A GIS-Based Evaluation of Landscape Quality

E. Pauditšová, A. Miklošovičová, and M. Kaczara

***Abstract*—Characteristic sign of landscape research is interdisciplinarity. Its direct implication is collecting of data, which were obtained from the monitoring of landscape components and elements. It is necessary to systematically classify and also summarise all these data and keep the information and knowledge, which result from them, for each hierarchical level in accordance to the size of research area. It is possible to use geographic information system (GIS) applications in each step of systematic landscape research: problem analyses, methodology selection (including the determination of level for data processing), collecting and assembling of existing data, collecting of new (actual) data, realisation of analyses, syntheses, evaluating and decision-making processes, outputs generating or results' interpreting. It arises from the assumption that database and analytical applications are as important for landscape quality evaluation as outputs' visualisation.**

***Index Terms*—GIS-based evaluation, landscape quality, landscape ecology.**

I. Introduction

Landscape is the object of interdisciplinary research. Due to this fact, its definition varies according to the field of research. Landscape, from the environmental point of view, is defined in the European Landscape Convention (ELC) as an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors [1].

Landscape quality is so broad term that it is not possible to define it precisely. The very flexible view on landscape quality is not only the result of different approaches and outcomes, but it also depends on the depth of its evaluation [2]. Landscape quality, respectively the indicators through which the improvement of landscape quality can be evaluated, is the main aim of many international agreements or strategies [3]. The most comprehensive is the concept of landscape quality as defined in the National Sustainable Development Strategy of Slovak Republic [4]: "Environmental landscape quality is the state and development of the human influence on landscapes, threats and destruction of individual landscape components, respectively different landscape systems. Environmental landscape quality also depends on the human actions in the landscape, which act as a long-term "pressure" to usage of primary landscape structure, its gradual change in the secondary structure and the creation of tertiary (socio-economic) structure, which represents, among other things, protection of economic interests in the landscape.

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E. Pauditšová, A. Miklošovičová, and M. Kaczara are with Faculty of Natural Sciences, Comenius University in Bratislava, Slovakia (e-mail: epaudits@gmail.com, miklosovicova.anna@gmail.com, kaczko@gmail.com).

In generally, it is possible to allege, that environmental landscape quality is a result of natural and anthropogenic processes including negative human pressure on landscape (environmental load, contamination of landscape components, etc.). When this landscape quality is evaluated, it is analysed quality of each landscape component, degree of its load, pollution, etc. [5]. For this evaluation is characteristic exact approach, clear qualitative and quantitative parameters substantiated by various numerical indicators. Nowadays, it is strictly differentiated term "total landscape quality", which arises from ELC. ELC extended the definition of landscape quality with social aspects or aesthetic-emotional dimension. Evaluation of landscape quality through the visual perception has been the aim of research of several authors since the end of 20^{th} century (the end of 90's) [6]-[8]. In recent years, it was developed a number of methodological standards for this purpose [9]-[14].

The approach, that landscape quality is perceived as a visual perception of aesthetic components, is based mainly on the subjective indicators and should be supported also by the objective indicators, e.g. evaluation of ecological stability, landscape diversity, natural risks and hazards, ratio between positive and negative landscape elements or ratio between the areas according their land use classification.

Since environmental landscape quality has been interconnected with aesthetic-visual landscape quality, it is possible to start talking about the "total landscape quality". It is difficult to interconnect information achieved from these two approaches (objective and subjective), but it is right to concentrate all the data to one unit – information system with spatial data – GIS.

All the monitored indicators can be evaluated and interpreted using GIS applications and the quality of final evaluation depends on the depth of assessment this demanding and wide-ranging issue.

Nowadays, GIS can be considered as a research tool, the carrier of many information about landscape, society and their cross interactions. Simultaneously, GIS represents the tool for generating of new information, knowledge and approaches for solution and decision making. These stated GIS options are appropriate for science and research about the Earth and also for the evaluation of landscape quality [15].

For the evaluation of landscape quality, it is acceptable general dividing of GIS usage according Maguire [16]:

- GIS as a database of spatial data
- GIS as a tool for spatial analyses and modelling
- GIS as a tool for creating of cartographic presentations.

Positive asset of GIS, in the landscape quality evaluation process, is creation of outputs which offer significantly wider range of information about the research area as traditional science practices. Not less important are the facts related to

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the faster processing of spatial data, flexible creating of outputs and possibility to apply the methods of difficult calculations. The spatial analyses are the greatest asset of GIS for landscape evaluations. Geoinformation techniques, for which is spatial aspect common, are able to afford such results and knowledge, that we are not able to achieve by conventional scientific methods of any other scientific fields.

The data sources and processing methods for generating DEMs have also evolved rapidly over the past 20–30 years — from ground surveying and topographic map conversion to passive methods of remote sensing and more recently to active sensing with LiDAR and RADAR [17], [18]. In continuous changeover, from traditional 2D visualisation to 3D model, were used several tools [19], which are still entering to the 3D modelling in partially changed forms [20]. Three-dimensional model does not substitute previous tools contrariwise it is using them and collects from them the necessary data [21].

The recent progress in technology, including global positioning systems (GPS), ground and airborne laser terrain mapping, ground penetrating radar and DEMs, has provided a framework to numerically represent ground surface relief and patterns [22], [23].

This paper presents the principles of using GIS in landscape research, which is applicable also for the evaluation of landscape quality, to ensure that the landscape quality will be evaluated in details and on the bases of objective indicators. Methodology is set-up from six main steps, which are schematically visualised in Fig. 1.

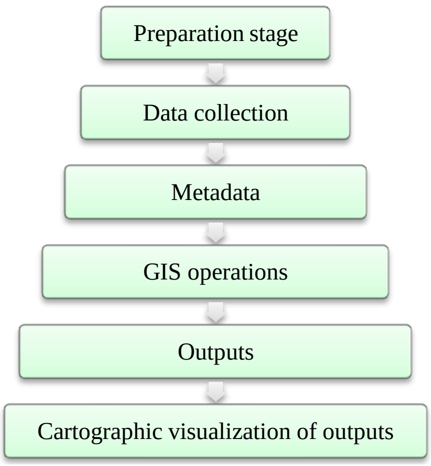

Fig. 1. General scheme of the principles of using GIS in landscape research.

From this figure results, that it is necessary to coordinate particular steps in landscape research. Environmentalists work with analytical data from the various scientific fields and they are able to interpret the results, incorporate them to the complex proceedings and use them in appropriate way to do not lose their quality and significance. All the steps of methodology stated below are not important for each research type of work, so it is possible to modify or exclude some steps due to the objective of research or according the applied methodology.

II. Preparation Stage

Preparation stage (Fig. 2) is focused on defining the aims which declares explicitly, what kind of research tasks will be solved. On the bases of aims, it is usually clear what kind of outputs are expected (maps, texts, tables, etc.). In the case that GIS-based research is included to the methodology, it is needed to identify the steps, which will be demanding from time, technical or realisation point of view and it is necessary to take this fact into consideration when the works on the research are being set up. GIS-based research is time consuming in the stage of data processing, but on the other hand it abbreviates the time needed for syntheses.

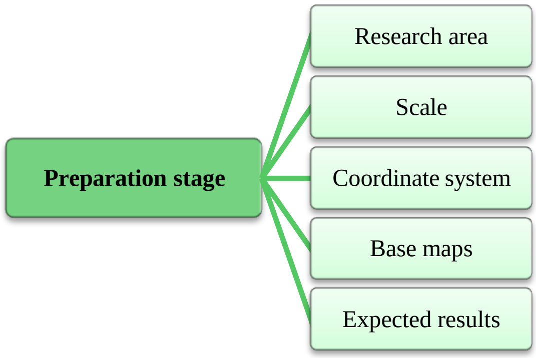

Fig. 2. Scheme of the steps in preparation stage.

In processes, which include the creation of digital maps or layers, is one of the basic requirements to choose the appropriate coordinate (reference) system. Each state uses its own preferred coordinate system (e.g. WGS, UTM, SPCS, ETRS, JTSK, etc.). Due to the high-quality software translators, it is not problem anymore to convert the data files to various coordinate systems, thereafter join or combine them and create various data layers. Nevertheless, it is right and methodically correct (in terms of errors minimizing) if all the obtained data, adopted or acquired by terrain survey, are customized to the preferred coordinate system in further research.

Research area should be defined in compliance with the aims of research, in the case that it was not defined explicitly in advance. Research area is the most often defined by administrative boundaries or boundaries of natural units (e.g. basin, watershed). In practice, it is often used also purpose-oriented defining of research area, which does not reflect administrative nor natural boundaries.

Base of each landscape-ecological research, including landscape quality evaluation, is the preparation of base maps for research area. Nowadays, it is preferred by the researchers to use the base maps obtained from Web Map Services (WMS) or use the orthoimages during terrain survey.

III. Data Collection

The collection (centralisation) and especially the verification of data is the most time consuming process of the environmental research, which is using GIS. Fig. 3 shows the basic steps of data collection and their processing into the form of geodatabase. All the categories of datasets (abiotic and biotic elements, current land use, socio-economic elements and visual and aesthetic characteristics) are represented by four basic groups of data, which are relevant for the landscape quality determination in the frame of landscape-ecological evaluation.

The traditional techniques of terrain survey (including the thematic mapping and GPS location), especially in the mapping across the large areas, are considered to be time consuming and it is still more and more popular (when the specific type of research enables it) to use the orthoimages and WMS. Nowadays, more than 10 000 map layers are available online through the Open Geospatial Consortium (OGC) specified interfaces, such as Web Map Service, Web Feature Service (WFS) and Web Coverage Service (WCS). WMS is a portrayal service, whereas WFS and WCS are geographic data services. Due to a simple design, small number of API functions, and a clear definition of these functions, WMS is now *de facto* standard for corresponding modules of mainstream GIS software packages [24].

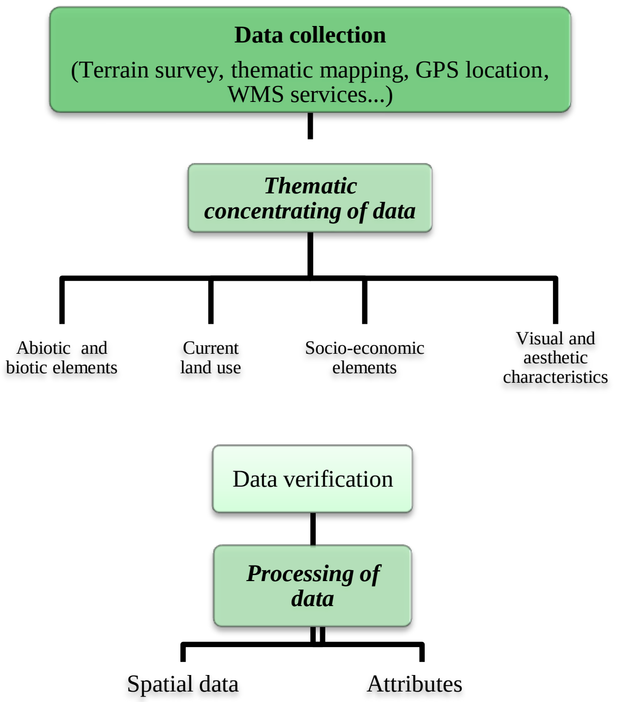

Fig. 3. Scheme of the basic steps in data collection stage.

Data about the abiotic landscape elements are usually sufficient from WMS, but for the complex landscape quality evaluation, it is necessary to realise the mapping of biotic elements (e.g. mapping of biotopes), secondary landscape structure (SLS) and socio-economic elements (positive and negative landscape elements – point, linear and polygon). This implies that the very important part of data collection stage is terrain survey, including thematic mapping and GPS location services, because the current stage of all biotopes and landscape structure elements, which are changeable in time, should be evaluated directly in the research area.

The most often monitored and recorded abiotic elements with the character of input data for evaluation of landscape quality are:

- geological ground and quaternary sediments
- soils and soil-ecological characteristics
- underground waters
- relief
- climate.

Landscape-ecological research uses mainly the following biotic elements in the data processing stage:

- potential vegetation
- geobotanical units
- phytogeographic regions
- zoogeographic regions
- biotopes specified according the vegetation cover
- biotopes specified according the selected groups of fauna (endangered species or bioindicators).

Biotopes are the most often specified according the vegetation cover, but it is possible to specify them according the selected groups of fauna (endangered species or bioindicators) and according their limitation to the land use. These species usually are: amphibians, birds, small terrestrial mammals, micro and macrozoobenthos from invertebrates, some groups and species of edaphic insects and as the most convenient are considered families or genera of beetles, which indicate the state and the preservation or disturbance of biotopes.

Classification of landscape structure elements depends on selected map scale and required work/research details. When the secondary landscape structure elements are classified, it is necessary to accept the following aspects:

- functional aspects (content of SLS elements and form of their usage)
- biotic aspects (characteristics of real vegetation elements or fauna biotopes)
- degree of anthropogenic changes (from natural up to artificial secondary landscape structure elements)
- spatial characteristics (spatial localization of SLS elements, their size and form, etc.).

The particularity of socio-economic elements (SEE) is the fact, that SEE may overlap and they usually do not cover whole research area. Overlapped entities, in the one vector layer, are incorrect in the terms of GIS. Due to the subsequent syntheses steps, it is appropriate to allocate particular elements to the several layers not only according their form (point, polyline, polygon), but also according their thematic focus. It is not desired if each SEE is represented by one vector layer, but on the other hand (e.g. when the maps of conflict of interests are created), contrary extreme is also not desired – it means, that all the SEE are in one or three vector layers (point, polyline, polygon layer). From the stated facts result, that desire arrangement of SEE to the digital layers is somewhere between these two extreme options. Arrangement of SEE to the several layers is specific. Possible solution is to arrange the SEE to the several layers according these recommendations:

- all the elements related to the nature and landscape protection defined as areas
- all the elements related to the nature and landscape protection defined as lines
- all the elements related to the nature and landscape protection defined as points
- all the elements related to the buffer zones of material objects
- hygienic buffer zones defined as lines
- point sources of air pollution
- spatial expression of air pollution
- point sources of noise
- line expressions of noise density
- spatial expressions of noise density
- spatial expressions of vegetation disturbance degree.

Visual and aesthetic characteristics can be also collected in

GIS and they are the subject of two basic principles. In GIS, there is possible to realise the objective evaluation of visual and aesthetic characteristics through the DMT, land use and visibility of particular landscape segments or concrete objects in landscape. Subjective evaluations are incorporated to GIS as a so-called auxiliary attributes, which are usually related to the concrete landscape structure elements.

When the database is being fulfilled in the landscape-ecological research, it usually works with encoded information. These codes (the most often numbers) used to represent numerical values, interval values or word description. The necessity of data and information encoding results from:

- dominant syntheses method of data processing
- number of data, which are used in landscape-ecological research
- efficiency of performing tasks (during database fulfilling, analyses and syntheses performed in GIS).

Codes are used also because of their practical aspect. Many long records are not several times repeated in the attribute tables (Table I), when codes are used instead of them. Hence, it is more efficient to prepare the separate table, which carries out the function of explanations. These tables contain only 2 columns: code and word description (Table II).

TABLE I: BASIC STRUCTURE OF ATTRIBUTE TABLE (FIELDS AND RECORDS)

ID	Code	Attribute1	Attribute3	…	Attribute8
26	1.5.1	10,5	Yes	...	2010
27	1.5.2	23,6	No	...	2003
28	1.5.3	16,2	Yes	...	2014

TABLE II: EXAMPLE OF CODE TABLE

Code	Description
1.5.1	National park
1.5.2	Protected area
1.5.3	Protected element
…	...

If it is needed, it is possible to interconnect "explanation table" with attribute table, whereby it will be created temporary new and extended attribute table containing all the primary codes and furthermore word description of particular codes.

IV. METADATA

The role of metadata is significant, so it was proposed structure of metadata for landscape-ecological and environmental research:

- identification of data set (name, if needed version)
- brief description of data set (purpose of creation, recommended map scale, form of elaboration)
- used coordinate (reference) system
- data quality elements (creation date, accuracy, updates, etc.)
- related documents, maps
- range (in location, time)
- data definition (on object level)
- classification (object types, attributes and relations)
- administrative metadata (information about ownership rights, authors, institution, contacts, etc.).

Metadata created according these recommendations are positive asset not only for the creators, but mainly for the users.

The set of metadata elements is necessary in order to allow the identification of information source for which metadata are created, classification and identification of their geographic location and temporal reference, quality and validity, conformity with implementing rules on the interoperability of spatial datasets and services, constraints related to access and use, and organisation responsible for their creation. It is also necessary to monitor if the created metadata are kept up to date, and it is important that through the metadata we can easily identify the organisation responsible for their creation and maintenance. The value domain of each metadata element is necessary for ensuring the interoperability of metadata in a multilingual context. It is obligatory to use the form of free text, dates, codes derived from international standards, such as language codes, keywords derived from controlled lists or thesauri, or character strings [25].

V. GIS OPERATIONS

Usage of specific GIS tools, in processes aimed on the determination of landscape quality, is closely connected with the concrete methodology of landscape-ecological research. Basic tools, for this purpose, are geographical analyses which use graphical and attribute data. The most often used tools of geographical analyses in landscape-ecological evaluations are: extract (clip, select, split), overlay (eliminate, erase, intersect, identity, union, update), proximity tools (e.g. buffer), statistics tools (frequency, summary statistics) and surface tools (cut & fill, visibility, volume). Graphical analyses work with vector oriented graphics. Several data are elaborated in GIS also in a form of raster graphics and it means that pixel (in 3D so-called voxel) is a carrier of limited data. Therefore, for the purposes of landscape-ecological syntheses, partial raster outputs are shaped into the vector form. Afterwards, it is possible to work with the wider range of attribute data. Several objective landscape quality evaluations related to the visual landscape characteristics are raster oriented. Contrariwise, the subjective attitudes of landscape observers are connected with the concrete landscape elements, which are vector oriented. Therefore, it is important to create a base with all data in the same geographic form before the crucial syntheses steps, aimed on landscape quality determination, are realised.

Syntheses, the result of which is landscape quality determination, appear from combination of map layers: land use, primary and secondary stress factors, positive socio-economical elements and effects and also visual and aesthetic characteristics. Following analytical data and results of partial syntheses in GIS background are relevant for landscape quality determination:

1) Abiotic characteristics:

- rock as a pollution source
- radon hazards
- soil contamination
- contamination of river sediments
- groundwater pollution
- surface water pollution

- air pollution
- water erosion and wind erosion hazards
- flood hazards distribution
- avalanche hazards
- and others

2) Biotic characteristics:

- abundance of European important biotopes
- abundance of endangered flora and fauna species
- degree of vegetation damage
- degraded biotopes
- abundance of invasive species
- and others.

3) Socio-economic effects (material/non-material; positive/negative)

- waste dumps, waste heaps and decanting plants
- degraded areas
- brownfields
- zones of hygienic protection
- noise zones
- electromagnetic smog zones
- vibration zones
- buffer zones of water sources and springs
- forests with protecting features
- elements of territorial landscape protection (including NATURA 2000 sites)
- ecological network elements
- protected areas of natural water resources/springs (thermal, healing)
- protected areas of natural resources (soil, water, vegetation and mineral resources)
- and others.

4) Land use

- All the landscape elements created landscape pattern

5) Visual and aesthetic characteristics

- important landscape types and landscape archetypes
- significant landscape elements
- landscape dominants (positive and negative)
- culture-historical objects
- degrees of landscape segments visibility
- and others.

For the determination of total landscape quality are used comparative analyses, which are based on the works with geodatabase (Fig. 4). Comparing the attributes of each record, in the frame of particular database fields, create new database fields which contain the combinations of alphanumerical strings. These record combinations represent the bases for determination of landscape quality degree. The classification of evaluated research area, in accordance to the landscape quality degree, arises from the variability of attribute record combinations.

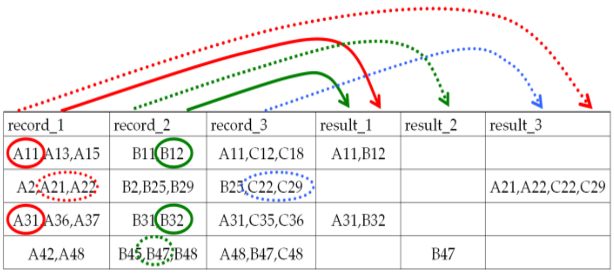

Fig. 4. The principle of comparative selection of strings alphanumeric characters.

After the realisation of spatial syntheses, through the geographical analyses operations and subsequent comparative analyses of alphanumerical strings (codes in geodatabase), is forthcoming the reclassification phase of research area. The result is the territorial determination of landscape quality categories:

1) **Landscape with very high quality** – landscape, which is in the terms of environmentalists, without load (hygienically convenient area without any pollution of particular components of environment) and with occurrence of positive socio-economic effects
2) **Landscape with high quality** – landscape, which is in the terms of environmentalists, minimally loaded (hygienically convenient area, where is acceptable minimal pollution, but this pollution should be deep under the pollution limits set for individual pollutants and for particular components of environment) and with occurrence of positive socio-economic effects
3) **Landscape with average quality** – landscape with increased concentration of pollution, where one or more components of environment are polluted, but pollution values should be under the pollution limits set for individual pollutants, and locally there should occurred the positive socio-economic effects
4) **Landscape with low quality** – landscape with intensive up to very intensive load – high concentration of pollution, where one or more components of environment are polluted (pollution values are minimally under the pollution limits set for individual pollutants, eventually they minimally exceed these limits) or some components of environment are intensively disrupted, and locally also with occurrence of positive socio-economic effects
5) **Landscape with very low quality** – very high concentration of pollution (pollution values exceed the limits established in the standards and legislation) or some components of environment are very intensively disrupted, and without occurrence of positive socio-economic effects.

Advantages of data processing in GIS are significant, e.g. each output (synthesis) graphical entity provide information about appropriate analytical input, which are saved in the attribute tables. Due to this kind of data storage, it is possible to purposefully create various map layers. These trends of map creation, which are created from purposefully map layers, are nowadays popular and used to provide the data through the WFS services. Through the WFS services, the client is able to communicate with the data servers on the level of geo-elements represented by vectors and is able to acquire or update spatial data. Request, submitted by user through the WFS, consists from (it is similar to GIS) the relational database products, the description of concrete inquiry on data and the operations of data transformation, which are entering to the data profiles through the Internet.

VI. Visualisation of Outputs

The major forms of graphical outputs in landscape-ecological research are the maps. Through the maps, it is generated visualisation of landscape, land use forms, spatial organization and also environmental characteristics (Fig. 5). Visualisation of outputs from scientific researches allows interactive exploration, interpretation and evaluation of results, simulations and models [26]. Scientific visualisation includes modern ways of visualisation through 2D and 3D models (Fig. 5), animations, perhaps even in connection to the other forms of multimedia presentation as models of virtual reality, illuminating materials and the others [27].

Scientific visualisation uses visualisation in the form of e-maps, hypermaps and other models on the bases of information technologies with the aim to elaborate, study, analyse, synthesise and present information efficiently [29], [30]. Development in scientific visualisation, in the area of landscape quality evaluation, is closely linked with the development of cartography, geography, geostatistics, geoinformatics and other disciplines related to the software development for creation, elaboration, analyses and visualisation of wide bases of geographical data. Development of these disciplines enlarged the original role of analogue and digital maps, acting as a base of geographical data and presentation media. New options allow their users to display dynamically, through the active interaction between them, only the data/information which are interesting, inspiring and explicatory [31].

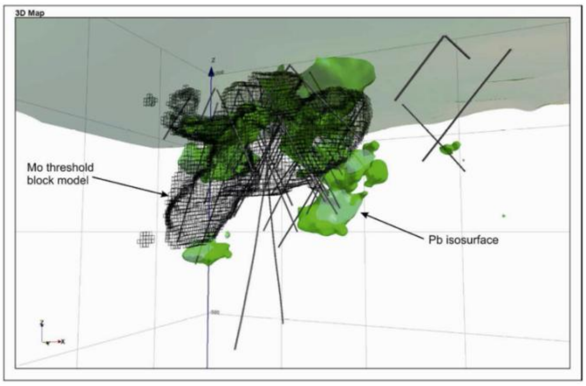

Fig. 5. 3D Visualisation-isosurfaces of block models of Mo and Pb bearings [28].

VII. Conclusion

GIS application, in landscape-ecological research, allows faster and exacter elaboration of outputs and detects various interrelations and interconnections between particular research objects – landscape units and elements or phenomenon and processes affecting within the research area. From cartographical aspect, GIS technology allows more efficient data processing and also exacter visual interpretation. Rationalize usage of GIS solutions in landscape-ecological research requires systematic approach and keeping the schedule. These statements result from the empirical experiences acquired during the works on various projects and funds, in which GIS acted as a creative or additional tool.

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References

[1] European Landscape Convention. (2000). European Council, Strasbourg. [Online]. Available: http://conventions.coe.int/Treaty/en/Treaties/ html/176.htm

[2] A. Miklošovičová and Z. Moravčíková, "The comparasion of ecological stability in lowland, upland and sub-mountain landscape (Case study in Slovakia)," *Journal of International Scientific Publication*, *Ecology & Safety*, vol. 4, no. 2, pp. 362-386, 2010.

[3] A. Miklošovičová, "Evaluation of rural landscape quality through its ecological stability," in *Proc. International Interdisciplinary Conference* on *Rural Landscape*, Brno, Czech Republic, ZO ČSOP Veronica, 2009, pp. 160-165.

[4] Ministry of the Environment of the Slovak Republic, *National Sustainable Development Strategy*, Bratislava, p. 235, 2001.

[5] Z. Izakovičová and E. Pauditšová, "Environmental problems resulting from the conflicts of interests in Žiar Basin region," *Ekológia (Bratislava)*, vol. 18, no. 4, pp. 367-380.

[6] I. Vorel, "Landscape character assessment - search for objectivity," *Land Use Planning and Urban Design*, vol. 24, no. 1-2, pp. 32-35, 1997.

[7] A. Lothian, "Landscape and the philosophy of aesthetics: is landscape quality inherent in the landscape or in the eye of the beholder?" *Landscape and Urban Planning*, vol. 44, pp. 177-198, 1999.

[8] G. R. Clay and T. C. Daniel, "Scenic landscape assessment: the effects of land management jurisdiction on public perception of scenic beauty," *Landscape and Urban Planning*, vol. 49, pp. 1-13, 2000.

[9] S. Wilson, *Guidelines for Landscape and Visual Impact Assessment Hardcover*, Landscape Institute, Institute of Environmental Management and Assessment, 2nd Edition, Spon Press, 2002, p. 166.

[10] C. Swanwick, "Landscape character assessment guidance," *Topic Paper 1. Recent Practice and the Evolution of Landscape Character Assessment*, Countryside Agency, Cheltenham and Scottish Natural Heritage, Edinburgh, p. 9, 2002.

[11] D. Štefunková and T. Cebecauer, "Visibility analysis as a part of landscape visual quality assessment," *Ekológia (Bratislava)*, vol. 25/Suppl. 1, pp. 229-239, 2006.

[12] Å. Ode, M. S. Tveit, and G. Fry, "Capturing landscape visual character using indicators: touching base with landscape aesthetic theory," *Landscape Research*, vol. 33, no. 1, pp. 89-117, February 2008.

[13] B. Chen, O. A. Ochieng, and Z. Bao, "Assessment of aesthetic quality and multiple functions of urban green space from the users' perspective: The case of Hangzhou Flower Garden, China," *Landscape and Urban Planning*, vol. 93, pp. 76-82, October 2009.

[14] E. Pauditšová, A. Salašová, and J. Oťaheľ, "Evaluation of landscape character," in *Landscape Planning*, M. Kozová, E. Pauditšová and M. Finka, Eds. Bratislava: STU Press, 2010, ch. 5.7, pp. 192-203.

[15] E. Pauditšová, "Geoinformatics for environmentalists," *University Textbook (CD)*, Comenius University in Bratislava, Faculty of Natural Sciences, 2009, p. 105.

[16] D. J. Maguire, "An overview and definition of GIS," in *Geographical Information Systems: Principles and Applications*, D. J. Maguire, M. F. Goodchild and D. W. Rhind, Eds. Essex: Longman Scientific & Technical, 1991, pp. 9-20.

[17] J. P. Wilson, "Digital terrain modeling," *Geomorphology*, vol. 137, pp. 107-121, 2012.

[18] J. P. Wilson and J. C. Gallant, *Terrain Analysis: Principles and Applications*, John Wiley & Sons, New York, 2000, pp. 1-27.

[19] K. Al-Kodmany, "Computer-based public participation," in *Planning and Urban Design Standards*, E. Sendich, Ed. Hoboken, John Wiley & Sons, 2004, pp. 63-64.

[20] J. A. M. B. van Beurden, R. J. A. Van Lammeren, T. Hoogerwerfand, and A. A. Bouwman, "Linking land use modelling and 3D visualisation – A mission impossible?" DDSS 2006, Wageningen University, The Netherlands, 2006, p. 17.

[21] E. Pauditšová and B. Slabeciusová, "Modelling as a platform for landscape planning," in *Proc. 14th International Multidisciplinary Scientific GeoConferences, Section: Cartography and GIS,* Albena, Bulgaria, 2014, vol. III, pp. 753-760.

[22] D. G. Brown, R. J. Aspinall, and D. A. Bennett, "Landscape models and explanation in landscape ecology — A space for generative landscape science?" *The Professional Geographer*, USA, vol. 58, no. 4, pp. 369-382, 2006.

[23] D. Sathyamoorthy, "The effect of morphological smoothening by reconstruction on the extraction of peaks and pits from digital elevation models," *Pattern Recognition Letters*, vol. 28, pp. 1400-1406, September 2007.

[24] H-Y. Wu, Z.-L. Li, H.-W. Zhang, C.-W. Yang, and S.-Y. Shen, "Monitoring and evaluating the quality of Web Map Service resources for optimizing map composition over the internet to support decision making," *Computers & Geosciences*, vol. 37, pp. 485-494, April 2011.
[25] Commission Regulation (EC) No 1205/2008 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards metadata. (2008). [Online]. p. 19. Available: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32008R1205
[26] J. Raper, "The 3-dimensional geoscientific mapping and modelling system: A conceptual design," in *Three Dimensional Application in Geographic Information Systems*, J. Raper, Ed. London, Taylor & Francis, 1989, pp. 132-146.
[27] J. Hofierka, "Spatial interpolation and terrain analysis," in *Geoinformation Technologies for Geocultural Landscapes: European Perspectives*, O. Bender, N. Evelpidou, A. Krekand A. Vassilopoulos Eds. Leiden, CRC Press/Balkema, Taylor & Francis Group, The Netherlands, 2008, pp. 189-206.
[28] J. Michňová, P. Koděra, and P. Pauditš, "Visualisation of mineralization and alteration zones in Biely Vrch Au-porphyry deposit by MapInfo3D," in *Proc. 12th Sga Biennial Meeting on Mineral Deposit Research for a High-Tech World,* Uppsala, Sweden, 2013, vol. 1, pp. 92-95.
[29] J. Kraak, "Geovisualisation illustrated," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 57, no. 5-6, pp. 390-399, 2001.
[30] M. Batty and P. M. Torrens, "Modelling and prediction in a complex world," *Futures*, USA, United Kingdom, pp. 745-766, 2005.
[31] D. Kusendová and V. Bačík, *Computer Map Creation —Exercises in MapInfo Professional software*, Bratislava, Geo-grafika, 2009, p. 160.

Eva Pauditšová was born in Žilina, Slovakia on May 9, 1971. She is a landscape ecologist and environmentalist graduated at the Faculty of Natural Sciences, Comenius University in Bratislava, Slovakia in 1994. She obtained her PhD degree in environmental planning and management, her habilitation was aimed on spatial planning, management and GIS. She has worked at the Faculty of Natural Sciences, Comenius University in Bratislava since 1994. Her research work and teaching activities are related to the field of landscape ecology, environmental planning and management, GIS, mapping, modelling; she is specialised in landscape planning, ecological network and green infrastructure, environmental impact assessment, evaluation of landscape changes. She is an author/or co-author of more than 150 scientific and professional publications, co-author of 8 monographs and 7 textbooks for university students. She is also supervisor of PhD students and she supervised more than 50 M.Sc. and Bc. theses. She is a co-worker on 30 scientific, research and also education projects. She attended two short-term GIS study stays in the Netherlands.

Assoc. prof. Pauditšová is a member and also secretary (2013-2017) of the European Association for Landscape Ecology (IALE-European) and also its regional organization IALE-SK (Slovakia). She is also a member of other organisations as: Society for Urban Ecology (SURE), Cartography Society (Slovakia), Slovak Ecological Society, Friends of historic parks and gardens (National trust). She is a co-author of three award-winning publications at the national level.

Anna Miklošovičová was born in Bratislava, Slovakia on April 12, 1984. She studied at the Comenius University in Bratislava, Slovakia, Faculty of Natural Sciences, Department of landscape ecology, where she finished all three degrees of university education (bachelor, master and doctoral degree) and also additional rigorous study (RNDr.). She studied environmental planning and management, specialised on abiotic parameters of landscape and their changes due to human activities. Her doctoral thesis was aimed on developing methodology for evaluation of rural landscape quality on the basis of selected indicators, which include objective and also subjective approaches of landscape quality evaluation.

She works at the oldest university in the Slovak Republic, Comenius University in Bratislava. Nowadays, she started to work on the project "The Comenius University in Bratislava Science park (Slovakia)" for the activity Environ-medicine for the 21st Century - biotic and abiotic factors of the country and their influence. Previously, she worked on the European Union's programme TEMPUS No. 511390-TEMPUS-1-2010-1-SK-Tempus-JPCR which supports the modernisation of higher education in the EU's surrounding area. During the doctoral studies, she cooperated on various VEGA projects of Cultural and Educational Grant Agency of Ministry of Education in Slovakia. She was also a responsible researcher of Comenius University grants for young scientific researchers. She was also participated in number of international summer/winter schools.

Dr. Miklošovičová is a member of the European Association for Landscape Ecology (IALE-Europe) and also its regional organization IALE-SK (Slovakia).

Martin Kaczara was born in Lučenec, Slovakia on March 16, 1985. He studied at the Comenius University in Bratislava, Slovakia, Faculty of Natural Sciences, Department of landscape ecology, where he finished all three degrees of university education (bachelor, master and doctoral degree). He studied environmental planning and management, specialised on abiotic parameters of landscape and their changes due to human activities. The doctoral thesis was aimed on the typification of the abiotic environment of grasslands in light of their liability to soil erosion due to livestock grazing.

He works at the oldest university in the Slovak Republic, Comenius University in Bratislava. Nowadays, he started to work on the project "The Comenius University in Bratislava Science park (Slovakia)" for the activity Environ-medicine for the 21st Century - biotic and abiotic factors of the country and their influence. During the doctoral studies, he cooperated on several VEGA projects of Cultural and Educational Grant Agency of Ministry of Education in Slovakia,. He was also a responsible researcher of Comenius University grants for young scientific researchers.