks, relatively flat relief or that has reduced pitches, with altitudes between 400 m and 800 m, relatively humid climate, with forest vegetation comprised of common beech stands, sessile oak stands and even oak stands. In these solidification conditions, the main soil type is luvosol, which occupies 22% from the forest fund surface. Preluvosols, fluvisols and chernozems can also be found in the case of low hills and fields, besides luvosol, and are occupying 11% from the surface of the forest fund.

4. DISCUSSION

4.1. Forest soil's map characteristics

It is argued that the quality of soil maps is specified by their "information capacity, completeness of the contents, reliability, adequacy to the current situation, geographic credibility, degree of detail, and visual clarity." (Simakova, 2011). We consider that these characteristics are ensured by our map.

The overlap of the forest districts limits and of the production units over the soil map allows a geographical placement of soils in the administrative territorial limits of our forest fund.

4.2. Spatial distribution of forest soils

By comparing the soil's participation percentage from the entire surface of our country with the one from the forest fund (Table 1), the following aspects can be observed:

The most striking differences with regard to soil class, are registered for Cernisols (27% for the entire country and only 6% for forest soils) and for Cambisols (24% per country and 48% in the forest fund). The explanation resides in the fact that, at a national level, Cernisols can be found (situated in the plain area), but these territories are occupied only on a small percentage by forests, while the Cambisols (spread in hill and low mountain areas) are mainly situated under forest.

As for the soil type, significant percentages are registered at national level in comparison with forest soils in the case of haplic phaeozems (16% per total, 3% in forests), chernozems (9% per total, 1% in forests), dystric fluvisols (12% per total, 5% in forests), while the forest soils have larger percentages in the case of dystric cambosols (14% per total, 35% in forests), haplic luvosols (16% per total, 22% in forests). The explication resides also in the very high degree of afforestation in the mountain area, high at hills and low at plains.

It can be observed, once more, that the main forest soils are dystric cambosol, haplic luvosol and eutric cambosol, while soils such as chernozems or haplic phaeozems are typical agricultural soils.

4.3. The utility of the forest soils map

Within the forest management activity, each forest district (in Romania there are approximately 300 forest districts with an average area of approximately 10000 ha) is covered once at 10 years and the main stand and environment characteristics are described (including the ones concerning forest soils). A number of soil profiles are located based on the relief (a minimum of 2 for mountains and hills and 1 for plains for each 1000 ha –Technical Norms for Forest Management nr. 5/2000, Ministry of Waters, Forests and Environment, 2000), from which soil samples are harvested and then analyzed in laboratory. Finally, the types of soil and forests stations are established and the best silvicultural measures are adopted.

Table 1. The areas occupied by the main soil types in Romania

Soil Type	Surface forest soils (ha)	Percentage forest soils	Total soil surface (ha)	Total soil percentage
Leptosols	43478	1	90029	-
Regosols	7279	-	19837	-
Arenosols	16988	-	161952	1
Fluvisols	330564	5	2707213	12
Total PROTISOLS	**398309**	**6**	**2979031**	**13**
Calcaro-calcic Kastanozems	9388	-	210514	1
Chernozems	46026	1	2129459	9
Phaeozems total	235282	3	3696516	16
Marnic Phaeozems	*32966*		*243915*	
Haplic Phaeozems	*5392*	-	*207894*	
Greic Phaeozems	*78233*		*476748*	
Clinogleic Phaeozems	*16616*		*138491*	
Cambic Phaeozems	*74712*		*2074961*	
Argic Phaeozems	*27363*		*554507*	
Rendzic leptosols	110751	2	208089	1
Total CERNISOLS	**401458**	**6**	**6244578**	**27**
Preluvosols total	335050	5	1673433	7
Haplic Preluvosols	*288542*		*1092492*	
Redish Preluvosols	*46508*		*580941*	
Luvosols total	1440052	22	3750955	16
Haplic luvosols	*1174711*		*2921323*	
Albic luvosols	*224743*		*636772*	
Redish luvosols	*40598*		*192860*	
Planosols	1057	-	8033	
Total LUVISOLS	**1776159**	**27**	**5432421**	**23**
Eutric Cambosols	869909	13	2346317	10
Eutric cambosols	*841476*		*2289900*	
Redish cambosols	*28433*		*56417*	
Dystric cambosols	2292385	35	3220295	14
Total CAMBISOLS	**3162294**	**48**	**5566612**	**24**
Entic podzols	447657	7	647686	3
Haplic podzols	38631	-	105386	-
Total SPODISOLS	**486288**	**7**	**753072**	**3**
Nigrosols	1651		5518	
Humic umbrisols	12161		8255	
Total UMBRISOLS	**13812**	**-**	**13773**	**-**
Andosols	176075	3	256240	1
Total ANDOSOLS	**176075**	**3**	**256240**	**1**
Vertisols	23419		340962	1
Total PELOSOLS	**23419**	**-**	**340962**	**1**
Gleysols	26843		731754	3
Stagnosols	15537		111400	1
Total STAGNOSOLS	**42380**	**1**	**843154**	**4**
Solonchaks	687		39751	-
Solonetz	909		145190	1
Total SALSODISOLS	**1596**	**-**	**184941**	**1**
Histosols	1967		11178	-
Total HISTOSOLS	**1967**	**-**	**11178**	**-**
Erodosols	126392	2	626424	3
Total ANTRISOLS	**126392**	**2**	**626424**	**3**
COUNTRY TOTAL	**6610149**	**100**	**23252386**	**100**

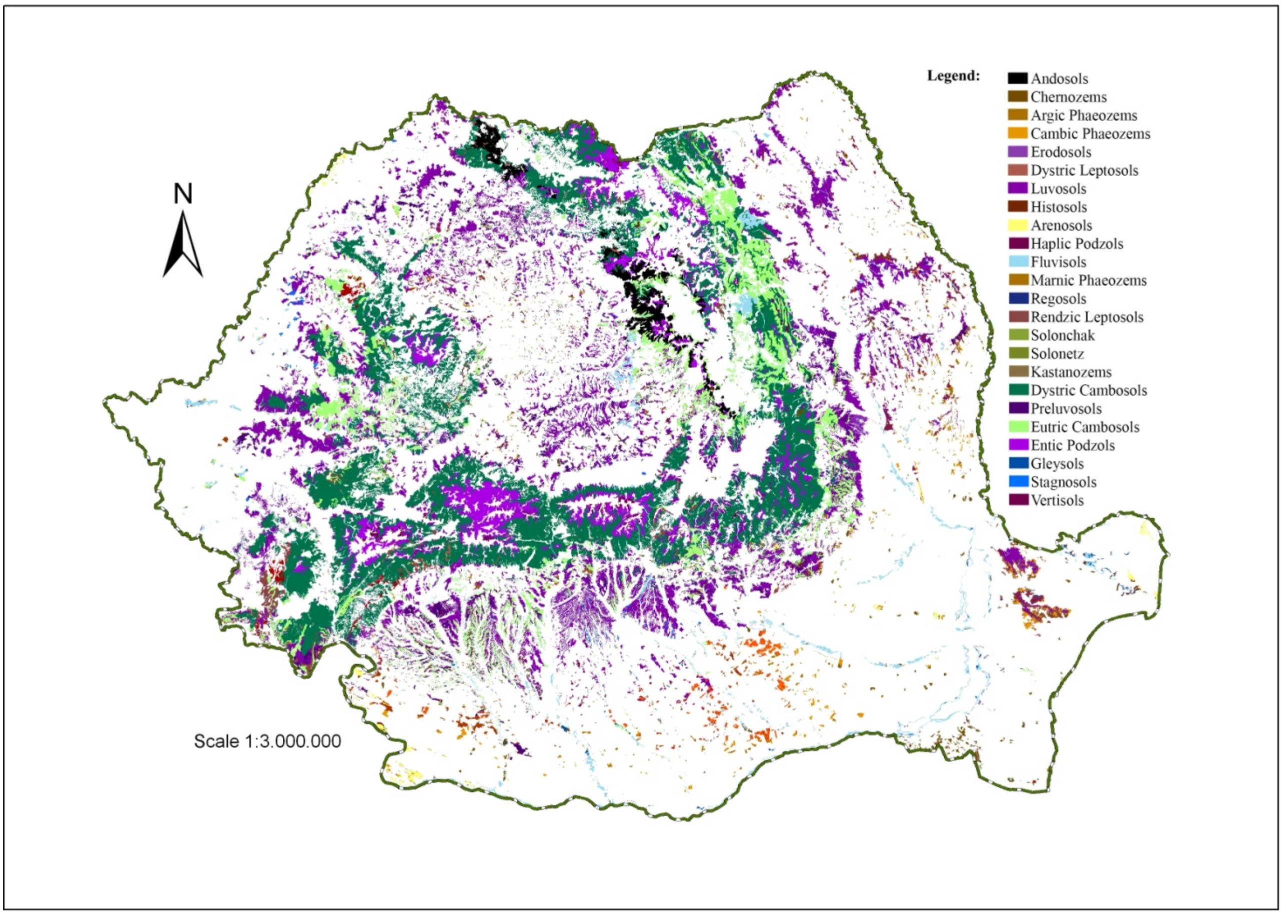

Figure 1. Romania’s forest soils map

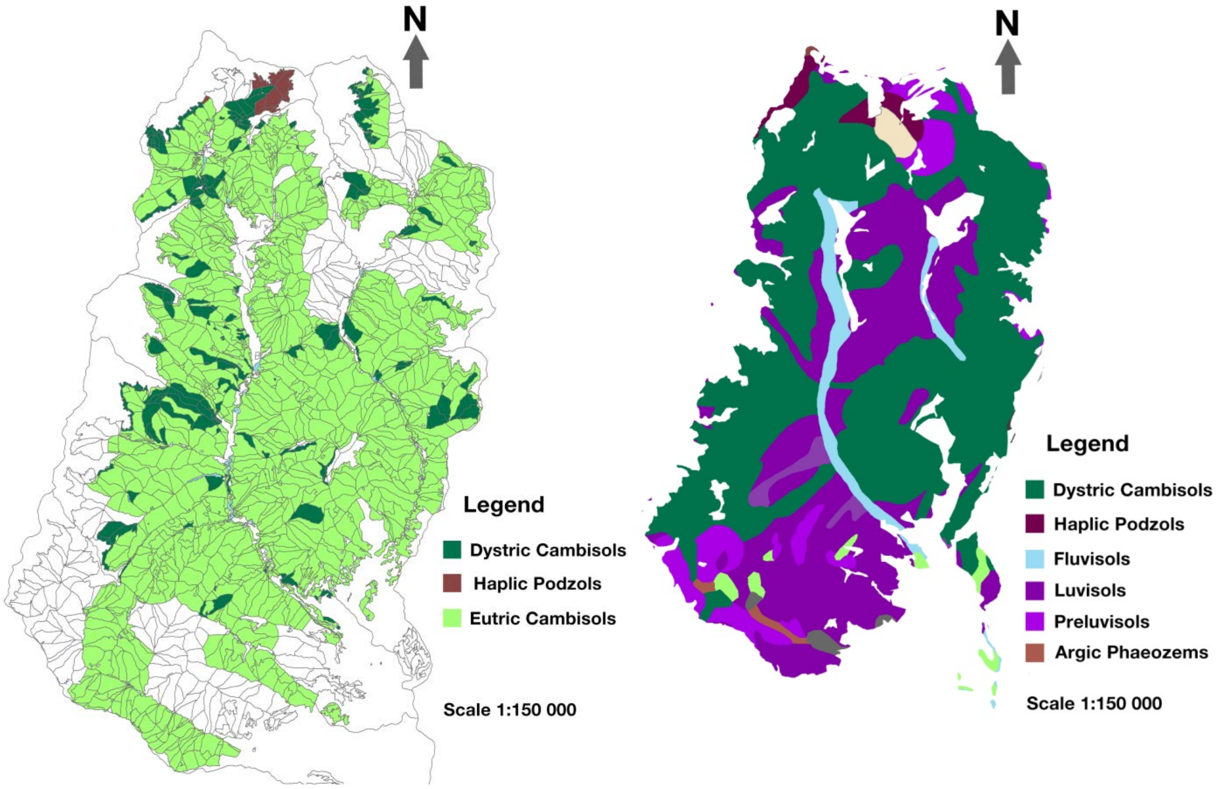

Figure 2. Măneciu forest district soils map. Left-from the forest management, right-new GIS map

Based on the present GIS map, the activity of forest management can be improved. For example:

-by studying this map before starting the field works, the soil profiles can be better placed (especially where special soils appear, such as rendzic leptosols or haplic phaeozems);

-special laboratory analyses can be accomplished (the pH in NaF in the case in which the andosol is presumed to exist, or soluble salts in the case that solonchaks exist).

-more accurate maps can be realized concerning the repartition of forest soils. In figure 2 significant differences between the present GIS map and the last management map from forest district Măneciu (in which many eutric cambosols appear in the detriment of dystric cambosols and the haplic luvosols are not present) can be observed. Furthermore, by designing Romania's GIS forest soils map, other significant benefits are obtained from the following point of views:

-a more precise situation exists nowadays regarding the areas that are occupied by different soil types in our forest fund: for example, in the year 2011 it was mandatory to report the area occupied by histosols in our country, in concordance with the obligations assumed as part of the United Nations Frame Convention for Climatic Changes (UNFCCC) and with the obligations assumed as part of the Kyoto Protocol (KP), within the project „Elaborating INEGES District, Land Usage, Changing Forest and Silvicultural Usages (LULUCF)". Based on former works, the area was estimated at 5000 ha (Târziu et al., 2004), or 5% from the total area of our country (Spârchez et al., 2011), when, in reality, based on the present GIS map, it is of 1967 ha.

-more realistic calculations can be realized concerning the organic carbon stocks from the litter and mineral soils of our country;

-the geographical repartition of different soil types is known, together with the consequences concerning the silvicultural or environment protection measures that have to be adopted;

-in order to accomplish feasibility studies and implementation projects in the hidro-technical constructions situated in the forest fund (dams for the correction of torrents, dams for the abstraction of drinking water etc.) it is mandatory to know the soils and the parental materials on which they are constituted;

-knowing the type of soil and its level of fertility is indispensible for the establishment of documentations that concern the extraction of some fields from the forest fund and for their comparison with the fields from outside the forest that have the same level of fertility;

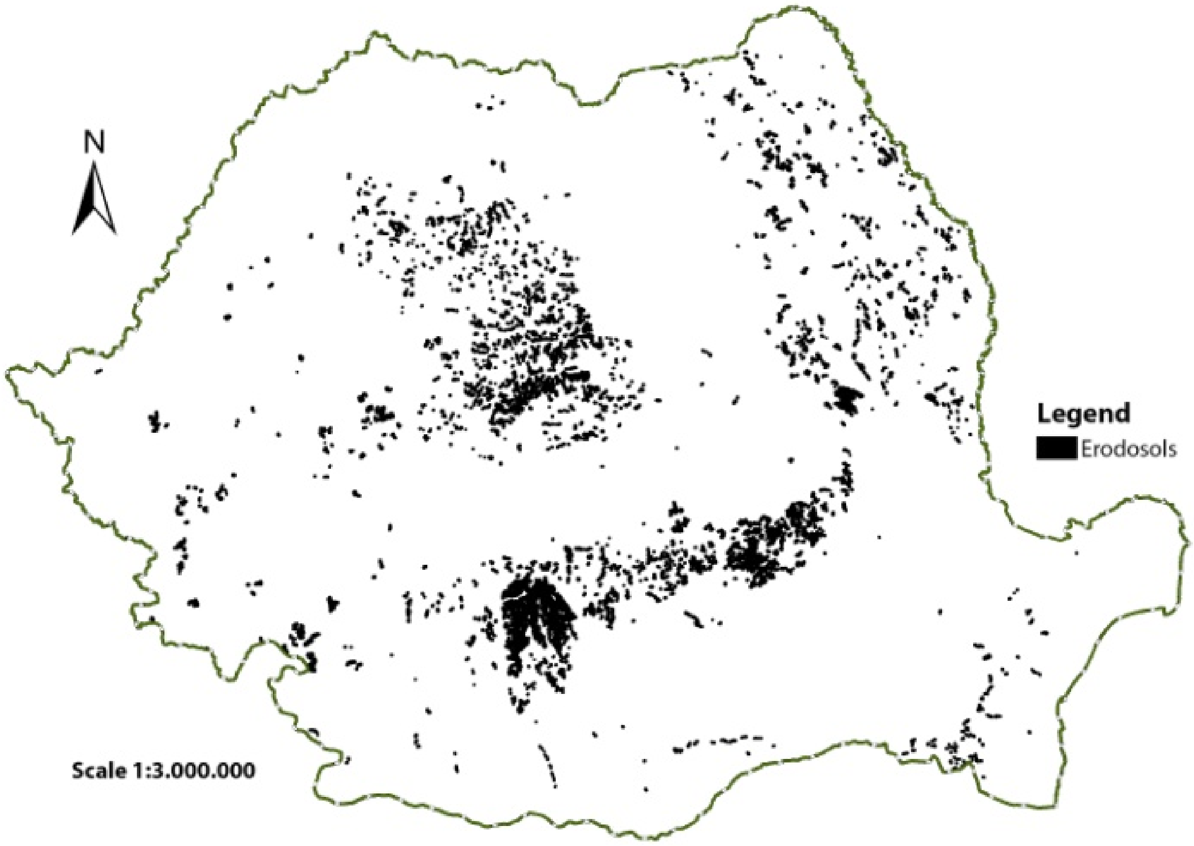

Figure 3. The spread of forest erodosols

-it represents a good support for different economical or research activities. For example: establishing the proper areas for developing and harvesting truffles (a mushroom species that is extremely valuable, that grows in the first 10 cm of soils with specific characteristics);

-the advantages mentioned by Behrens & Scholten, (2006) are also valid in the case of our country: ”Even in highly developed countries like Germany, digital soil mapping becomes essential due to the decreasing, time-consuming, and expensive field surveys which are no longer affordable by the soil surveys of the individual federal states”;

-SIGSTAR-200 is intended for administrative levels (strategy and tactics within ministries and county departments) as well as for scientific investigation (choice of pilot zones, selection of models and methods, validation for other spatial and descriptive data), being a powerful tool for sustainable use of soil resources (Vintilă et al., 2004);

- obtaining derived maps concerning the soil’s degradations (Lăcătușu et al., 2000) processes (erosion through water, wind erosion, gleyzation, pseudogleyzation, salinization and alkalization, Fig. 3).

5. CONCLUSIONS

Based on the occupied area, the most spread forest soils are dystric cambosols (2292385 ha), haplic luvosols (1440052 ha) and eutric cambosols (869909 ha), followed by entic podzols (447657 ha), preluvosols (335050 ha) and dystric fluvisols (330564 ha). The soils from the mountain area (areas that are generally forested) represent an important percentage from their total national repartition: dystric cambosols (2292385 ha in forest fund from a total of 3220295 ha, which means 71%) and entic podzols (447657 ha in forest fund from a total of 647686 ha, namely 69%).

Significant differences exist between soil repartition at a national level and the ones from the forest fund:

-larger percentages are registered at a national level in comparison with the forest fund for Cernisol soil class (27% per country and only 6% forest soils), respectively for phaeoziom (16% per total, 3% in forests) and chernozem soils (9% per total, 1% in forests);

-larger percentages are registered in the forest fund in comparison with the ones at a national level for Cambisols (48% in forest fund and 24% per country), respectively for dystric cambosol (35% in forests and 14% per total) and haplic luvosol (22% in forests 16% per total).

The map, together with the afferent database, has numerous practical applications: in the activity of forest management (the judicious placement of soil profiles, realizing some specific laboratory analyses, the proper identification of station types, projects concerning the compensation of forest areas with other kind of lands), in national or international reports (the areas covered by different types of soil, evaluating the stock of organic carbon, in local or national strategies), in derived maps and databases (erosion, gleyzation, salinization) and in other economical and scientific activities (areas for harvesting truffles,hidro-technical projectsetc).

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