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17. Application of GIS in studying the drainage basin of the Ipoly river

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ABSTRACT. GIS (Geographical Information Systems) gained broad application in all the landscape ecology, earth and environmental sciences. The technical development of GIS is very fast and the user sciences are not able to follow this process sufficiently or to use all the advantages offered by GIS. The paper deals with problems of the lack of unified cartographic-topographic base, of proper choice of corresponding indices of elements of geosystems, and with their correct georeferencing on raster and vector elements. Methodical questions are discussed on the basis of a recently completed project on the GIS of Ipoly river basin. The Ipoly GIS is a unified, interconnected system of catalogues and map sheets, which strictly follows the hierarchy of the methodical levels of the geosystem structure ("component – property of component – index of property – value of index"). According to their material character, the properties (thematic map sheets) are ordered as follows: georelief (bearer of indices of space and position); components of primary landscape structures (geological basement, soils, waters, air); components of secondary landscape structures (vegetation, animals; land cover); landscape ecological complex (synthesis of the primary and secondary landscape structures); components of tertiary landscape structures (nature conservation areas, areas of protected natural resources, infrastructure zones; state of environment, indices connected to administration units - territories, inhabitants, infrastructure, environmental care in communities, districts, counties). Also, the paper presents three different interpretations (of possibilities offered by a well-established GIS), which derive the run-off conditions in landscape, ecological quality of landscape and level of ecological services of the landscape.

Key words: GIS, unified environmental system, cartographic base, georeferencing, indices, interpretation

INTRODUCTION

Today, the transforming social objectives of the intensive economic development, the changing requirements of landscape use and regional development, and the modifications of national strategies increasingly confront with the internationally declared objectives of sustaining the natural environment. Understanding these global challenges, several international organizations concerned with the future of the Earth declare those requirements and barriers that, once realized, will guarantee the long-term sustainability of the development of humankind.

The processes in the uniform environmental system are connected by numerous physical, chemical and biological interactions. Their common feature is that they all act in common space. The Hungarian count Pál Teleki expressed (in 1917) that "it is absolutely clear for us that there exists a complex organic relationship that integrates every factor of a region" [***29***]. The only common point – actually the surface – of this "integration" is the common space, in which the natural, social and economic processes act. For the exploration of these relationships, we have now **regional** information systems (known as **GIS** = Geographical Information Systems) available. They exceed the **capability of maps** by the way they structure the information, data and map layers in real space, by which they guarantee a much better visualization of the processes as well as the realization, study and modelling of transdisciplinary relationships.

Various institutions of the European Union have already defined their expectations, such as the INSPIRE [***36***] on forming the infrastructure for spatial information and the framework directive on the integrated management of waters [***32***]. Other concepts such as the GMES and WISE may also be mentioned. The importance of information systems and monitoring is expressed by the European Landscape Convention [***33***].

A uniform and well-structured geographical information system based on the above guidelines is capable of satisfying all those regulations that are laid down for collecting, describing and using information concerning the individual parts of the environmental system.

The project, "HUSK/0801/2.1.2/0162/ GIS FOR AN ENVIRONMENTAL MONITORING SYSTEM OF THE DRAINAGE BASIN OF THE IPOLY RIVER" (01.11.2009 – 31.10.2010) was developed as the model of a spatial information system to meet these requirements. The drainage basin of the river lies in Hungary and Slovakia. This project satisfies, and will surely harmonize these expectations. This harmonization is a complex, transdisciplinary task, because it practically demands the integrated study of impact sources and affected factors.

It is important to note that this project is closely related to the aims expressed by the United Nations when launching the International Year of Planet Earth.

MATERIALS AND METHODS

1. Study area, objectives and research methods

1.1 Drainage area of the Ipoly river

The Ipoly river has a length of 254 km, its total drainage area in Hungary and Slovakia is 5,145 km² (**Fig. 1**). The difference between its low and high water discharge is very big (LW = 1.5 m³/s, MW = 25.4 m³/s, HW = 480 m³/s), which makes it difficult for the local population to live with the frequent floods and excess water. At the same time, the area possesses several protected natural and environmental values.

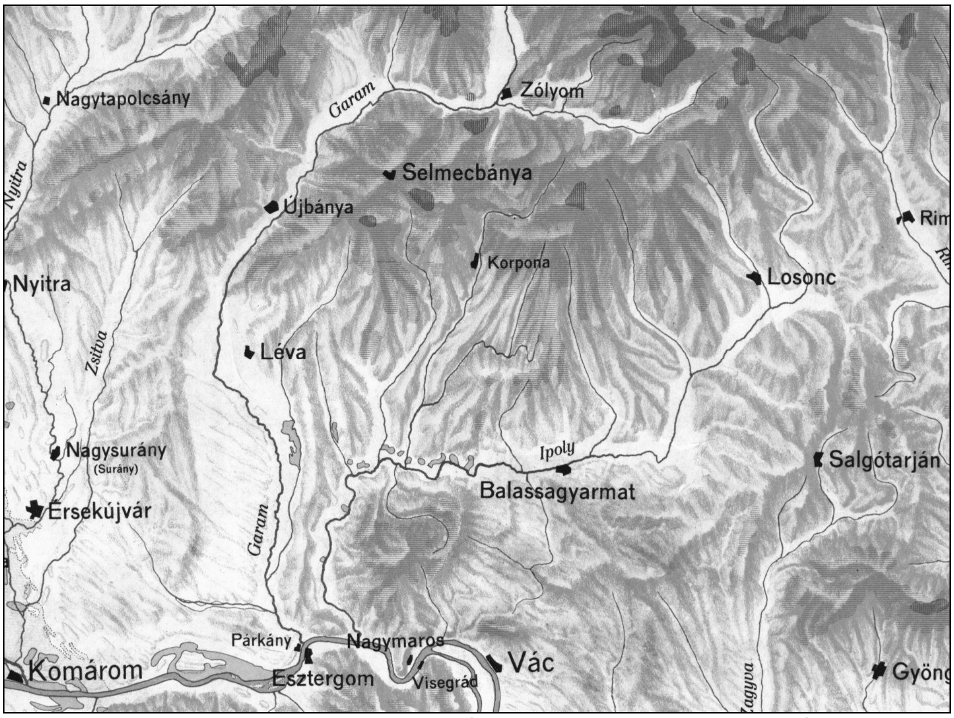


Fig. 1. Ipoly river basin and the location of the main human settlements of the region.

The reasons of choosing the Ipoly drainage area for studying the development methods of a GIS-based monitoring system were as follows:

- the sample area can be handled as a unit;
- the protected and to be protected environmental values can be uniformly defined independently of political borders, and the determination of the level and demand for protection can be uniformly defined;
- as the river and its tributaries pass through various landscapes from the source to the mouth (relief difference is almost 900 m on about 250 km), the impact of climatic change can be modelled;
- as the project area was cut by a political border for several decades, most of the area retained its natural state fairly well;
- the countries, now separated by the Schengen border only, are interested in the joint protection of the values and in introducing uniform law by the authorities;
- the two EU member countries are interested in developing a uniform European information space;
- the regional and professional relationship with the Danube Strategy makes it easier to apply and adopt the methods in other areas.

Fortunately, the study area has favourable natural conditions. The use of the project achievements and their involvement in the decision-making processes can and should base the sustainable harmony of regional development and environment protection policies as well as contribute to generating jobs. This will be a significant achievement of the project in creating the Single European Information Space.

1.2 Environmental-political and environmental protection objectives of the project

Changes in the use of the landscape generate different demands also in the study area. Satisfying or rejecting them brings along various conflicts in the environmental protection. These conflicts can be solved only on condition the general compromise is based on solid considerations. The establishment of a monitoring system based on GIS, which is the final objective of the project, and the use of its achievements in a standardized way can satisfy the following general aims in the study area:

- uniform surveying and evaluation of the state of the environment in the whole drainage area of the Ipoly river, defining the final state to be achieved;
- uniform management of the conflicts between the environmental impact sources and affected factors, establishing a sustainable harmony;
- establishing and managing a uniform environmental information network of the cross-boundary area;
- establishing and strengthening the environmental conditions of economic and cultural cooperation;

- reducing the social-economical disadvantages of the region, improving the use of its advantages;
- recognizing the demands for further complex studies;
- reducing the tension and distrust originating in the past separation.

Naturally, the planned system has enormous importance when carrying out a uniform study on any other drainage basins or regions. The information system and the monitoring, with the common handling of the content elements of spatial relationships, will make the early detection of changes of elements possible as well as the early prognosis of the possible consequences of such changes and the modelling of the changing environment. This is the way of providing an exact methodological ground for the integrated **landscape management** policy.

1.3 Spatial information systems – an imperative necessity for researchers

Understanding and implementing the measures to define and realize the aimed states of the environment is impossible without the clear knowledge of the past and present states as well as the changes of the landscape. For this purpose, it is necessary to use a cartographic information system, which guarantees the comprehensive study of regional and functional relationships. The spatial information systems, known as GIS (Geographical Information Systems), make it possible to study the landscape in 4D, which means the study of the land in the changing time.

The cartographic visualization offers a special method of environmental impact assessment, because it makes it possible to assess the potential spatial consequences of the use of the environment. Cartographic visualization can show that the same or similar social impacts may not lead to identical environmental changes and consequences in other places.

Thematic maps represent the inner characteristics, structure and functions as well as the spatial structure of those natural and social phenomena that can be related to the surface of the Earth and show spatial distribution. This means that when the environmental sciences carry out their analysis they cannot neglect cartography, which has been using modern techniques. The cartographic approach uses the information technologies, and offers great opportunities to understand the consequences of social impacts on the environment, to forecast the spatial distribution of impact mechanisms, and to explore transdisciplinary relationships. In this way, cartography meets the requirement of interoperability set by the directives of INSPIRE [***36***].

Following the above considerations, the objective of the project is to develop a uniform spatial information system and use it for a sample study area.

This spatial information system will be capable of analyzing the following elements in complexity for the whole territory of the drainage area of the Ipoly river.

- protected and to be protected natural values;
- geological maps;
- soil maps;
- groundwater conditions;
- conditions of the riverbed, floods and excess surface waters, the historical changes in the drainage area of the river;
- meteorological and climatic changes;
- typical land-use forms;
- present environmental damage, the objects that potentially endanger the environment, and the endangered objects.

In this phase, the development of the information system was considered most important, and we did not deal with the comprehensive analysis of the data entered into the system – this will be the task of the next phase.

The revolution of information technology in the 1980s produced such development in the hardware that was unimaginable before. This was followed by the fast development of software in the 1990s. As a result, now the computers “can do everything”. Today, we naturally use programs that are parts of a worldwide system, which include thousands of work hours of lots of experts. With their help, it is possible to study and plan several social problems and organizational tasks in a typified, homogenized, globalized and universal way. The second half of the 20th century was mostly dominated by a very intensive technical-technological development along with large-scale specialization.

However, the object-oriented databases have not yet been established and developed. This is one of the most important tasks to be solved. This lack very much hinders a broader use of the capacity of information technology! “Machines” (including hardware and software) would be able to do almost everything, if we had enough systemized data. Ordering or reordering the object-oriented data would help us understand the natural, social and economic processes, and in particular, would help us explore their complex relationships.

1.4 Spatial data and development in informatics

The information societies soon realized the great opportunities that the spatial data systems offere for social use. The European Commission initiated the development of the European spatial data infrastructure (INSPIRE) to intensify their application. A paper of the GINIE project (Geographic Information Network in Europe, coordinated by the University of Sheffield) said the following: a survey completed in December 2001 indicated that 120 of the 192 nations in the world were working on their national spatial data infrastructure, with half having already established catalogues of key data resources searchable on the Web. “In Europe, most countries are in the process of developing SDIs at national and/or regional/local levels. … **In addition to this foundation work there is also a need to harmonize the data layers and achieve seamless coherent information**”, says the GINIE Book on the SDIs (Spatial Data Infrastructure).

Table 1.

Environment = Landscape

		Supposed changes in the environment			
Landscape elements	**Anthropogenic environmental changing processes**	**in the lithosphere**	**in the hydrosphere**	**in the atmosphere**	**in the anthroposphere**
Geological structure	Man-made structures and the melting of the continental ice-sheets result in growing quantity of water and in a new state of equilibrium in the crust. The generated electromagnetic oscillation and the relieved radioactivity influence geophysical processes.	The rearrangement of the equilibrium increases the number of tectonic micro- and macro-phenomena	Tectonic movements result in changes of hydrological conditions		The man-made structures of global importance are increasingly endangered by landslides, earthquakes and sinking
Geological composition	The extraction of artesian water and hydrocarbons accelerates compaction. Packing waters into the strata, which waters are by-products of hydrocarbon mining and geothermic energy utilization, change the processes of dissolving. The sedimentation processes of the artificially patterned surface water system are changing, and the growing quantity of wastewater sediments results in a new type of diagenesis	The compaction of the strata results in accelerating diagenesis and metamorphism. Result: subsidence of the surface.	Wastewater sedimentation accelerates the filling up of the lakes. Natural supply of subsurface waters is decreasing.		The man-made structures of global importance are increasingly exposed to hazard due to the landslides, earthquakes and subsidence.
Morphology	The degree of building-up, the intensive agricultural activity and the change of run-off conditions modify the rhythm of erosion–accumulation. The changes in the tectonic and lithological composition result in changes in morphology	Morphological changes taking place in the surface of the lithosphere by the processes of accumulation and erosion result in considerable changes.	The minor morphological changes influence run-off conditions; the considerable ones change the track and water balance of the surface waters.	Morphological changes and the degree of building-up modify the micro- and mezo-climate.	Agricultural activity is hindered by efforts against erosion. In built-up areas, the processes of accumulation, such as accumulation of sediments cause difficulties. Morphological changes may damage man-made structures.
Climate	The concentration of SO_2 and CO_2 is increasing in the atmosphere and the warming up accelerates. The UV and radioactive radiation is increasing.	The rising temperature and the growing quantity of SO_2 and CO_2 content of precipitation promote disintegration. Increasing sea level reduces the area of continents, transgression processes become more frequent.	Under the influence of rising temperature the quantity of sweet water in the continental ice sheet is decreasing, the sea level rises. The hydrological cycle accelerate.	The decreasing differences of temperature weaken the large wind systems. Cloud cover will be constant, the quantity of sunshine decreases. Special town climates are developing.	On the decreasing areas of the continents the concentration of population is growing, which results in increasing the CO_2 and SO_2 content of the atmosphere. This may damage the buildings and technical structures.
Hydrological factors	The artificial governing of the surface water increases pollution, the fauna and flora of the water and its self-purification ability decrease. Because of increasing extraction, the pressure conditions are changing	The eroding and accumulating role of surface waters becomes insignificant.	Draining moorlands promotes the filling up of lakes. Groundwater level is sinking; the duration of lands under water is increasing. The sea pollution results in changing the chemical composition of the seawater.	Running dry of the springs, drying out of the lakes, and the heat pollution of watercourses change the micro- and mezo-climate. The polluted seas do not take part in purifying the atmosphere.	The quantity of clear water, which is the most indispensable material of human life, is decreasing.
Biogenous factors	Owing to the extinction of the natural biotopes, the mammals die out and are succeeded by the man. Cultivated plants replace the natural vegetation.	The intensive agricultural activity decreases deflation. Wastewater slurry contributes to new biogeneous sedimentary processes. The overturned ecological balance leads to the extinction of lithogenic organisms.	Changing of the natural fauna and flora stops the self-purification of surface waters. As a consequence of deforestation, the rate of inflow and run-off is accelerating. The danger of floods is increasing.	The oxygen production of smaller and smaller forests is decreasing, and the oxygen cannot bind the increasing quantity of CO_2 in the atmosphere.	The human biomass is increasing, while the quantity of water and food is considered constant. The infrastructure of transportation segregates the fauna and flora.
Soil	The balance of the alimentation chain turns over, and the natural process of soil development comes to an end	The increasing erosion, the decreasing of humus development, the accelerating weathering result in the dominancy of B and C levels in the soil instead of A levels.	Chemicals getting into the natural waters change their chemical composition and living organisms.	The stop of natural soil development changes the micro- and mezo-climate.	The saving of the soil requires more and more energy. Artifical fertilizers cannot replace the decreasing quantity of stable litter.

Considering the above, we have set the following aims for the realization of a GIS for the Ipoly drainage basin information system.

- The biologically, physically and/or chemically interrelated elements and processes can and should be connected as well as the changes and cause-and-effect relationships can be analyzed in space and time;
- The impact sources and affected factors can be studied, assessed and confronted;
- The information and data sets (e.g. that of the state of the environment) can be analyzed in a coherent system;
- The GIS can
  - assist in decision-making by providing information to the authorities;
  - produce information on the state and changes of the environment for a broad circle of the society;
  - assist in the society's adaptation to the environmental conditions and changes;
- The GIS is a uniform basis of the expectations set in the EU directives for individual disciplines.

Table 1 illustrating the structure of map layers that will serve as a guideline for understanding the term "environment = landscape".

2. Methodological-practical problems in the application of geographical information systems

2.1 The use of GIS in solving analytical and complex problems

As said, many "classical" sciences cannot easily follow the advancement of the geographical information systems due to the fast development of computer science and information technology. This explains why the technical capacities of the GIS are not yet fully used. On the other hand, the GIS specialists have not answered all the problems that are considered elementary by the users from various sciences. The problems of using GIS mostly arise when we want to analyze the **complex** relationship of components in the geosystem and want to use an information system based on GIS. There are several basic questions, some of which follow bellow.

2.1.1 The structure of the system – geographical information and cartographic basis

The map is the basic tool to understand, scientifically describe and visualize the space. The maps will be the basis of geographical information systems even if they are not produced as conventional prints but presented in electronic form. The most important property of a map, that is the definition of the location of each point in space by a coordinate system [x, y, z], has remained the basis of the electronic GIS. The material objects of the geosystem are also represented in this coordinate system.

As the GIS is based on systems theory, we have to manage the methodological steps of forming and filling up the GIS according to theory of the geosystem (e.g. [***3***]; [***26***]; [***23***]; [***15***]). We also accept that the geosystem is a complexity of the components (elements and objects) of the geosphere and their interactions. The geosystem itself includes the content of the landscape and environment. Naturally, a concrete material section of the Earth does not know the attributes given to it, and it will not change just due to these attributes.

For the GIS it is most important to set up a line of terms to describe the structure of the geosystem: the geosystems are constructed of **components**, and **their properties** are studied through **indices** that have concrete **values** for concrete areas. To achieve any result, the functions of the terms ***component (object) – property – index – value*** must not be confused when using the GIS technology.

a) Geometrically unified projection system

This is not a problem in itself for information technologists, because it is expected from every good atlas that the maps are prepared in the same scale, and they have the same projection and execution. Organization problems, however, do exist. For instance, it was not, and is not always possible to expect from the authorities that they place all the necessary information on the same cartographic base.

b) Unified topography – unified system of the surface and objects

This is not a problem in itself for information technologists either. Modelling the surface is not a difficult job at all, because this is done by the computer by using the digital model of the terrain. However, harmonizing the material components existing in space, the basic (topographic) map elements on the one hand, and the elements of thematic maps on the other hand, has been a **problem that has to be solved urgently**.

The basic topographic map elements often appear in different positions and locations in maps of various origins even though they were prepared in the same projection. It may happen that a stream electronically transferred from a map onto another map flows on the hillside and not in the valley, the roads are sometimes entwined like someone's hair in plaits, rendzina soils come over the alluvial deposits, acid forest soils cover the limestone slopes, the lake is placed on a ten-degree slope, etc. These mistakes lead to chaotic combinations in the complex assessment and in overlapping, and they may produce misleading results.

The experts of informatics state that they can "transform" any map projection into a uniform basis. However, this is only the transformation of the coordinate system! The original thematic information (and not the multi-scanned copies) of thematic maps was manually placed on the map, and this content cannot be transformed by mathematical rules. If we need the complexity information and we want to analyze the interaction of individual components, we have to standardize them and we have to exclude the absurd combinations. The basic elements of the topographic map and the basic elements of land-use can be accurately projected into their uniform position only manually and with expertise as well as with the comprehensive understanding of the relationships between the components of the geosystem. The availability of orthophoto maps and georeferenced space images, which can be handled electronically, is of great help today. In fact, it is the discipline of the complexes of abiotic, social-economic or other spatial units should determine the quality of the information system.

In spite of problems, there are developments in this direction too. In Slovakia, for instance, the Geodesy, Cartography and Cadastre Authority of the Slovak Republic, the Institute of Geodesy and Cartography, and the Topographic Institute (formerly the Military Topographic Institute) worked out together a GIS-based catalogue of objects ([***35***]; [***37***]). This catalogue has been continuously harmonized with the Central Regional Database of the Military Regional Information System, updated with the georeferenced aerial photographs (orthophoto maps), and uniformly presented in maps. During the execution of the GIS project on the Ipoly drainage basin, we used this information basis.

In Hungary, the first, “manually made” GIS-based thematic maps were published in 1993 in the atlas „A Ráckevei üdülőkörzet környezeti jellemzői” (Environmental characteristics of the Ráckeve holiday resort) by Klinghammer and Verrasztó, 1994 [***11***]. However, this atlas could only process just a few environmental features due to the lack of the necessary data. The Institute of Landscape Ecology of the Slovak Academy of Sciences in Bratislava worked with “manually made” GIS systems. The computers were substituted by tracing paper and transparent foils, and the foil layers were placed onto each other to gain complex information of interactions necessary for the analyses [***14***]. The projects included landscape ecological plans developed by LANDEP for various levels, from country level (known as General Ecology) to quite small areas like the Ipoly drainage basin [***25***]. The largest scale project of these “manually made GIS-based projects” was the landscape ecological plan prepared for the East Slovakian Plain at 1 : 25,000, where more than fifty thematic map layers were harmonized on a uniform cartographic basis [***18***]. However, computers were already also used towards the end of the project. This was of great methodological importance, because it showed what a computer can do and cannot do [***19***]. There are three new atlases made by the Institute of Landscape Ecology worth mentioning, which were completely prepared by using GIS technology: Landscape Atlas of Slovakia [***17***], Atlas of the representative geoecosystems of Slovakia [***20***], Atlas of the geoecosystems of the Trnava district [***9***]. The experiences gained during their preparation were implemented in the development of the GIS for the Ipoly drainage basin ([***7***]; [***21***]).

c) Projection, representation, raster–vector transformation

The difficult task of landscape ecology scientists in these respects is to decide on the following questions:

- how to structure the information into data components for the planned thematic maps so that the relationships between the impact sources and affected factors can be analyzed,
- which projection and representation method should be used for the individual thematic layers so that they can be transferred from vector format into raster format or vice versa, and the thematic layers can be combined and properly interpreted.

These phases also make great use of the experiences collected during the time of the manually building of the GIS.

2.1.2 The structure of the system – elements of georeferencing

Although this point seems to be a trivial task for IT professionals, this is of great significance concerning the usability, filling up and updating – that is the management of the future monitoring – of the system.

The elements of georeferencing can be divided into two groups:

a) Elements of georeferencing for the determination of place and position – primary spatial location

All points of the surface of the Earth are described by the geographical coordinate system (that is by geographical latitude, longitude and elevation above sea level – **φ, λ, h**) or by a geometric coordinate system (x, y, z coordinates). This coordinate system makes it possible to create the digital terrain model (DTM) of the surface. This is in fact a coordinate system of the intersection points of the **grids** of predefined side length (say of 10 x 10 metres). Calculating the morphometric indices of the surface and their representations are based on the DTM, which has been of immense importance in landscape ecological research. The DTM is also the basis of forming various isolines.

Naturally, it is the geographical or the geometrical coordinate system that determines the place and position of all the other elements of georeferencing. They are considered **secondary** elements of georeferencing.

We should not forget that, in addition to those mentioned above, recording the time factor in the system is also of great significance, because the **environmental changes** can be studied only on condition the past states of the environment are processed in the same map system. The proper cartographic combination of the impact sources and affected factors makes environmental modelling possible.

b) Elements of georeferencing that carry the properties of the material components of the geosystem

Naturally, the **grid of the coordinate system** mentioned above can be used to locate **any component** in space. It can be mainly used for the representation of those material components that quickly change in time and for which it is impossible to create a constant georeferencing element (e.g., the momentary location of a thundercloud, the spread of air pollution). However, the following elements of georeferencing are used much more frequently and effectively for the material components.

- **Raster** – this is a grid with regular sides too. However, the georeferencing does not deal with the intersection points, but it refers to the area of the mesh. This gives us the great opportunity of representing, analyzing and comparing numerous components of the geosystem. Therefore, it can be used in many ways.
- **Vectors** – they define components as **points**, **sections** and **polygons**.

These are the carriers of the geographical information in the most important topographic and thematic maps. These components can be used in lots of areas and can be excellently used to fill up a system with data continuously. Let us mention that the complex spatial units are also georeferenced according to polygons. The indices related to points give us the opportunity of compiling isolines.

Finally, the following can be stated on the elements of georeferencing:

- the properly chosen elements of georeferencing – that is the spatial carriers of the database – make it possible to update, reload and complete the information almost without any limitation as well as to compare all kinds of data at present and in the future without changing the spatial system;
- if the elements of georeferencing are not chosen properly, the whole data line may be used only once, and they cannot be combined or updated; a non-uniform system, though may be full of data, does not offer the logical combination of information therein.

Let us see a simple example. If the meteorological stations are the elements of georeferencing, they can receive newer and newer sets of data at any time independently of the indices we have at present. However, if we enter the properties of some atmospheric phenomenon into the system in the form of isolines only, they cannot be updated or completed even if they are in a large number or in excellent resolution. The new isolines will have to be digitized, georeferenced and represented.

The most frequent applications of the elements of georeferencing are shown in **Fig. 2**.

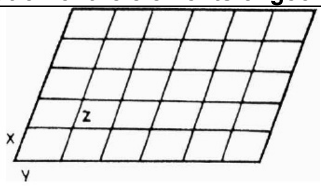
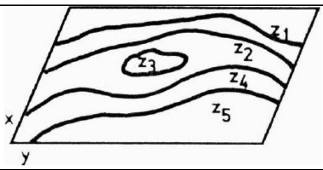
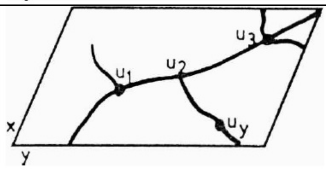
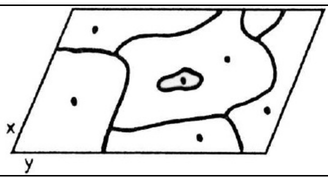
Representation of the elements of georeferencing	Name	Most frequent indices
	**Grid of coordinates** x, y, z **φ, λ, h** **Pixel**	**DTM** **Morphometric indices** **Surface**
	**Isolines**	**Altitude (a.s.l.)** **Level of groundwater**
	**Point** **Section**	**Hydro and meteo stations** **River and road sections** **ID points of settlements**
	**Polygon** **Reference points of polygon**	**Territorial units** **Complexes**

Fig. 2. Frequent applications of the elements of georeferencing

2.1.3 Content of the system – indices

The essence of information systems is the indices and values of the properties of the elements of the geosystem. The elements of georeferencing are their spatial representatives. It would be ideal to enter a large number of usable indices into the system, but there are some practical barriers. This explains why it is so important to choose the proper indices. Another important condition was already mentioned: this is the system of the proper elements of georeferencing, which, at a later stage, makes it possible to systemize the not yet classified indices, though they are already related to certain elements of georeferencing.

Naturally, the indices are primarily chosen according to the aims of the information system. The main aim at present is collecting and systemizing information, and later it will be scientific research, planning and decision-making. The ideal state would be a multi-purpose use of the system, which would be a system filled with lots of analytical information and completed with a filter/search module; in this case, the necessary information could be filtered for any purpose. At present, however, rather the minimal aims have to be defined and the system has to be built user-friendly.

When building the system, it is very important to know the degree of originality of the indices, in other words, to what extent these indices had been interpreted. Naturally, a good information system predominantly should contain elementary, analytical – that is primary – information, which allows the users to obtain derived and interpreted indices. The thesis is that if the analytical indices are correct, lots of derived data can be obtained and assessed! However, this idea does not work backward: even if the derived index is a very good one, maybe it is impossible to know the basic index! Let us see a simple example. If we know the usability of a soil or the degree of its erosion, we cannot deduce properties like the size of the soil particles or the angle of slope. However, if we know the angle of slope and the size of the soil particles, we can calculate the degree of erosion and the usability of the soil from these data; in addition, several other indices can also be interpreted.

These ideas are not new: landscape ecology and earth science always made a difference between causes and effects. This consideration got special emphasis in the study of environmental issues (e.g. Verrasztó, 1979 [***30***]). These theses were first directly used in developing the LANDEP methodology for building a spatial information system, and were described in the steps ***"Analyses – Syntheses – Interpretations – Evaluations – Propositions"*** [***24***] and successfully also in later projects.

2.1.4 Monitoring and its information system

Though monitoring has become a fashion word today and it has been scientifically justified, the term needs some explanation. In science, monitoring usually means **continuous** observation with the aim of collecting data in a series of time so that scientists can draw conclusions from certain processes, relationships and interactions. As for spatial information systems, the term, "continuous" is of special importance, because the spatial elements of the geosystem can be monitored in various ways:
- continuously – without any break;
- constantly, but with breaks – **periodically**, in shorter or longer regular periods;
- seasonally, in various periods according to need.

Naturally, some of the elements or factors may have to be monitored in various periods: e.g., let us compare the monitoring of geology, land-use or weather. It can be stated that monitoring rather means regularly repeated or renewed research in many cases.

The major question here is how the observed data, including the actual monitoring data, can be built into the spatial information system. It is important to note that the information system does not register the processes, neither the interactions nor the relationships, but "only" registers the various **states** – preferably in different periods. However, from these states, scientists can already interpret the interactions and relationships. For this purpose, it is an important condition that the registered states of elements should describe the same location and preferably should refer to the same time or period. In other words, for the interpretation of observations the **information system of monitoring** is most important, namely:
- the system of georeferential elements, and
- their primary data.

Then follow further steps, which already may have the character of monitoring such as
- the continuous collection and storing of information,
- updating of time series, and
- distributing and using information.

2.1.5 Implementing the INSPIRE directives

The Sixth Community Environment Action Programme [***34***] requires an integrated community environmental policy at local and regional levels. Its realization needs good quality and systemized databases. This principle led the European Parliament and the Council to form its Directive 2007/2/EC, which was approved on 14 March 2007 [***36***].

The task of INSPIRE is to regulate and oblige the members states to serve and share their data (metadata, spatial data) needed for environmental policy so that the spatial information infrastructures of the member states can be integrated and can be used within the community as well as in cross-border relations.

The directive does not oblige any country to collect new data, because it relies on the existing databases.

INSPIRE makes it possible to search in multiple languages in the professional metadata-bases supervised by the ministries of each country. The whole process has been coordinated by the Joint Research Centre (JRC) of the European Union.

In the **Ipoly project**, the collected and systemized databases covering the total area of the river drainage basin in Slovakia and Hungary connect with the existing spatial databases, thus offering a uniform, systemized and accessible multi-lingual database service.

The users after registration can get access to different levels of professional information on the geoweb portal (www.ipoly/Ipel.eu).

Due to the holistic planning of the system, the project offers outstanding support to the **special administration departments in Hungary and Slovakia in their authorization and decision-making tasks**. Naturally, other interested users (researchers, enterprises, civil organizations, individuals, etc.) can also receive a wide range of information from the spatial database collected from the region, extended in time and space, systemized and published on the web.

3. The Ipoly GIS

The methodological principles of spatial information systems were applied for the construction of the Ipoly GIS.

3.1 Structure of the Ipoly GIS

The concrete principles set for the sample area were as follows (**Fig. 3**):
- uniform Gauss–Krüger projection of the cartographic base;
- digital surface model in uniform coordinate system;
- uniform system of topographic objects on each thematic map layer;
- system of pre-determined, carefully selected georeferential elements, which allows that new information can be entered, systemized, updated and monitored at any time. They are the agents of spatial information, namely:

- raster – mainly morphometric indicators, content of space images;
- point – hydrological and meteorological stations;
- line – sections of watercourses, roads;
- polygon – spatial agent of the indicators of other elements, that is the indicators of abiotic complexes, biotic complexes and land-use, socio-economic complexes, indicators related to settlements and cadastral areas;

- indicators selected for the purpose and their concrete values, which characterize the primary (abiotic complex), secondary (biotic complex and land-use) and tertiary (socio-economic complex) structure of the geosystem.

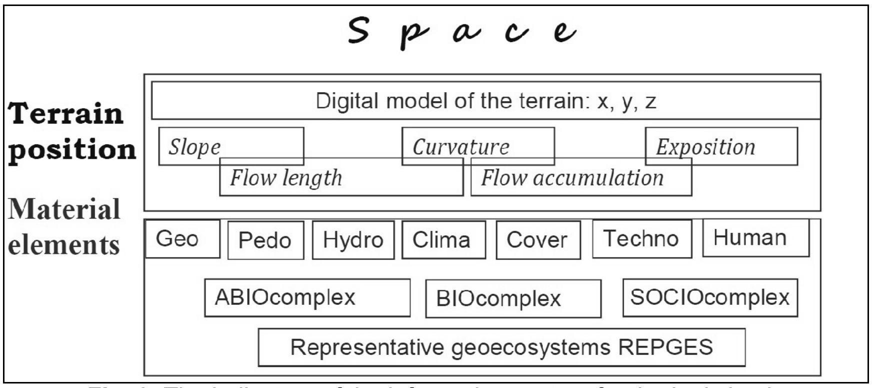


Fig. 3. The indicators of the information system for the Ipoly basin

3.2 Catalogue of the GIS and its representation

A key issue of using GIS is to make it user-friendly. The catalogue is the basic tool for getting an overview of the system and for understanding the structure of the information system. This is in fact the metainformation system of the GIS. The catalogue is prepared in electronic, interactive form, and is connected to the cartographic processing of the thematic layers listed in the catalogue. Those terms appear in the GIS that are also used in the catalogue, on the sidebar of the map layers, where the legend of the map is equal to the most detailed level of the catalogue, which introduces the concrete values of indicators.

The content of the catalogue is best shown by its heading:

Component	**Georeferential element**	**Thematic overlay**	**Indicator**	**Unit of measure**	**Value** Data in the database	**Description**

The catalogue is compiled according to the logics of the geosystem:

a) Hierarchic levels in the following order:
- **element** of the geosystem (**Component** level)
  - **property** of the element (**Thematic layer** level)
    - **indicator** of the property of the element (**Indicator** level)
      - **value of indicators** (**Value** level).

Explanation of these levels:
- **Component** of the landscape – in the geosystematic interpretation, they are the basic elements of the system, which carry its material essence.
- **Thematic overlay** – this is the **properties of the component** processed and projected on a map related to a concrete database.

Of special importance is the overlay ***KEK_Sk – Landscape-ecological complexes***, in which each spatial spot carries the values of 19 properties of the landscape. They are all spatially harmonized according to their real functional relationships.

The types of the georeferential elements are given for each thematic overlay. In this case, they are vector data – polygons, lines (sections), points – and raster elements.

The Ipoly GIS contains 77 thematic overlays, to which concrete maps are related.
- **Indicator** – each thematic map is regularly described by several indicators. The measure of unit is also given for the value of each indicator. This can be a text (naming), code, date, real numerical data, serial number, ratio.
- **Value** of the indicator – this is the most detailed level of the system. In fact, this level represents the **database**. They contain the values of indicators in the study area. The values can also be seen when clicking on the element.

The individual levels of the hierarchy can be wrapped in and out in the electronic version of the catalogue.

b) The components are arranged according to their **material** form in the following way:
- **surface of the land (relief)** as the material element of the landscape;
- elements of the **primary landscape structure**: abiotic components (geology, soils, waters, atmosphere);
- elements of the **secondary landscape structure**: flora, fauna, present land cover;
- **landscape-ecological complex** as the synthesis of primary and secondary landscape structures;
- elements of the **tertiary landscape structure**:
  – protected areas, protected areas of natural resources, infrastructure zones;
  – indicators of the state of the environment;
  – indicators related to administrative units (settlement, district, county) – areas, population, infrastructure, environment protection.

The overlay of **Landscape use RL001_Sk** is characterized by 3 indicators. Due to its large volume (3 hierarchy levels, 14 element groups, 32 elements and 96 parts of elements), it is individually catalogued. Each part of elements is completed with detailed description, which is available by clicking on the object. Also due to the large volume, the overlay of **Cadastral area TU001_Sk** (altogether, 191 indicators in 14 groups with demographic and social data) cannot be accessed directly but through the tables of settlements.

The catalogue now includes 635 indicators and more than 1100 values, which are represented in the map. Naturally, the system is built up so that numerous other, not yet mapped indicators and their values can be entered into the system of the established georeferential elements without reorganizing it.

Table 2 and **Table 3** show the graphical structure of the catalogue.

Table 2.

Levels 1 and 2 – Components and thematic overlays (extract)

Component	Georeferential element	Thematic overlay
Relief	RASTER	**MORFOMET_Sk**
Waters	POLYGON	**PW001_Sk** – Small drainage basin
	POLYGON	**PW002_Sk** – Basic drainage basin
	POLYGON	**PW003_Sk** – Partial drainage basin
	POLYGON	**PW004_Sk** – Main drainage basin
	LINE	**PW005_Sk** – Divide
	LINE	**RW001d_Sk** – River
	LINE	**RW001_Sk** – River section
	POLYGON	**RW002_Sk** – Lake surface
	POLYGON	**SA010_Sk** – River surface
Climate	POINT	**RM004_Sk** – Meteorological station
	POLYGON	**PO002_Sk** – Climate-geographical area
Landscape-ecological complexes	POLYGON	**KEK_Sk** – Landscape-ecological complex
Socio-economic complexes	POLYGON	**SEK_SK** – Socio-economic complex **TU001_Sk** – Cadastral area
Environment	POLYGON	**ENVIRO_SK**

Table 3.

Levels 3 and 4 – Indicators and data (extract)

Component	Georeferential element	Thematic overlay	Indicator	Unit of measure	Value Data in the database	Description
Relief	RASTER	**MORFOMET_Sk**	hillshade		Data	Visual representation of the illumination of the surface
	RASTER		heights	[m]	Data	Elevation above sea level
	RASTER		heights_smt	[m]	Data	Elevation above sea level after applying smoothing algorithm
	RASTER		slope	[°]	Data	Value of slope drop
	RASTER		aspect	[°]	Data	Data of the raster refers to the azimuth
	RASTER		curv_profile	-	Data	Minus sign means concave, plus sign means convex form
	RASTER		curv_plan	-	Data	Minus sign means concave, plus sign means convex form
	RASTER		flowlength	[m]	Data	Length of the flow from the ridge to the measured pixel
	RASTER		flowacc_d8 (D8)	[m^2]	Data	Size of the area above the measured pixel calculated by D8 algorithm
	RASTER		flowacc_dinf (D-infinite)	[m^2]	Data	Size of the area above the measured pixel calculated by D-infinite algorithm
	RASTER		radiation	[$Wh.m^{-2}$]	Data	Solar radiation in 2010
	RASTER		radiation_dur	[hour]	Data	Duration of solar radiation in 2010

4. The interpretation of analytical data

The complete catalogue of the GIS of the Ipoly river contains more than 1100 rows of analytical data. They are all shown in maps and they can be compared on each land spot. This set of information is by far not the final content of the system. It is possible to generate numerous derived, interpreted or evaluated indicators from these analytical data. This paper presents here the process of three different interpretations, which can be derived from a relatively small number of simple indicators. However, they also use abiotic, biotic, landscape use and socio-economic indicators of the landscape, which are confronted with each other.

Table 4 shows the indicators used in the process; the names of indicators shown here are also used in the description of the interpretation processes.

Table 4

Overlays used in the interpretation

Component	Georeferencing element	Thematic overlayt	Indicator	Unit
Relief	raster	Morphometry	slope	[°]
			curv_plan	number
			flowacc_d8 (integrated surface)	[m^2]
Climate	polygon	PO002_Sk (geoclimatic unit)	subtype (climate subunit)	text
			prec_max leto (average maximum summer rainfall)	[mm]
Landscape complex	polygon	KEK_SK (Lanscape complex)	MORFO_POL (morphographic type of relief)	category
			GSK (geological-hydrologycal complex subtype)	Category
			HG_K (coeffincient of hydrogeological types)	[$m^2.s^{-1}$]
			PODNY_DRUH (type of soil)	category
			LANDUSE	category
			KEK_Limit (classification of disadvantaged complexes	category
Territorial units	polygon	TU001_Sk (register)	Shape_Area	[m^2]
		SEK_SK (socio-economic indicators)	POCET (number of inhabitants)	number
			POCProd (population of productive age)	number
			POCEkon (economically active population)	number
			POCPrac (working population)	number
Environment	polygon	ENVIRO_SK (environmental indicators	ZATAZ (degree of environmental pressures)	category

Important note: This article does not deal with the methods of calculating the coefficients, ranks and special values that describe the various functional properties of the abiotic and biotic components, because specialized institutions and scientists deal with them. Our task was to enter these special values into the GIS and relate them to the proper components and to their properties so that they be also spatially related to the georeferenced elements. Such data are, for instance, the coefficients that describe the water retaining capacity of abiotic elements (see [***1***]; [***5***]; [***6***]; [***12***]; [***13***]; [***31***]); the coefficients that analyze the inner ecological and social values of land-use elements (see [***4***]; [***8***]; [***10***]; [***16***]; [***22***]; [***28***]); the works evaluating the limitations on agricultural areas (see [***17***]; [***27***]); or the maps ranking the environmental loads (see [***2***]; [***17***]).

4.1 Accumulation of water at a given point in the drainage basin

The conditions of water discharge are of special importance for understanding the soil erosion and the danger of floods. Since it is practically impossible to have measured data at each point of the landscape to protect the area against these dangers, the interpretation procedures offered by the regional information systems are of great importance. In this case, interpretation means that from the landscape-ecological properties of the area entered into the information system and by modifying them, we can conclude on the discharge conditions. The logical steps of this process are as follows:

a) Absolute area - flowacc_d8

The basic analytical overlay is **flowacc_d8 – Integrated area**. This is an absolute area, from which the total amount of water would flow down and would accumulate in a point or profile without any hindrance. Naturally, there is no area like that, though in principle this could be a drainage basin fully covered by asphalt. However, this can be used for comparison after modifications in the following steps:

b) Area modified with abiotic elements – flowacAbio
flowacAbio = flowacc_d8.(slope/morfo_pol/GSK/HG_K/PODNY DRUH)

This is a reduction of the absolute area, which expresses the ratio of the abiotic complex and the water retaining capacity of the “asphalted” area ([***5***]; [***6***]; [***12***]). Practically, we will receive a figure as if the water had accumulated from a smaller area. This is not true, but the amount of water is reduced proportionally to the reduction of the area.

c) Area modified with abiotic elements and land-use – flowacLand

These are the elements of the real, existing landscape, which are reduced proportionally to the water retaining capacity of the landscape ecological complex. These are the most realistic data.

flowacLand = flowacAbio .(LANDUSE)

Naturally, the elements of the LANDUSE overlay are elements that can be found in the area, and they contain their water retaining capacity in a synthetic way, in the form of coefficients ([***12***]; [***13***]).

d) Accumulation of water from the area in the case of complete forest cover – flowacForest

This is an imaginary modification, which can be used for various comparisons (e.g. to what ratio would a fully forested area retain the water compared to the present real landscape use). This information may be considered when forming the recommendations. The process is the same as before:

flowacForest = flowacAbio .(LANDUSE_Forest).

e) Accumulation of water in the case of typical rains

Naturally, it is possible to modify the amount of rainfall in the real area proportionally to the reduction of the area, if the amount of rain is substituted in the expression:

flowacRain = flowacLand .(prec_max leto)

In this modification, the result shows the amount of water and not the size of the area. As the amount of precipitation changes in time and space, for giving forecasts it is more important to study the relative differences (which are constant data) of the areas (micro drainage basins) than the expected amount of water from imagined precipitation. Such constant data may be e.g. the differences of areas expressed in percentage. For example, let us see the data of three neighbouring micro drainage basins from the area of the Ipoly river (Veľký Krtíš/Nagykürtös District) (**Table 5**) according to the interpretations described above.

Table 5

Data of three neighbouring micro drainage basins from the Ipoly river area

1	2	3	4	5	6	7	8	9
		flowacc_d8	**flowacAbio**	**flowacAbio** : **flowacc_d8**	**flowacLand**	**flowacLand** : **flowacc_d8**	**flowacForest**	**flowacForest** : **flowacLand**
Pribelyi Stream	m^2	1993.76	1082.44	**54%**	380.00	**19%**	216.52	**57%**
Csábi Stream	m^2	2339.88	1241.60	**53%**	513.80	**22%**	248.35	**48%**
Nényei Stream – common drainage basin	m^2	4091.00	2027.85	**49%**	1006.75	**48%**	405.60	**40%**

Fig. 4 represents some thematic overlays of the micro drainage basins (not for detailed analysis, but only to show the spatial character and graphics).

4.2 Ecological quality of the cadastral area

Preserving the ecological stability is an exciting, practical challenge today. We have to answer questions like the state of individual areas and what kind of improvements they need if we want to achieve a certain level of the ecological service of the area. Measurements cannot answer these questions. However, comparisons and interpretations can help us again to evaluate the differences in various areas, and we may set a model value on this basis to be achieved. Such an opportunity is evaluating the area of settlements on the basis of data in the information system. This interpretation again means the modification of the areas according to their landscape ecological properties in the following steps:

a) Cadastral area of the settlement – Shape_Area

This is the basic data. Naturally, this area consists of several area spots with different land-use, which is stored in the **LANDUSE** overlay. These area spots represent different inner ecological values according to the land-use, which are described by coefficients $\mathbf{k}_{\mathbf{LANDUSE}}$ developed exclusively for them [***10***].

b) Ecologically qualified area of the settlement – Shape_AreaEcol

This is the weighted sum of the LANDUSE area spots, which is smaller than the total area of the settlement. This size depends on the proportion of the ecologically higher or lower quality land-use elements in the area:

Shape_AreaEcol = Σ ($\mathbf{LANDUSE_n}$. $\mathbf{k_{LANDUSEn}}$)

From this, it is possible to calculate the overall quality of the area expressed by a coefficient:

Koef_AreaEcol = Shape_AreaEcol : Shape_Area

This calculation can be done for various intervals, which then can be compared; this basic data can be modified further, such as:

c) Ecologically and climatically qualified area of the settlement – Shape_AreaEcolKlima

In this case, our results are weighted with the coefficients of climatic sub-types observed in the area [***17***]:

Shape_AreaEcolKlima = Shape_AreaEcol .[Σ(ShapeSubtyp$_n$. k$_{subtypn}$) : Shape_Area],

which expressed by coefficients is:

Koef_AreaEcolKlima = Shape_AreaEcolKlima : Shape_Area

To this, we can add the possible environmental load that reduces the quality of the ecological-climatic comfort, which can be expressed as:

e) Ecologically, climatically and environmentally qualified area of the settlement – Shape_AreaEnviro

This area is calculated by the weighting of the coefficient of the environmental load ([***2***]; [***17***]):

Shape_AreaEnviro = Shape_AreaEcolKlíma . [Σ(ShapeZataz$_n$ .k$_{zatazn}$): Shape_Area],

or:

Koef_AreaEnviro = Shape_AreaEnviro : Shape_Area.

Naturally, all these can be shown in maps and can be compared, and the value of a selected model area can be considered as a target (**Fig. 5.**).

4.3 Ecological quality of the cadastral area and the structure of population

Naturally, it is important to know the number of people and the structure of population to whom these indicators of the cadastral areas offer their ecological services. Several rational interpretations can be produced from the existing regional database. The starting point may be the following interpretation:

a) Environmentally qualified area per population – Shape_AreaEnviroPOC

This can be easily calculated:

Shape_AreaEnviroPOC = Shape_AreaEnviro : POCET.

Naturally, the larger the qualified area per inhabitant, the higher the level of the expected positive impact of the ecological services of the landscape will be.

This simple data can be modified several times. For instance, if we compare the environmentally qualified area with the economically active population, we will get a result that expresses the pressure of the population on the landscape.

In another way, we can interpret the agriculturally qualified areas, e.g.:

b) Quality agricultural area per non-active population – Shape_AreaAgriPOCUnemp

In this interpretation, we consider the quality of agricultural lands and the coefficients that may reflect their disadvantageous state [***17***]:

Koef_Limit = [Σ(ShapeLimit$_n$. k$_{limitn}$) : Shape_Area]),

and this data is confronted with the economically active, but unemployed population at the moment:

Shape_AreaAgriPOCUnemp = [Shape_AreaAgri.Koef_Limit] : POCUnemp

This data might be viewed as an indicator of the chance of out-breaking for poor and marginal areas. The larger the size of the qualified area per head, the larger the potential in the use of the land and in employment will be. If the same figure is used with the number of employed women, we may receive information on the potential of women employment (**Fig. 6**).

5. Tasks executed in the Ipoly programme

- Conceptional, logical and detailed system planning, definition of the data groups relevant for the project;
- Identifying the available databases in cooperation with professional service providers in Slovakia and Hungary;
- Adjusting the data to the objectives, examining their usability;

- Defining the data types and variables;
- Defining and standardizing the metadata;
- Providing multilingual search for elements in the metada;
- Harmonizing the databases;
- Making the harmonized databases available for authorized users;
- Monitoring the use of the database;
- Modifying, correcting the system according to feedback.

In the Ipoly project, we defined, by considering the ISO 19115:2003 standard set out in the INSPIRE Directive, the metadata related to professional data.

Again, let us consider the table of ENVIRONMENT = LANDSCAPE (**Table 1**). This is an operation system, which provides the basis of “conceptional, logical and detailed system planning”, the “definition of the data groups relevant for the project”, the structural basis of data demands, the principle of the continuous and interactive relationships of real processes in the environment. ***This is the basis of organizing the thematic maps and the harmonization of data layers.***

5.1. Content elements of the metadata (in Hungarian, Slovak and English language)

- Term of the professional data;
- Author and copyright holder of the data;
- Availability of the data;
- Rights of the user;
- Geometry of the database;
- Projection system of the spatial data;
- Description of variables in free text.

The free description of variables was extended and we built the complete descriptive database, in which the metadata related to professional data are separate elements (thus, they can be harmonized) in the complete descriptive database system.

During the development, we completed the system of spatial and thematic information in the descriptive database with further professional-specific metadata elements.

5.1.1. Type of the geometry of the database (point, line, polygon or raster/cluster)

5.1.1 Data of the point-based system
5.1.2.1. Method of sampling: *once*;
5.1.2.2. Method of sampling: *averaged*;
5.1.2.3. Density of sampling points (point/ha, point/km^2);
5.1.2.4. Location of sampling points: *random*;
5.1.2.5. Location of sampling points: *consequent or along a grid*;
5.1.2.6. Location of sampling points: *along a grid*.

5.1.2. Data of the line-based system
5.1.2.1. Interpretation method: *isoline*;
5.1.2.2. Interpretation method: *special or other*;
5.1.2.3. Type of data source: *primary*;
5.1.2.4. Type of data source: *uniform/derived*;
5.1.2.4.1. The *uniform/derived* data should characterize the interpolation of the original database as well as the method of calculating the isoline (name of the data source, preferably reference to literature, maintaining and producing institution)

5.1.3. Data of the polygon-based system
5.1.3.1. Content: *homogeneous* or *complex*;
5.1.3.2. Scale;
5.1.3.3. Type of data source: *primary* (based on terrain data) or
5.1.3.4. Type of data source: based on data extension;
5.1.3.5. Type of data source: *uniform/derived*;
5.1.3.5.1. The *uniform/derived* data should characterize the original database (name of the data source, preferably reference to literature, maintaining and producing institution).

5.1.4. Data of the raster system
5.1.4.1. Resolution: *point extension*, *bulk majority* or *bulk average*;
5.1.4.2. Content: *uniform* (one value or class) or
5.1.4.3. Content: *several values/classes* (probability of appearance, percentage of occurrence);
5.1.4.4. Spatial resolution of the raster data, cluster classification;
5.1.4.5. Data type: *primary*;
5.1.4.6. Data type: *interpolated*;
5.1.4.6.1. In the case of *interpolation,* information on the original database is needed (name of the data source, preferably reference to literature, maintaining and producing institution);
5.1.4.7. Data type: *scanned*;
5.1.4.7.1. In the case of *scanning*, information on the scanned database is needed (name of the data source, preferably reference to literature, maintaining and producing institution).

5.2. Professional characteristics and variables
5.2.1. Name of the variable – *it is important to note that there are differences in the specific terminology of professions and that the changes in the geographical names can also lead to difficulties of identifying places!*
5.2.2. Place in the system of landscape forming factors;
5.2.3. Categories of properties;
5.2.3.1. Physical properties;
5.2.3.2. Chemical properties;
5.2.3.3. Biological properties;
5.2.3.4. Other.

5.2.3.2 Chemical properties
5.2.3.2.1. pH;
5.2.3.2.2. Soluble salt content;
5.2.3.2.3. Chemical qualification _1st class;
5.2.3.2.4. Chemical qualification _2nd class;
5.2.3.2.5. Chemical qualification _3rd class;
5.2.3.2.6. Chemical qualification _4th class;
5.2.3.2.7. Chemical anomalies of natural origin *(e.g. geochemical peculiarities)*;
5.2.3.2.8. Chemical peculiarities of pollutants;
5.2.3.2.8.1. Heavy metals;
5.2.3.2.8.2. Organic pollutants;
5.2.3.2.8.3. Other.

5.2.3.3. Biological properties
5.2.3.3.1. Flora;
5.2.3.3.1.1. Indicator species;
5.2.3.3.1.2. Food species;
5.2.3.3.2. Fauna;
5.2.3.3.2.2. Indicator species;
5.2.3.3.2.3. Food species.

5.2.4. Soil classes
5.2.4.1. Physical properties of the soil;
5.2.4.2. Chemical properties of the soil;
5.2.4.3. Local factors of soil development processes;
5.2.4.4. Diagnostic properties/levels/materials;
5.2.4.5. Bonitation, land assessment.

5.2.5. Name of the measuring method, ISO reference

5.3. Type of the variable
5.3.1. Type of the variable: *number_integer*;
5.3.2. Type of the variable: *number_float*;
5.3.3. Type of the variable: *text*.

5.4. Time of sampling
5.4.1. Time of sampling: *once*;
5.4.2. Time of sampling: *several times, irregular*;
5.4.3. Time of sampling: *several times, regular (repetition interval)*.

5.5. Data communication
5.5.1 Data communication: *raw data*;
5.5.2. Data communication: *estimated data*;
5.5.3. Data communication: *classified*.

5.6. Accuracy of the data
5.6.1. Accuracy of the data: *uncertain*;
5.6.2. Accuracy of the data: *authentic*;
5.6.3. Accuracy of the data: *statistical average, other*;
5.6.4. Accuracy of the data: *estimated (poor, average or good)*.

The Ipoly project was started to harmonize the professional databases. We made steps to standardize the basic environmental data according to the directives of INSPIRE. It was a major task to establish an environment-specific system of the descriptive data for the Ipoly river following the requirements of ISO 19115:2003. This structure is indispensable in environment protection also as a framework of the specific descriptive data system for the complete geoinformatic system, which holistically contains every professional area of environmental sciences.

One of the results is the „***Ipoly Thesaurus of Environmental***”, which contains the standardized key terms used in the profession, thus guaranteeing unambiguous search in the harmonized metadata of the databases.

The users can use the system through the Internet in three official European languages (Hungarian, Slovak, English). In this way, other available European and national databases become more easily accessible.

The creation of the standardized metada is a common interest of users, professionals and data providers. The project may become a part of the European Union's cross-border, uniform environmental policy and decision-making system supporting environmental protection as well as of the information portal supporting the distribution of spatial data among institutions and countries.

6. Practical experiences in the Ipoly project

The drainage basin of the Ipoly river shows a variety relief. Its general map was made by using the DTA 1:50,000 georeferenced raster image developed for military purpose and the vector image at the same scale. These images were fitted on the Slovakian 1:50,000 scaled raster and vector maps made for civil purpose. The best fitting was achieved in the UTM 34 projection.

There were significant fitting problems at the country borders, which were solved by analyzing the data content of 1:10,000 topographic maps used in both countries. For this, several iteration steps had to be made.

The thematic maps for the Hungarian and Slovakian parts were available at scales between 1:10,000 and 1:500,000. In certain sciences (hydrology, soil cover, geology, pedology, flora, fauna, land-use, etc.), the mapping (partly graphically, partly digitally) was carried out in different scales, just like the representation of related attributes and their collection in professional databases.

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In a standardized spatial information system, every data in the system can be corresponded to a place; therefore, it is an objective to represent the data spatially in the most accurate way. However, the MÉTA database is an exception, which offers the weighted representation of the vegetation cover in the form of hexagonal units in the study area. The natural capital index (NCI_{lin}) of vegetation was calculated for each MÉTA hexagon, which expresses in percentage (0–100%) the natural character of the area/landscape. The coefficient of natural character in the Slovakian RGÖSZ areas is interpreted in a similar way.

The MÉTA database made of weighted data does not satisfy the needs of users in every respect due to the statistical processing, but it provides useful information about the studied regional units (**Fig. 7.**).

Our GIS technology makes it possible to separate the vegetation species, their representation in vector format on individual layers together with the attributes related to individual species. This is of great significance, because our developed method makes it possible to study – by the various combinations of the overlays of thematic maps – the impact sources and affected factors in the complete system of landscape elements. We can, for instance, realize the real risks and model the potential environmental future by confronting the geographical (morphological, hydrological, etc.), physical, chemical and biological data that determine the ecological demands of protected species with the relevant map layers of anthropogenic emissions and regional planning concepts.

Please note that the military survey maps prepared in the XIXth century were also studied, because they can be considered as representations of the state of the environment. In this way, we can evaluate the changes in the environment, the modification of land-use, the impacts and consequences of the natural and anthropogenic factors of the landscape.

Character of the geoWEB portal

The interactive user program developed for Internet is based on the microATLAS PlainLine© frame system.

The system in multi-user / multi-task mode can actively serve several users in the environment of a high security level LINUX operation system.

The vector maps in of various formats (shp, dxf, dwg, dgn, mif, etc.), the georeferenced raster maps (tif, jpg, pgn, etc.) and the attribute data are stored in a relational database manager integrated in the framework system.

The server converts the various formats of graphical and alphanumerical data into its uniform format. In this way, the native handling of data is possible and the reaction time to requests is shorter.

At present, the surface for general and registered users is available in Hungarian and partly in Slovak language.

After testing, the three-language GIS service and the interactive analyzing and statistical service system will probably be available in 2014.

CONCLUDING REMARKS

This project worked out a model of theoretical and methodological processes. However, in the application of spatial information systems, there is still a major challenge to be solved; namely, the technical potentials, cartographic basis, and the **establishment of a balance** between the topographic elements and thematic map elements. The answer can only be given by the continuous joint work of the users' experts and the GIS specialists.

The project is also a good example of cross-border cooperation. We very much hope that our knowledge and experience will be developed further and they will contribute to the forming of a modern information society; to the uniform and transdisciplinary study of interactive processes in the environmental system; to supporting the conservation of the habitats of protected species; to guaranteeing the harmony between the society and its environment.

"The history of geographic thought is not the same as the history of the science of geography, because in my view the geographic thought is the general understanding of the outside world and environment. This thought is not owned by a single discipline but it is a general human idea reflecting the conscious men's relationship with their home, with the Earth." … "Maybe this approach is more important in respect of the development of geographic thought than the specific details of reasoning or combinations with data, the elaboration of which would require several volumes." … "The man of every age searches those moments in the relationship of earthy phenomena, objects and processes, and particularly in his relationship with the Earth, … which are needed for his uniform understanding of this relationship." – said Count Pál Teleki in his inauguration address in the Academy in 1917 [***29***].

Now it is time to implement this idea in practice by making use of the opportunities provided by the information technology.

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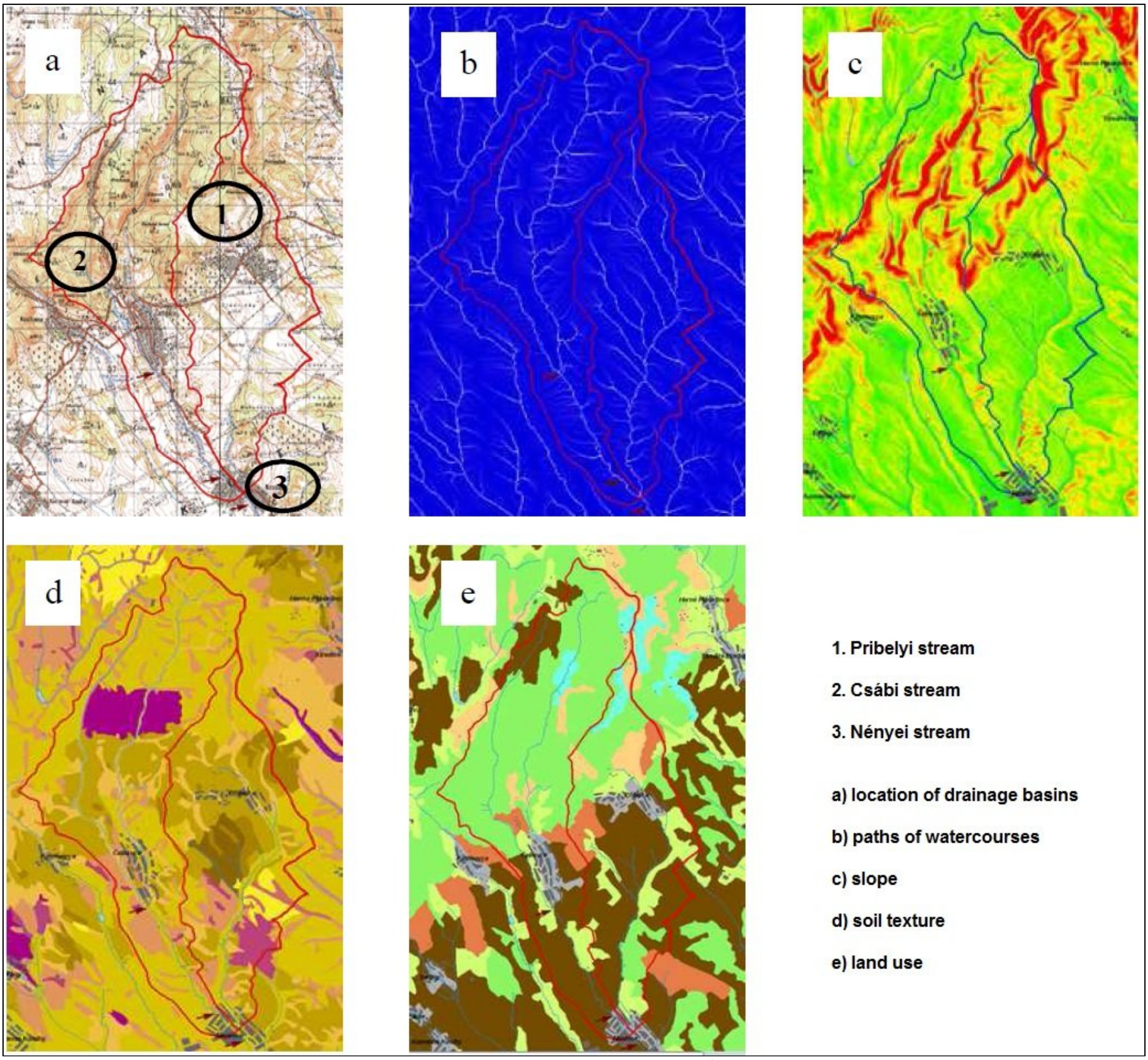

Fig. 4. Three micro drainage basins – examples of thematic overlays

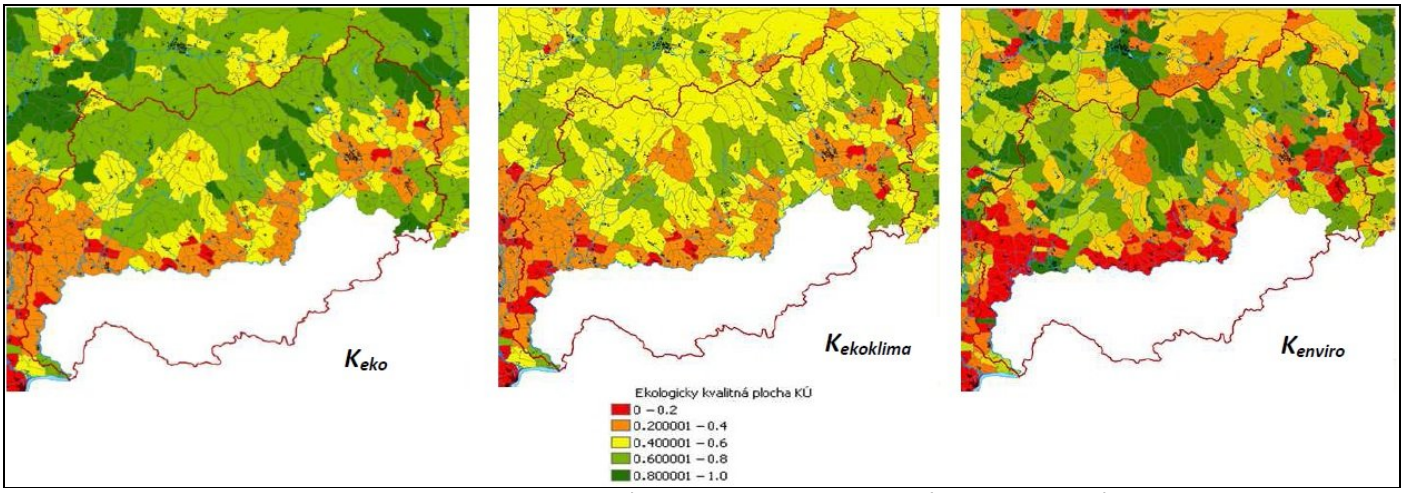

Fig. 5. Ecological, climatical and environmental quality of the cadastral areas on the Slovakian side of the Ipoly drainage basin.

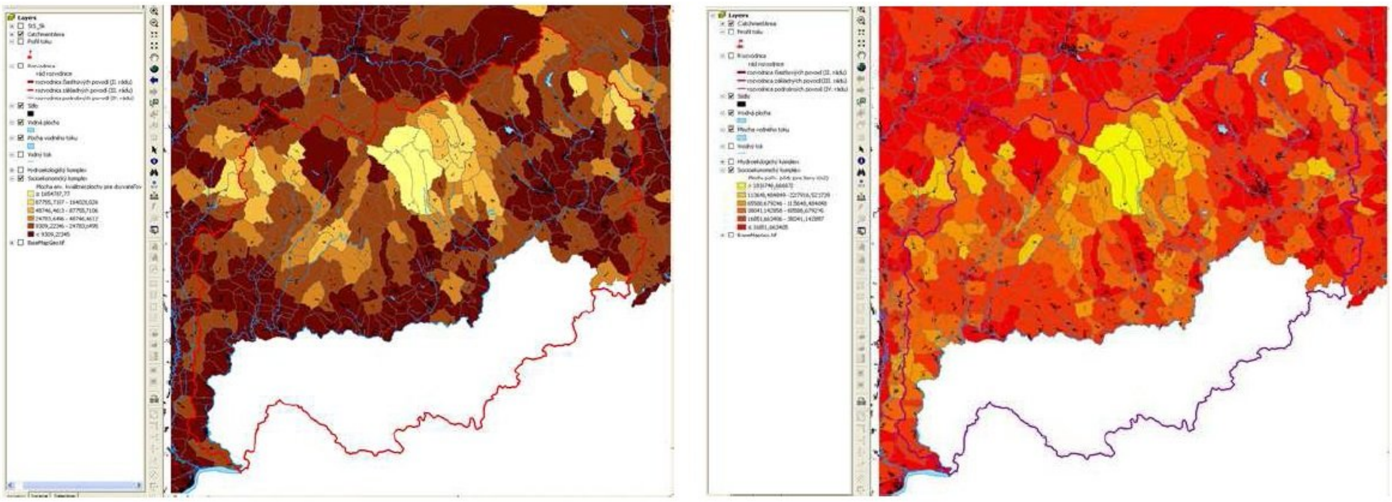

Fig. 6. Environmentally qualified area per population (left) and qualified agricultural area per women population (right)

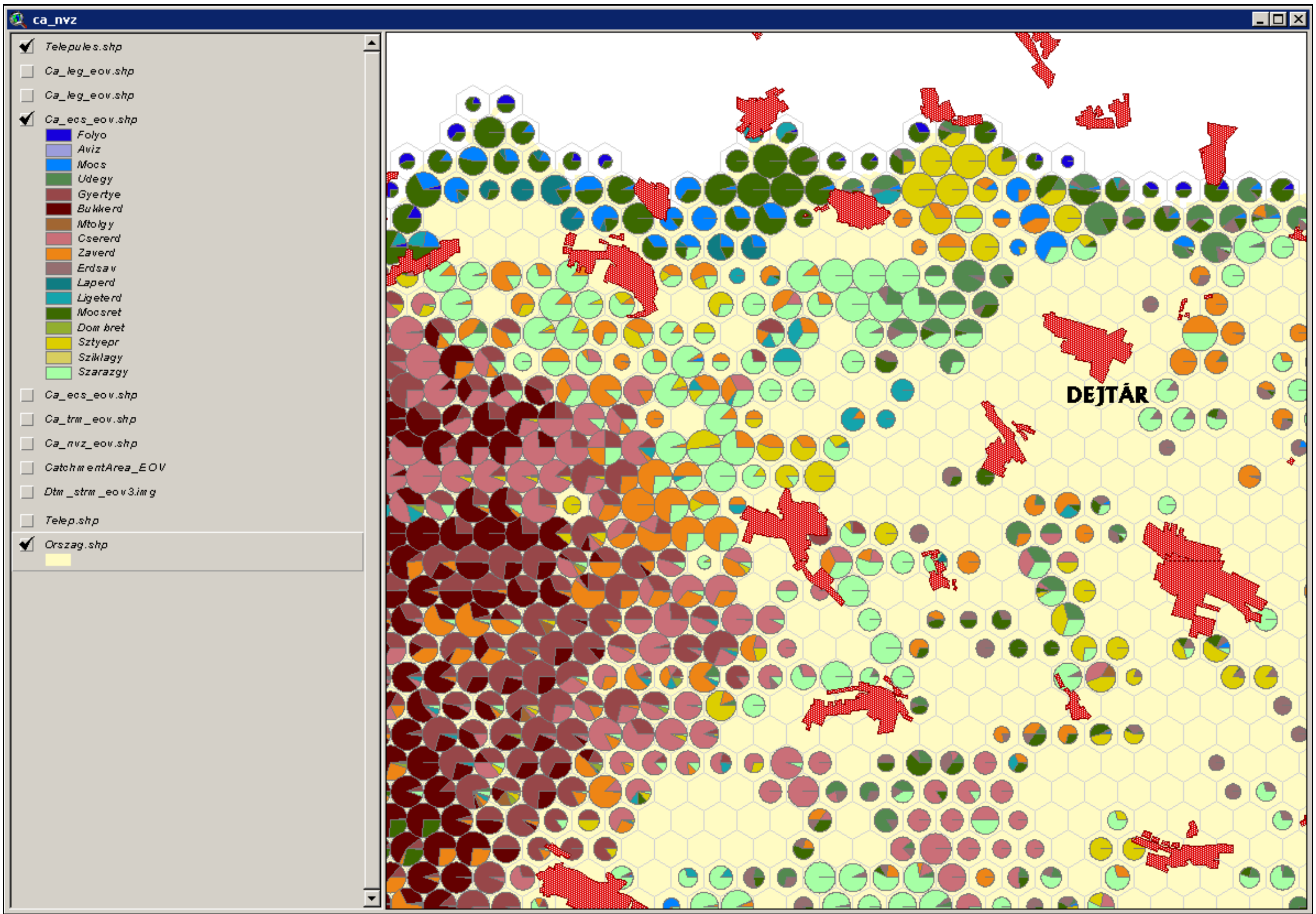

Fig. 7. MÉTA map of biotope groups in the Hungarian part of the Ipoly drainage basin; pie charts are used on a smaller part of the area