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DIDACTIC ASPECTS OF GIS APPLICATION IN GEOGRAPHIC SCHOOL EDUCATION

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ABSTRACT

Didactic aspects of GIS application in geographic school education

GIS is recognized as very powerful tool in many aspects. However, its application within education system is still problematic, due to many obstacles, which are in particular present in less economically developed countries. This paper is focused on introduction of innovative concept of GIS education within geography classes in primary and secondary schools. Existing theoretical base is used to emphasize multiple benefits of geoinformation technology application in education, in particular from geographic perspective. Under this concept, GIS is considered as natural partner to geography, where it is not viewed only as a tool, but also a methodological foundation of contemporary geographic science. In the didactic context, GIS can be used in education as a teaching aid, method, or content. Optimal pedagogical and practical framework for successful implementation is yet to be found.

KEYWORDS
GIS, geographic education, teaching aid, teaching method, teaching content

1. Introduction

Geography as a systemic science that studies natural and human components on the Earth surface, as well as their mutual interactions and connections, have contemporary role in identification of intensity and spatial-temporal dynamics of features and processes. This function is particularly important from aspect of defining optimal solutions in valorization of natural and social resources, environmental management, regional and spatial planning, economic development, geopolitical issues etc. Considering described significance and role of geographic science, it can be said that one of the crucial elements that defines quality if assigned tasks implementation is geographic education. This process is fully grounded at all levels of education, from primary, through secondary, to university level. In accordance with contemporary pedagogic and didactic trends in general education, informatization in preparation, interpretation and presentation of educational contents has become integral segment of teaching at all aforementioned levels. In this regard, geography has got its own digital expression. Because of its basic purpose in the field of multi-user geospatial research, it is called Geographic information system – GIS (Drešković et al., 2015).

There are many definitions of GIS, whose content usually depends on type of users, purpose of application, or gained experience in certain field. Basically, it can be stated that there are groups definitions, which interpret GIS only partially, i.e. on the basis of just one or two its elements. They are also the most numerous. In a broader context, various mapping systems, like digital atlases, or complex systems for geovisualization and partial database manipulation, fit within this framework. Unlike mentioned system types, narrowly defined GIS applications have possibilities of absolute geodata management from every aspect of its application – starting with preparation, through procession and creation of thematic map sets, to storing and editing. In this regard, as one of the most adequate definitions in the sense of completeness is one which considers GIS as information system (hardware, software, experts and data), that is designed for automated graphic and numeric treatment of geographic data from the aspect of its entry, methodologically controlled procession, presentation, output of final (digital and printed) product and storage (Drešković, Đug, 2012).

Even though there are numerous possibilities that is offered by GIS, as well as its various available applications, educational dimension of GIS is still largely limited, and its potential is not achieved so far, especially in the context of primary and secondary education. Disparities between more and less economically developed countries exist in this case too, however general global situation in this field cannot be rated as satisfactory, in the first place because there are more barriers and problems that complicate GIS entrance in

classrooms, than solutions for them. Nevertheless, considerable progress is achieved in the last three decades through active engagement of academic and school workers, thanks to whom are developed certain basic concepts of GIS application in geographic education, as well as in some other subjects. Whole that process is founded on interdisciplinary research in the various geographic fields, information technologies (especially geoinformatics) and off course didactics and pedagogy. Didactic and pedagogic aspect of this issue represents key domain where argumentation for GIS technology incorporation in school system can be found.

2. Geovisualization aspect of GIS education

GIS should not be identified only as a cartographic tool, because it is just one of its numerous functions. However, though educational application of GIS emphasize is primary placed on the development of students cartographic skills. This aspect of cognitive development is recognized in geographic didactics much before the appearance of geoinformation technology. In that sense, it seems meaningful to make a comparision of maps that are traditionally used in geographic education (wall maps, atlases, textbook maps, blank maps etc.) with digital cartographic dimension, which is promoted by various types of modern technology, including GIS. According to Vemić (2009), there are four basic distinctions of virtual cartographic models in relation to traditional ones. These are: computer generic nature, possibility of programmed management of synthesized geovisual representations, interactive operability on created representation and virtual environment, and reducing features of symbolism and conditionality through adding realistic contours of naturalness.

Virtual georepresentation also has a variety of other immanent features, like program management, properties of animation, multidimensionality, multimediality, multithematicity and high level of informativeness (Berlyant, 2001). Considering that human acquire most of its knowledge and information about environment visually, it is obvious that visualization of geographic contents represents issue of essential significance, not just for GIS technology, but also for the comprehensive concept of geographic education.

Maps have always been a rich source of information about various themes. Their main advantage is the fact that they represent a medium that occupies pretty small space in relation to amount of information which is contains. Digital maps and virtual models of geographic reality went even further in that sense, because they do not represent only the visualization of spatial distribution of certain natural and human-made objects on the Earth surface.

They also provide a possibility to students to used them in more than few different ways, by prompting of understanding of relationships, connections and patterns within spatial phenomena, such as ecoregions, land use, demographic characteristics, river basins, trade, natural hazards etc. With evolution of cartographic technology and by increasing its availability to a wider range of users, with help of Internet among other things, teachers and students have, as never before, very abundant spectrum of data and tools at their fingertips, which enables them to do research on key issues and problems of 21st century, from local to global scale. Now, it is easy for them to use contemporary cartographic visualizations, as well as to create their owns and to share them with each other. These kinds of maps have became multimedial teaching material, which could realize possibility of students engagement for the purpose of acquiring of interdisciplinary knowledge and skills (Kerski, 2013).

Full creativity in the process production of digital maps and their analytical treatment is enabled only by GIS. Many authors interpret application of GIS and other geoinformation tools as a reflection of transition from behaviorism to constructivist approach. GIS methods, which are based on exploration and problem solving, have introduced different perspective on educational practice in schools. There is a discussion about which student age is appropriate for introduction with GIS technology. Some opinions suggest that this type of software are not suitable for primary school, but certain research studies showed that it can be useful at this level if materials are adequately prepared and effective guidance through program is provided (Çepni, 2013). Sinton and Lund (2007) emphasize that GIS can turn students into cartographers, by giving them a possibility to visualize the world in the way they see it. That is how they take responsibility for implied messages of their own maps. By gaining this kind of experience, even very young students become wise interpreters of information that is communicated through cartographic contributors. GIS helps them to perceive geographic maps in much ‘deeper’ sense than just identifying distribution of lines and colors.

3. Geographic aspect of GIS education

There is notion in certain papers about GIS as one of the greatest achievements in the context of technological development of humanity in the 20th century. Wiegand (2001) gives the opinion that GIS represents the biggest contribution of geography to society since the Age of Discovery. Besides revolution that it has brought to the spatial analysis methodology, GIS also encourages discussion about comprehensive reforms in education, especially in geographic education.

It application in educational purposes was firstly implemented at university level, and after that it slowly began to expand into lower education levels. That process emerged in the late 1980's, together with maturation of theoretical and intellectual bases of GIS (Mark et al., 1999). In this period, GIS is recognized as a tool that provides possibility of bringing closer functional usage of technology to students and motivating them to choose carrier in science or engineering. Soon after that, many research studies found out that GIS represent powerful educational tool, which crates adequate conditions for inquiry learning. Because of these pedagogic advantages, GIS has found its place within secondary school (somewhere even within primary education) curricula of many countries, and not just for geography, but also for biology, chemistry, mathematics, history, social and environmental studies etc. (Demirci, 2008)

Purpose of GIS in education is to support and stimulate spatial thinking, but also to prepare students for active participation in handling social issues. GIS can be considered as a tool for spatial analysis of such, however GIS software unavailability seems as a problem difficult to overcome in the practice so far, because of high expenses, lack of expert knowledge or other kinds of barriers. To eliminate large number of these barriers, it is necessary to expand educative courses about spatial information application, which would have wider social significance. Gryl et al. (2010) suggested that GIS study environment should be adapted to human interests and existing knowledge. That in particular means that GIS has to be applied as a auxiliary teaching aid for finding a solutions to everyday spatial issues, especially within the framework of integral and multidisciplinary lessons. On the other hand, Chen (1998) asserted that even though there are no universal consensus about the most effective ways of GIS application in education, great need for continual discussion and revision of GIS education will always be needed. He also advocate an approach based on examples from real geographic and multidisciplinary perspective, which would attract students attention and expand their horizons.

Since the beginning of 21st century, increased interest for educational usage of GIS has been a reflection of broad social interest for geospatial technology. In the meantime, geographic information have become omnipresent in everyday life, which is the fact mirrored in widespread use of devices that have functions of location and navigation. In response to this trend, many international initiatives emerged in accordance with the emphasis on the need for appropriate geospatial education. E.g., European Union directive establishing an infrastructure for spatial information from 2013 put an emphasis on citizens being able to understand, interpret and apply geographic information. Stronger involvement of geospatial technologies (GIS in particular) in school systems is imposed as a logical step with respect to social tendencies explained above (Riihelä, Mäki, 2015).

European context is emphasized also by Donert (2014), who points out that digital geotechnology enables scientists and educators to focus on actual challenges of today's Europe, like economic efficiency, resource scarcity, renewable energy, natural hazards, food and water supply, environmental degradation, migrations and smart cities. However, European Union is highly aware of disproportion between pompous presentation of geoinformation technology and weak response in education systems, and because of that, it set as a primary target intensification of geoinformation application, especially for the purpose of acquiring practical skills in usage of various web pages with geodata (Svatoňová, Mrázková, 2010).

GIS is natural partner to geography, and regional geography in particular. Capable geography teachers can easily integrate GIS methodology within inductive, as well as deductive thinking processes (Sinton, 2009). According to Montello (2003), geography education, which is usually perceived in traditional sense of concise description of Earth surface differentiation from natural and social aspect, always will require some form of regional concept. Well-intended regionalization also will always be very helpful in the context of visualization of geographic information. Geodata are frequently positioned within the regional units framework, but even when that in not the case, they are represented by isolines, which again give expression of regional organization.

Even attempts to represent geographic data exclusively with continuous, i.e. raster fields, cannot change natural human tendency to organize information into discrete units, because perceptual grouping and identifying of clusters is one of the basic principles of spatial cognition. This is important to emphasize, since many behaviorist geographers suggest that our attitude toward places and regions is closely related with two phases – foremost perceptual, and than cognitive. As early as infancy period, an individual develops strong emotional attachments to places that are known and important to him/her, creating in such manner quite clear mental boundaries around those areas. At the same time, level of geographic thinking about distant places (regions) is under strong influence of the way geographic information are being presented (Fargher, 2010). There is need to consider the potential role of GIS precisely in that context.

4. Methodological aspect of GIS education

Framework structure of GIS in education as a field of scientific research emerged in formal sense together with the call for an agenda and center for GIS education research (Baker et al., 2012). On that occasion, it is stated that teaching about GIS partially represents education about GIS software, primarily within geoinformation science, carrier skills and technology aspect.

Through this approach, focus is placed on geodata analysis and representation methods, and participants in of this particular type of education are being prepared for carriers in the fields close to application of GIS and geoinformatics. On the other side, teaching with GIS implies education process where GIS is used only as an aid or tool, which helps students how to solve problems and understand concepts from various disciplines, e.g. geography, but also environmental science, history, mathematics, biology, chemistry etc. In this case, educational goals are focused on functional application of spatial analysis for recognition of patterns, relations and trends between phenomena and processes in geographic space.

To enable instructors and educators to use GIS, significant effort has been invested in this concept since the end of 20th century, by academic community, various companies, teachers, government agencies and non-profit organizations from different parts of the world. Purpose of these activities is to provide opportunities to school teachers and their students to effectively use GIS software, methods of spatial analysis and spatial perspective to improve their skills, content knowledge and adaptation to labor market. Targeted skills belong to different domains, ranging from purely educational (critical thinking, exploration, or peer interaction) to geoinformational (geodata creation, operations with map projections, data overlay, various analysis, etc.). Role of GIS in acquiring content knowledge includes applicability in existing themes within curriculum, i.e. data manipulation and visualization, e.g. in the context of scale, biodiversity, spatial relations between human and natural environment, or simply the phenomenon of region. Equally important aspect of GIS education is introduction of geoinformation science to students in purpose of building future carrier skills in the field of related sciences, marketing and business management, government institutions, or education (Baker et al., 2012).

As GIS has become easier and more practical for use, its proliferation happened in many different school subjects and scientific study fields. Teaching with GIS in many countries now starts at the primary or secondary level of education, within themes like plate tectonics, biomes, climate, migrations and other issues with geographic essence. In the meantime, insights have emerged about applicative value of GIS also in natural sciences and mathematics, especially at the university level (Sui, 1995; Arlinghaus, Kerski, 2014). This process has been followed by diffusion of geoinformation technology through other fields, like economy, sociology and engineering. Although GIS has increasing application in geographic and non-geographic fields, there is relatively scarce research about GIS impact on scientific work and education process. Previous research about GIS in education is generally focused on particular technology effects in the context of learning outcomes.

However, there is obvious deficit of research on how and under which circumstances GIS as teaching aid can be effective (Segall, Helfenbein, 2008). Its general effectiveness has foundation is interdisciplinarity, which moves the boundaries of geography, mathematics, literacy, Earth sciences, cartography, remote sensing, cognitive psychology, biology, IT science and other disciplines. GIS has also set platform for establishment of dialogue and cooperation between scientists in aforementioned fields, with particular focus on questions about spatial, critical and analytical thinking, technological dimension of education and scientific research.

5. Proposition of multifunctional GIS education in Bosnia and Herzegovina

Strong requisite for modernizing concept in geographic education in primary and secondary schools in Bosnia and Herzegovina is based on the fact that educational contents and teaching aids have not been significantly changed in progressive way for decades. Education process is strictly limited to application of traditional teaching methods, and particularly alarming consequence is referred to absence of needed dynamism in school geography. This ascertainment rests on obsolescence of existing textbooks, maps and other teaching material that is currently used in primary and secondary schools in Bosnia and Herzegovina. Application of out-dated and inadequate teaching methods and aids is also detected as a significant deficiency that contributes to general devaluation of acquired knowledge and skills within student population. This can be considered as one of the reasons for decreasing importance of geography at all levels in the national education system.

Considering all stated facts, demands for multifunctional modernization of geographic education process are seemed unavoidable, starting from the aspect of teaching aids to methods of interpretation of geographic contents, especially regional ones. The most obvious solution that can be applied in order to meet these demands is identified in geoinformation potentials of GIS, as innovative method and resource in exploration and presentation of geographic features and processes. To be more precise, GIS has potential to completely satisfy pedagogic and didactic demands of geographic education process in primary and secondary schools. Its application could open many new opportunities in the context of acquiring knowledge and skills by students. Although GIS resources and methods have wide range of educational possibilities, for the purpose of this paper, three didactic aspects of GIS in geography are selected here:

- GIS as a teaching aid
- GIS as a teaching method
- GIS as a teaching content

Application of GIS as a teaching aid, method, or content is based on the concept of presentation of lessons through geovisualization of spatial contents and qualitative-quantitative attribution of supporting geodatabase. Geovisualization of education contents is related to digital creation of adequate spatial entities, and it can be implemented at two different levels – raster and vector. Raster is the graphic model that represents continuous visual fields resembling the Earth surface. It is often generated by taking images from satellites, special planes, or drones (Figure 1.). Fundamental raster features are spatial resolution and geocoding format. Contemporary raster types are created in high resolution, where each of his segments (pixels) is spatially defined very precisely. On the other side, vector model is the most common way of geovisual representation of geographic reality, in regional context in particular, by use of points, lines and polygons. Specific significance of its application lies in the fact that these spatial contents are also organized through supporting database in the form of table. Attributes of spatial entities are defined in a table columns, while their content record is represented in a rows (Figure 2.). For educative purpose, it is important that vector model of geodata allows application of mathematical algorithms for creation of new attributes. This is important for development of cognitive and practical skills within spatial analysis.

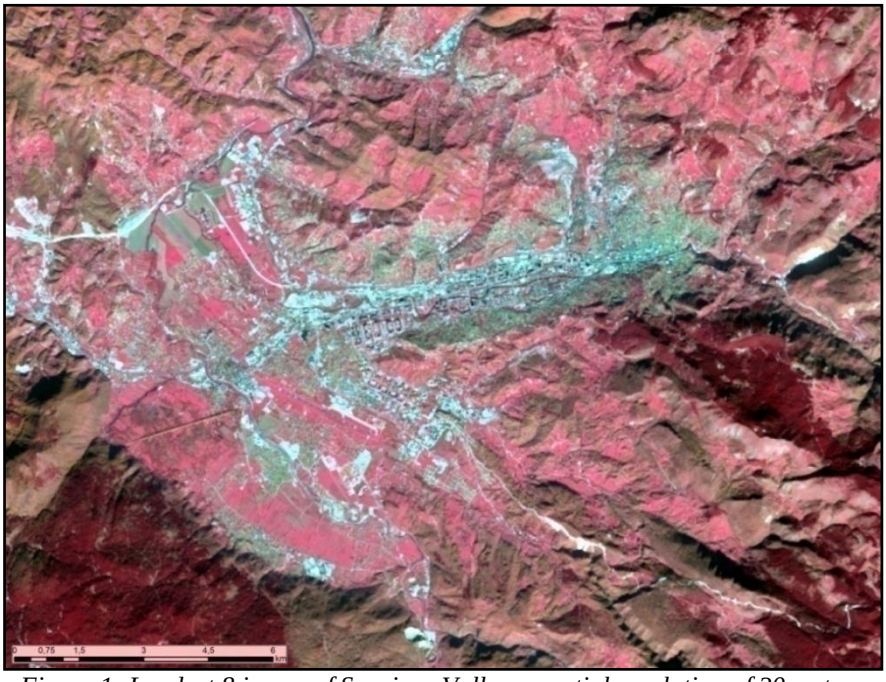
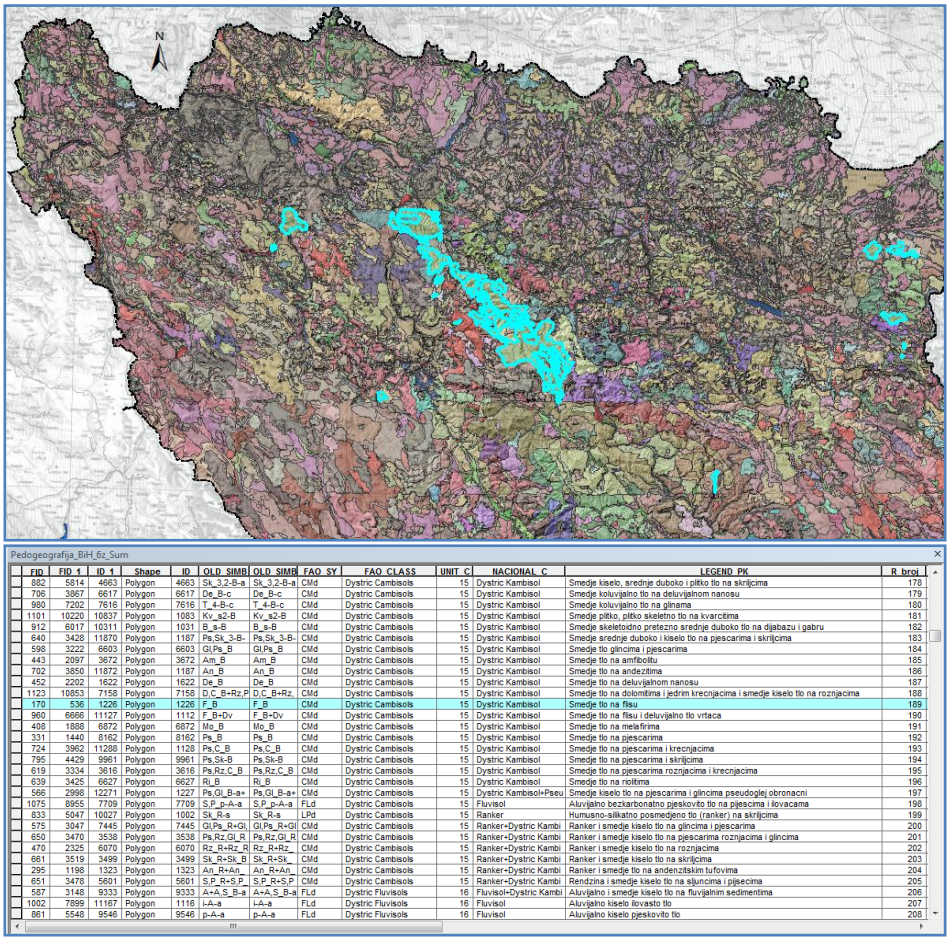


Figure 1: Landsat 8 image of Sarajevo Valley – spatial resolution of 30 meters (example of raster graphic model)



FID	FID_1	ID_1	Shape	ID	OLD_SIMB	OLD_SIMB	FAO_SY	FAO_CLASS	UNIT_C	NACIONAL_C	LEGEND_PK	R_broj
882	5814	4663	Polygon	4663	Sk_3,2-B-a	Sk_3,2-B-a	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe kiselo, srednje duboko i plitko tlo na skriljcima	178
706	3867	6617	Polygon	6617	De_B-c	De_B-c	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe koluvijalno tlo na deluvijalnom nanosu	179
980	7202	7616	Polygon	7616	T_4-B-c	T_4-B-c	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe koluvijalno tlo na glinama	180
1101	10220	10837	Polygon	1083	Kv_s2-B	Kv_s2-B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe plitko, plitko skeletno tlo na kvarcitima	181
912	6017	10311	Polygon	1031	B_s-B	B_s-B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe skeletolnino pretežno srednje duboko tlo na dijabazu i gabru	182
640	3428	11870	Polygon	1187	Ps,Sk_3-B-	Ps,Sk_3-B-	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe srednje duboko i kiselo tlo na pjescarima i skriljcima	183
598	3222	6603	Polygon	6603	Gl,Ps_B	Gl,Ps_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo glincima i pjescarima	184
443	2097	3672	Polygon	3672	Am_B	Am_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na amfibolitu	185
702	3850	11872	Polygon	1187	An_B	An_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na andezitima	186
452	2202	1622	Polygon	1622	De_B	De_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na deluvijalnom nanosu	187
1123	10853	7158	Polygon	7158	D,C_B+Rz,P	D,C_B+Rz,	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na dolomitima i jedrim krecnjacima i smeđe kiselo tlo na roznjacima	188
170	536	1226	Polygon	1226	F_B	F_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na flisu	189
960	6666	11127	Polygon	1112	F_B+Dv	F_B+Dv	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na flisu i deluvijalno tlo vrtaca	190
408	1888	6872	Polygon	6872	Mo_B	Mo_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na metafirima	191
331	1440	8162	Polygon	8162	Ps_B	Ps_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na pjescarima	192
724	3962	11288	Polygon	1128	Ps,C_B	Ps,C_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na pjescarima i krecnjacima	193
795	4429	9961	Polygon	9961	Ps,Sk-B	Ps,Sk-B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na pjescarima i skriljcima	194
619	3334	3616	Polygon	3616	Ps,Rz,C_B	Ps,Rz,C_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na pjescarima roznjacima i krecnjacima	195
639	3425	6627	Polygon	6627	Rl_B	Rl_B	CMd	Dystric Cambisols	15	Dystric Kambisol	Smeđe tlo na rolitima	196
566	2998	12271	Polygon	1227	Ps,Gl_B-a+	Ps,Gl_B-a+	CMd	Dystric Cambisols	15	Dystric Kambisol+Pseu	Smeđe kiselo tlo na pjescarima i glincima pseudoglej obronacni	197
1075	8955	7709	Polygon	7709	S,P_p-A-a	S,P_p-A-a	FLd	Dystric Cambisols	15	Fluvisol	Aluvijalno bezkarbonatno pjeskovito tlo na pijescima i ilovacama	198
833	5047	10027	Polygon	1002	Sk_R-s	Sk_R-s	LPd	Dystric Cambisols	15	Ranker	Humusno-silikatno posmedjeno tlo (ranker) na skriljcima	199
575	3047	7445	Polygon	7445	Gl,Ps_R+Gl	Gl,Ps_R+Gl	CMd	Dystric Cambisols	15	Ranker+Dystric Kambi	Ranker i smeđe kiselo tlo na glincima i pjescarima	200
650	3470	3538	Polygon	3538	Ps,Rz,Gl_R	Ps,Rz,Gl_R	CMd	Dystric Cambisols	15	Ranker+Dystric Kambi	Ranker i smeđe kiselo tlo na pjescarima roznjacima i glincima	201
470	2325	6070	Polygon	6070	Rz_R+Rz_R	Rz_R+Rz_	CMd	Dystric Cambisols	15	Ranker+Dystric Kambi	Ranker i smeđe kiselo tlo na roznjacima	202
661	3519	3499	Polygon	3499	Sk_R+Sk_B	Sk_R+Sk_	CMd	Dystric Cambisols	15	Ranker+Dystric Kambi	Ranker i smeđe kiselo tlo na skriljcima	203
295	1198	1323	Polygon	1323	An_R+An_	An_R+An_	CMd	Dystric Cambisols	15	Ranker+Dystric Kambi	Ranker i smeđe tlo na andenzitskim tufovima	204
651	3478	5601	Polygon	5601	S,P_R+S,P_	S,P_R+S,P	CMd	Dystric Cambisols	15	Ranker+Dystric Kambi	Rendzina i smeđe kiselo tlo na siljuncima i pijescima	205
587	3148	9333	Polygon	9333	A+A,S_B-a	A+A,S_B-a	FLd	Dystric Fluvisols	16	Fluvisol+Dystric Kambi	Aluvijalno i smeđe kiselo tlo na fluvijalnim sedimentima	206
1002	7899	11167	Polygon	1116	i-A-a	i-A-a	FLd	Dystric Fluvisols	16	Fluvisol	Aluvijalno kiselo ilovasto tlo	207
861	5548	9546	Polygon	9546	p-A-a	p-A-a	FLd	Dystric Fluvisols	16	Fluvisol	Aluvijalno kiselo pjeskovito tlo	208

Figure 2: Soil map of Bosnia and Herzegovina (example of vector-based geodata, which is strictly related to attribute table)

6. Conclusions

Obvious discrepancy between technological development of human society and educational practice in a countries like Bosnia and Herzegovina calls into question appropriateness of a education process as a whole. Modern geographic concepts in education are focused on GIS technology application, which simply offer too many opportunities to be ignored in this context. However, numerous problems and barriers make the process of GIS implementation in a classrooms not easy at all. Because of that, cooperation between geographers on different levels of education, experts form other fields, government institutions and non-governmental organizations is necessary, at least for raising awareness about existence and possibilities of this relatively new technology, as a first step.

Concept of GIS as a teaching aid, method and content has potential to redefine significance of geographic (but not just geographic) education in the functional sense, because it emphasizes development of critical and analytical thinking, as well as variety of applicable skills. To better clarification of this topic, it is necessary to raise the level of scientific researchers engagement, in order to create pedagogically appropriate and optimal didactic approach to GIS use, through elaboration of theoretical bases and empirical experiments.

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