GIS Soil Maps of Vojvodina for Integrated Water Resources Management

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Abstract

Sustainable management of land and water, demands rational organization of the observation and measurement of various phenomena in time, to establish their physical, chemical and biological characteristics, etc. In the analyses of natural phenomena, it is necessary to use modern information systems for integral managing of land and water resources, which enable fast and efficient exchange of data, experiences and knowledge.

The development of land reclamations measures, as a long-term goal in the realization of new strategies of sustainable development for the purpose of management of water and land resources, requires primarily the collection, systematization and analyses of topographic, pedologic, hydrographic and other bases. Besides, it is concerned with the choice of computer programs and entering data into the basic GIS (Geographical Information System) programs, as well as the applications for hydrologic, hydraulic and other analyses, and for making digital maps (hydrographic systems, soil maps), application of research results, etc. Methodologically, this is the best way to precisely define the whole complex of mentioned problems and build up a good basis for sustainable development of agriculture and water management in Vojvodina.

This paper is concerned with the soil resources as part of the environment and with degradation processes that can influence these resources. It presents the main elements of GIS and working procedure for the GIS layer of Vojvodina´s soil map, serving as the basis for the integrated protection of soil resources in Vojvodina.

Keywords: soil resources, land, environment, ecology, GIS

Introduction

In addition to solar radiation, water and air, land may be considered a basic natural resource that is indispensable for man. Soil is not only a necessary environment for organisms, but at the same time it is a product of living organisms. It has been formed by a combined action of numerous factors, called pedogenetic factors. To these belong parent material (parent rock), climate, organisms, relief, groundwater, anthropogenic activities, together with the weather influence (Rohon, 1984).

The application of the Soil Map of Vojvodina in the form of a GIS layer is possible in a number of areas such as agriculture, water resources management, forestry, environmental protection, etc., first of all in the strategic planning of sustainable development of these areas and integral protection of land and water resources in Vojvodina.

With the aim of developing GIS applications, the Department of Water Resources Management has initiated the work on the research projects "Reclamation in the Sustainable Development of Water Resources Management of Vojvodina", financed by the public water management company "Vode Vojvodine" and Ministry of Science and Environmental Protection of the Republic of Serbia. The results presented in this work are related to the part of these investigations undertaken with the aim of pointing out the importance and possibilities of using GIS in the integral protection of land resources in Vojvodina.

Soil and the degradation processes

The basic unit in soil classification is soil type, which can be further divided into subtypes and forms. Soil classes encompass soil types, whereas series are distinguished on the basis of the character of soil wetting and composition of the soil solution (Miladinović, 1996). Pedogenetic processes - the processes taking place in the soil and yielding certain changes in its profile, are long-lasting processes. They can be influenced by both natural and anthropogenic factors.

When soil fertility, that is its capacity for plant growing, is reduced, we speak about the degradation of agricultural soil. According to FAO directives, the processes leading to soil degradation are: water erosion, wind erosion, salinization, sodification, chemical degradation, physical degradation, biological degradation, transformation of agricultural soil into non-agricultural one, etc. Degradation can be either permanent or temporary. In the latter case the restoration of the conditions existing before the degradation process can be achieved either in a natural way or by human intervention.

In the process of urbanization, soil is being covered by diverse constructions or by layers of asphalt, concrete, or some other building material, so that these areas are lost for agricultural production. It can be assumed that the loss of fertile soil caused by urbanization in Vojvodina is very pronounced.

Permanent degradation of a given soil occurs in the case of removal of the upper fertile layer for the purpose of extracting raw material, e.g. for brick plants, surface mining, and the like. In the course of exploitation of these deposits, the active soil layer is practically removed and carried away, so that it is not possible to grow plants there any more. After depletion of the raw material, the remaining depressions are usually used for the disposal of waste materials, which can bring about contamination of the adjacent soil. Hence, it would be advisable to make efforts to restore conditions for plant growing on these abandoned areas (Benka, 1997).

Soil contamination by harmful matter means the presence of the harmful agents in the soil, which hinders or endangers the vital processes in plants. These substances can reach the soil from the air by settling of air-borne solid particles, then through precipitation, through groundwaters, or from the man-made depositions of waste materials. Harmful matter are mainly a consequence of the industrial development, where they appear as byproducts of the industrial processes. They can be discharged into atmosphere during the industrial process and through precipitation reach the soil. When the industrial waste is deposited in the landfills, it can directly contaminate the soil and, by the circulation of surface and ground waters, contaminate also the adjacent soil.

In a wider sense, soil degradation can be defined as the process that lowers qualitatively and/or quantitatively the existing capacity of the soil to produce goods and services (Gostović, 1989).

Basic elements of GIS

In order to describe and present geographic forms or information about certain phenomena on the Earth surface, man has long ago begun to construct geographic maps. On a map, a phenomenon to be recorded is presented by a certain symbol or description. In the process of presenting earth surface on a map it is necessary to solve a number of problems, one of them being the mapping of the objects from the curved earth surface into the map plane.

The emergence of computers and corresponding software packages has yielded their application in cartography too. The software development has resulted in computer systems that enable collection, treatment, storage, and presentation of data concerning a particular place on the Earth surface. These functions comprise the Geographic Information System (GIS). They enable constructing the maps that present particular areas, but this is only one of the ways of graphical presentation of data that are built-in in the GIS. The possibilities of GIS use are much wider. This system enables various spatial analyses, either through the data search in databases or data search according to spatial criteria. On the basis of the available data the GIS can offer the answers to many questions of the type: 'What'? 'How much'?, 'True'? and, of course, the answer to the mandatory question 'Where'?

The phenomena on the earth surface can be presented in the form of vector picture. With the aid of vector picture space can be presented by the following spatial elements: point, line, and polygon. Depending on what one wants to present, a particular element type is selected. The surface on which a certain soil type is observed is presented by a polygon. To make easier handling of these graphical presentations, different phenomena are grouped into layers. To each graphical element presenting a

given phenomenon are linked the data from the accompanying database. To the database are introduced the other data about the defined phenomenon. It is just this linking of graphical presentation and database that provides all those advantages offered by GIS in comparison with maps in classical form.

Constructing the GIS layer 'Soil Resources'

One of the GIS layers which can be used in the domain of integral protection of land and water resources is the layer concerning soil types. Taken independently, this layer represents a soil map with soil types presented in digital form. The basis for constructing the soil map of Vojvodina served the Soil Map of Vojvodina released by the Institute of Agricultural Research in Novi Sad in 1971. The map is made in a scale 1:50,000, and the Vojvodina territory is presented on 60 sheets. For the need of GIS the classical map has to be transformed into digital - vector form.

Scanning of a map gives as a result the raster picture. In order to be used for digitalization the raster picture has to be geo-referenced. In this procedure the raster picture was placed at the corresponding place in the coordinate system, rotated, and its scale changed. For the purpose of geo-referencing it is necessary to know the coordinates of certain points presented on the map. In the procedure of geo-referencing of the scanned sheets use was made of all the apexes of the square network, so that the number of points per sheet was up to 190. By selecting the appropriate transformation method in the process of geo-referencing it was possible to eliminate the existing deformations.

The geo-referenced raster picture was used as the basis for digitalization. Digitalization was carried out by drawing the vector picture over the raster picture, that is the boundaries between particular soil types were drawn out. This was the most substantial part of digitalization.

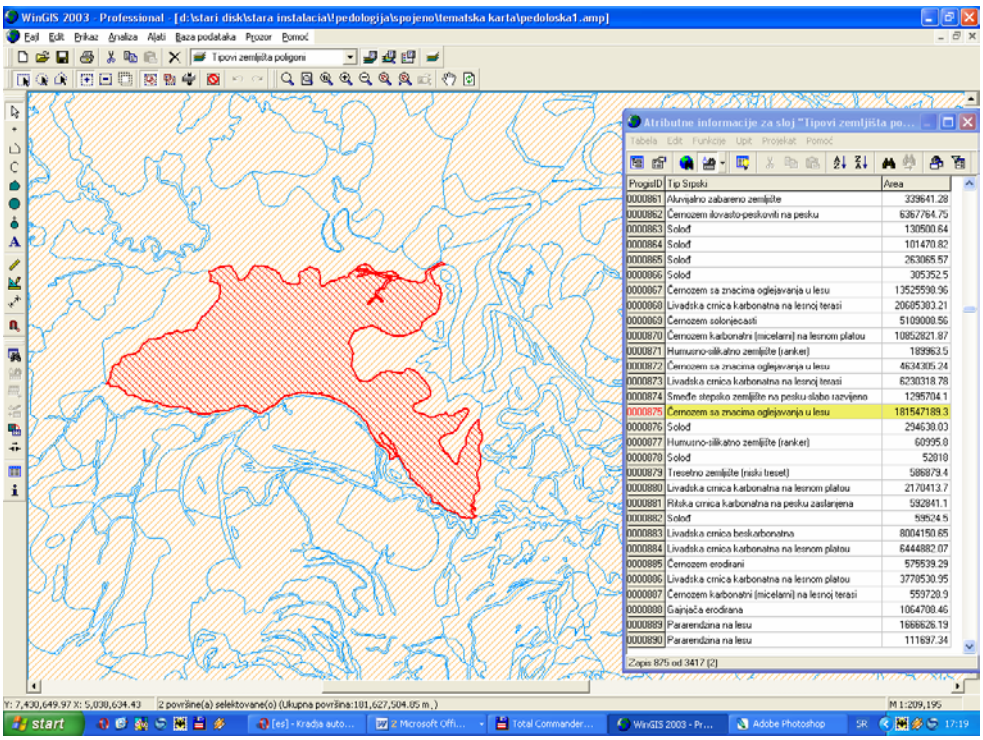

Figure 1. User interface for WinGIS 2003 software

The areas with the same soil type were represented by polygons. The polygons were obtained on the basis of digitalization of the boundaries of soil types. This resulted in 3417 polygons with the areas from 1 to 134,401 ha. Along with these polygons, a database was formed, with the designation, series, name of type and subtype or soil variety. There is the possibility of introducing parameters for each type, subtype or soil variety, depending on the purpose the GIS layer is to be used. The database contains also the areas that are obtained from the digitized boundaries of the polygons. These areas are somewhat different from those obtained by planimetric measurements on the map after its construction (Benka, Salvai, 2005).

Application of GIS Soil Maps of Vojvodina for Integrated Water Resources Management

The GIS layer 'Soil Types' and the related table in the database enable the use of standard GIS functions. Upon selecting a certain data from the database, graphical presentation of the area to which these data are related is simultaneously obtained (Figure 1). The selection can be performed for more data from the database according to the desired criterion. For example, on selecting the records containing the word 'chernozem', the graphical presentation shows all the areas on which appear some of the subtypes or varieties of chernozem.

Table 1 shows the areas from the digitalized soil map according to particular soil types (Živković et al., 1972) that were obtained by the corresponding query into the database.

Table 1. Proportions of particular soil types in Vojvodina

Soil Type	Area [ha]	%
Regosol	26494	1.20
Pararendzina soil	16391	0.74
Rendzina soil	17	0.00
Humus-silicate soil (ranker)	20705	0.93
Chernozem	964734	43.55
Smonitza soil	36785	1.66
Brown forest soil	53719	2.43
Acid brown soil	1380	0.06
Pseudogley	14085	0.64
Alluvial soil	186555	8.42
Deluvial soil	3056	0.14
Alluvial-deluvial soil	12980	0.59
Chernozemlike Meadow soil	386517	17.45
Hydromorphic black soil	253738	11.46
Hydromorphic smonitza	107381	4.85
Hydromorphic gleyed soil	15884	0.72
Peaty soil	400	0.02
Solonchak soil	24702	1.12
Solonetz soil	82991	3.75
Solodi soil	6558	0.30

A thematic map can be obtained as a GIS product. On this map, the areas with identical characteristics, e.g., with 'chernozem' in the name, are shown by the same color. The thematic map obtained on the basis of data from Table 1, showing percentages of particular soil types on the territory of Vojvodina, is given in Figure 2.

Selection of particular data from the database is also possible on the basis of the preset spatial conditions. For example, this may be the selection of the areas that are encompassed by an area or intersected with another area or a line, and the like.

Some wider applications of the digitalized soil maps can be obtained by using them together with other layers that contain terrain surface elevation, mode of land use, hydrographic network, meteorological data, etc. It is possible to obtain a new layer which represents an intersection of these layers. For that new layer, a new table in the database is obtained, which is also a result of the intersection of the tables pertaining to the intersecting layers. For example, the intersection of a periodic (annual) layer of urbanized land areas with the layer of soil map gives precise data about the loss of fertile soil due to the urbanization in the selected period. Besides, the intersection of the mentioned layers gives the areas for which calculation was made, for example, of water discharge in dependence of the slope, amount of precipitation, land coverage, infiltration coefficient for this type of soil, and other parameters. These data can be used in the course of designing drainage systems, to analyze different variants and select the most favorable one.

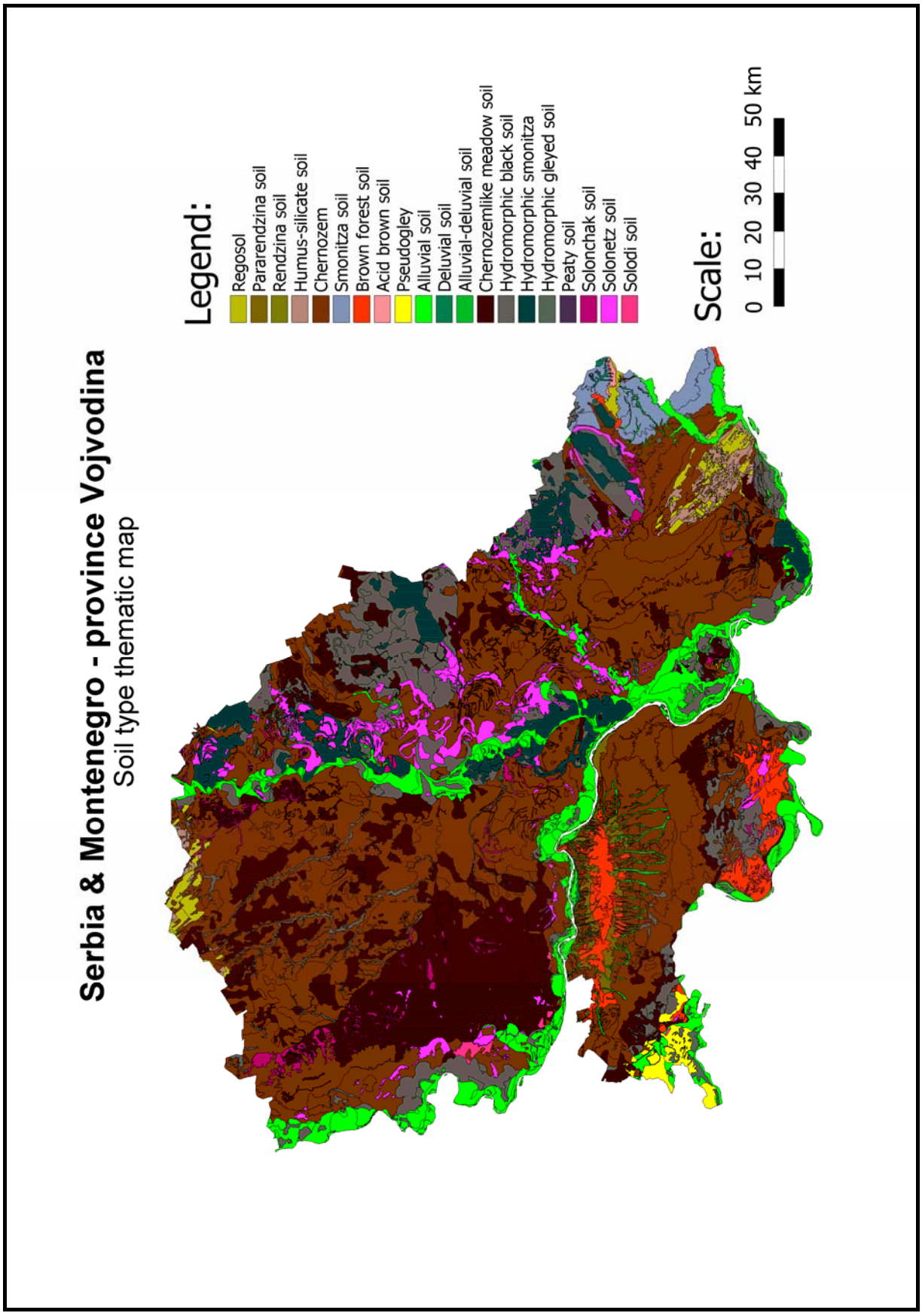

Figure 2. Proportions of the particular soil types in Vojvodina (Živković et. al., 1972)

Conclusions

The application of GIS allows one to describe various phenomena on Earth surface in a more complete way than it is possible to achieve by classical maps. The construction of the Soil Map of Vojvodina in a digital form, as one of the GIS layers, ensures a new way of using this map.

The basis for the digitalization served the Soil Map of Vojvodina issued by the Institute of Agricultural Research in Novi Sad. Digitalization was carried out on the basis of the scanned sheets of this map, which were previously geo-referenced. In the course of geo-referencing it was possible to eliminate deformations caused by the effect of moisture and temperature on the map, as well as potential errors made in the course of scanning. By linking the database to the layer 'Soil Types' it is possible to present the areas from the database and vice versa, to find out the desired data by selecting the given area on the graphical presentation.

Another potential application would be the possibility of constructing thematic maps showing the spread of particular parameters related to soil types. In the combination with other GIS layers it is possible to obtain new layers that are the result of the intersection or difference of these layers connected to the corresponding databases, which will be subject of our further research.

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