University of West-Hungary

PhD thesis

THE APPLICATION OF GIS IN NATURE CONSERVATION

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SUBJECT JUSTIFICATION

Human beings, as creatures capable of using and transforming material and energy cannot exist without natural resources and ecosystem-services (OLÁH, 2004). Humanity has always relied on natural resources – considered infinite for a long time – for building materials for its culture: sampled nature for its unfathomable richness of form, colour and scent. Still, or maybe just because of this, human culture has been created more or less everywhere subsequent to the decline of natural creations (RAKONCZAY, 1995). An important characteristic of natural resources is their geographic location (geometry), which enables them to be studied after they have been organised into Geographic Information Systems (DANGERMOND, 1994; DAVIS *et al.*, 1994).

The late 20th century has brought revolutionary changes in computer and information technology (IT). Data once only used by a handful of researchers has gained widespread interest, since IT and more specifically GIS enabled the decision processes to consider information which had previously been regarded irrelevant based on technological difficulties. (SÁRKÖZY, 2001).

The timeliness of the subject is also signified by the promulgation of the EU INSPIRE Directive (15th May, 2007), which aims to facilitate the distribution of more and better quality environmental data in EU member states in order to increase efficiency in relevant decisions.

The basic task of governmental conservation organisations is the preservation of natural diversity of the living and inanimate world. Conserving natural conditions and processes can be ensured by continuously operated monitoring mechanisms (TERBORGH, 1974, TARDY, 1994).

The Conservation Law (LIII. of 1996) stipulates "*the operation of a unified information system for nature conservation that is also compliant to international requirements*". However, up till now the problem of conservation informatics has been of low significance.

PROBLEM DESCRIPTION

The issues of scale are central to experimental ecology, landscape ecology and vegetation science (WIENS, 1989). Based on his studies in the field of vegetation the author agrees with the conclusions of PALMER (1988): he considers the common characteristic of every vegetation related analysis to be spatial dependency. Spatial thinking is just as important in cognitive sciences as in solving scientific problems.

The author began his research activities by performing local, large-scale (1 : 1-10) auto-ecological examination of solonchak alkaline plant communities under strong abiotic influences using photosynthesis-physiology toolset (TAKÁCS, 1993). As a consequence of the general ecological indicator theory (JUHÁSZ-NAGY, 1970, 1986) the characterisation of population fragments in various physiological conditions was performed by quantitative physiological parameters.

The author first recognised the efficiency of GIS methods regarding simultaneous management, processing and display during the analysis of informative data obtained from stress-physiological examinations. GIS applications merge the advantages of conventional mapping and alphanumeric data management systems (TAYLOR, 1991). The author's first GIS application was the performance of eco-physiological pattern analyses supported by vegetation mapping on population fragment – plant association level. (TAKÁCS, 1994).

From 1993 the author's vegetation research concept changed from local phenomena to the assessment of larger area (1 : 1000 – 25 000 – landscape detail) units. The process was greatly accelerated by the fact that beginning this year he started his work as a professional conservationist, and the focus of his duties was changed from Fehér-Lake, Szeged and a few-hectare stretches of Dorozsma-Nagyszék to the working area of the Duna-Ipoly National Park Directorate (million hectares). The change of scale necessitated a change in the author's toolset,

for when evaluating areas of a few square kilometres there is no way to personally visit every single blade of grass. The targets of analysis have also changed: in addition to alkaline habitats came wetlands, the grassland "puszta" of Mezőföld and the forest habitats of Vértes and Velence Mountains. This was when the author became interested in the analysis of patterns in vegetation using remote sensing techniques (TAKÁCS, 1998e, 2002b). The method is highly significant in the evaluation of water and wetland habitats, since the precise assessment of extended reedbed wetlands – considering the difficulites of field transportation – can only be performed rationally by remote sensing (MÁRKUS, I. 1993; TAKÁCS, 1996, 1998a; TAKÁCS – DIÓSZEGI, 1997b; SZEGLET *et al.,* 2001). The author compiled vegetation and habitat maps for the areas of Juhdöglő-valley (Vértes) forest reserve (TAKÁCS, 1997a), the Székesfehérvár Sand-Pit Nature Reserve (NR; TAKÁCS, 1998d), the Székesfehérvár Alkaline Lake NR (TAKÁCS, 2000a), the Sárkeresztúr Sárkány-lake (TAKÁCS – TAKÁCSNÉ, 1997), the Sárszentágota Alkaline Lake (TAKÁCS – TAKÁCSNÉ, 1999-2000), the Felsőszentiván Alkaline Lake (TAKÁCS *et al.,* 1997), the Dinnyési-Fertő NR (TAKÁCS, 1997h), as well as the Csíkvarsa-grassland, the Zámoly-basin, the Sárrét Protected Landscape Area (PLA), the Sárvíz-valley PLA, the Lake Velence Bird Reserve (TAKÁCS, 1998e), and in the framework of the National Biodiversity Monitoring System on landscape scale (25 km^2 each) study areas around Lake Velence T5×5_095 (TAKÁCS – DIÓSZEGI, 1997a; HORVÁTH *et al.,* 2006), Székesfehérvár R5×5_120 (TAKÁCS, 1998c) and of Nagykáta T5×5_089 (TAKÁCS *et al.,* 1999).

The author's landscape scale vegetation concept moved further away beginning in 2000 to the scale of the Pannonian biogeograpical region (1 : 25 000 < ; BOROS *et al.,* 2005). The job change of the author contributed to the broadening of the spatial scale towards more wholistic approaches. From 2002 he became a head of department of the Central Conservation Authority to continue his work in biodiversity preservation – taking part in regional programmes using GIS technologies with his colleagues (CSÖRGITS *et al.,* 2005; TAKÁCS, 2004; TAKÁCS *et al.,* 2004a, 2004b, 2006).

In 2002 the author received a call to become the head of the Advisory Board for Nature Conservation IT guiding the development of the Hungarian National Nature Conservation Information System (NCIS). This step provided an opportunity to use his experience obtained developing local geographic information systems in designing and implementing a GIS matching the scale of the Pannonian Biogeographic Region (TAKÁCS, 2002a; TAKÁCS – SZILÁGYI, 2004).

STRUCTURE OF THE DISSERTATION

The dissertation consists of four main sections.

First the author discusses the significance of the subject, setting the scope of analysis and the goals.

The second part describes the study area and discusses the methods of examination.

The third main part deals with the literature background of the subject, terms of reference, the GIS basics of the analysis, followed by describing the details of the precedings, elements, objectives, and implementation of the Nature Conservation Information System as a geospatial application.

The fourth chapter demonstrates the results of the preparatory work performed in support of system development as a biotic case study containing the species preservation plan for the endangered *fen orchid –Liparis loeselii* (L. RICH. 1817.)– species.

GOALS

The general goal of the dissertation is to demonstrate the utilisation opportunities of GIS in conservation by giving a thorough description of the development and implementation of the Nature Conservation Information System according to the following:

1. Scientific overview of the topic.
2. Critical review of the elements planned for implementation.
3. Demonstrating the operation of NCIS.
4. Assessment of practical usability of GIS environment and toolset in supporting the species preservation plan of *fen orchid*.

MATERIAL AND METHODS

The dissertation demonstrates the characteristic methods of operating the Nature Conservation Information System:

- digital biotic (organisms and their habitats relevant for nature conservation) mapping, the unique data collection method with geodatabase updating
- data conversion of digital parcel map files: geodatabase construction
- opportunities for internet publication of geodatabases (including nature conservation records, using client and server side methods, as well as Google Earth as a platform)

RESULTS

An important attribute of natural resources is its spatial location (geometry), which allows of studying the researched object in a Geographical Information System.

The author present the recent results of the decade-long issue of conservation: data collection, registration, display, service by the case of the development of the Hungarian Nature Conservation Information System (NCIS).

In the **first chapter** of the dissertation the subject of the thesis has been reviewed aiming the problems and goals should be analyzed.

The **second chapter** of the dissertation demonstrates the representative methods of the operation of the Nature Conservation Information System:

- digital mapping of biotic data (vegetation mapping), specific data collection methods of the NCIS with multiuser geodatabase editing,
- functional steps of conversation of digital cadastral maps into geodatabase, and advantages their usage in the NCIS,
- possibilities of internet map services (publication of conservation register), client and server side applications, as well as converting for Google Earth display.

The **third chapter** reviews the scientific background of the subject in the aspects of the development of the Nature Conservation Information System. Beyond that it considers the motivation of development, describes the details of the initiatives, the system elements, objectives, and the details of the implementation of the NCIS as a geospatial application.

The author laid down that prior to NCIS the administrative and professional decisions were based on persons –not data– with appreciable field experience at the National Park Administrations. Regarding dataflow, since 2005 the decision making process has changed. The tasks are differentiated in time and space. The data collection is a role of the National Park Administrations, but the authority decisions are taken by the Environmental, Conservation and Water Inspectorates (so-called "Green Authorities"). The dissertation lays down that a unified framework of conservation management tasks, field investigation, education efforts and authority roles can be established by developing the Nature Conservation Information System.

The author critically reviewed the 22 most important primary databases of NCIS.

He summed up the user, hardware and software environments of the system, and presented the operation principles of the eight functional modules and the data flow process of the Nature Conservation Information System.

The author confirmend that the Nature Conservation Information System is a flexibly sizable GIS tool in raising the efficiency of the administrative institution's (National Parks Administrations and Green Authorities) routine, further more:

- subsequent to the critical level of uploaded data it will release experts from mechanical tasks, consequently their knowledge will be more usable for professional duties (increase of efficiency).
- NCIS systematizes the primary databases of conservation regarding cognition of recent and preliminary flora, fauna and communities of distinct spatial areas, and becoming acquainted of trends.
- It builds a professional basis for conservation management, a legal process of protection declaration, and supports authority tasks, moreover it increases its rapidity and efficiency and decreases possibilities of error.
- Assures professional background to monitoring. Opens the door to follow processes of change resulting from influences of intrusions and new establishments etc.

- It is suitable to run a proper, uniform, detailed and lawful register of protected areas and areas proposed for protection concerning spatial location (geometry) and attributes.
- Supplies information, with analysis together with different datasets it increases efficiency of conservational property and forest management and preservation of livings and communities. With more accurate register it ensures maximization of available resources.
- It means assistance in executing national and international obligations, and supports report preparation, assists in national and international data services.
- Local research institutes and educational institutions procure a greater degree of classified information about conservation potential of their local area. Various educational programs, forest school activities promote getting acquainted with local natural values, and support environmental education.
- Provides well arranged and systematized information for regional landscape design and landscape utilization.

At the end of the third chapter beside the representation of public relation module of NCIS, the author introduced one Hungarian and seven international conservation map servers.

In the **fourth chapter**, by the example of the potential reproductive zone model of the *fen orchid* (*Liparis loeselii* (L.) RICH. 1817.) the author introduced possibility of application of GIS toolset in practical conservational adoption.

The GIS model consists of two arguments (the distance of the willow fen and the distance of its populations), five parametrals called attention to crucial habitats, where essential conditions of germination of *fen orchid* can be limited by the lack of the fungy partner living in symbiosis with the *grey sallow* roots (*Salix cinerea* L.).

Results of the case study can be directly applied in planning *fen orchid* germination experiments or rather can be adopted in the species conservation.

CONCLUSIONS, RECOMMENDATIONS

– The development and implementation of the Nature Conservation Information System may cause a significant increase in process efficiency, but also bring about significant changes in the entire profession of conservation. These changes manifest in the possible and inevitable transformation of decision procedures: today's subjective decision making procedure must be replaced, even if gradually, by more objective, data driven decisions, considering data reliability, currentness, precision and completeness. It is inherent to conservation issues however that decision procedures can never become fully automated. The system notifies the user how many records the aggregated value made up of, thus quantifying the risk of the decision, and advises the decision maker whether there is enough data to make a thorough decision or if further field study is required.

– The system remains an empty GIS environment without strict data collection protocols and operation codes, up-to-date principal data catalogs, making the most important task of current months to devise a conservation data collection strategy and protocols and their promulgation as laws.

– Introducing the system will significantly increase the reliability, objectivity of decisions made by conservation authorities and professionals. With the improvements, come an increase of work requirements, when after the introduction, the system must be kept up-to-date requiring data entry, data updates (every source of biotic data related to conservation must be discovered and imported with geocoding into NCIS). In addition there is also the problem of "unknown territories" which will greatly intensify biotic data recording requirements from the national park professionals.

– Without the existence and frequent updates of conservation base data the NCIS database becomes obsolete rapidly. Current legal environment and pricing policies in terms of geodetic and remote sensed data greatly thwarts professional conservation as well as reforming public awareness. In addition, it is completely contradictory to the spirit of the Aarhus Treaty and the governmental data policies of the USA, the so-called cradle of GIS. The most important hindrance of fully enhancing the possibilites of the Nature Conservation Information System, the most important obstacle of its operation is the so-called free acces to external current databases, i. e. those created and maintained by other government agencies. The lack of such access is also the main inhibitor of e-government aspirations.

– When the EU project financing of NCIS development ends in 2008 the system will require further improvements: implementing new modules and functions, periodically occurring hardware and software upgrades or technological changes. Further NCIS developments can be financed partially from the state budget but larger projects will definitely require new subsidies.

– From 2008 there will be the constant cost of operating the IT system, maintaining the network infrastructure, database, periodic backups, occasional error reparation, optimisation (fine-tuning, speed improvements), activities pertaining to minor changes (support activities). The costs depend on the final quality of the system and the new requirements which must also be incorporated into the budget.

NEW SCIENTIFIC RESULTS

The author's results and statements of the dissertation consider the scientific results listed above as most significant:

1. He worked out the information conception of conservation, which laid down the fundamentals of the development of The Nature Conservation Information System. It laid down the unprecedented, new, separated, symmetrical, flexible architecture of the countrywide system, which was able to serve authority and management functions divided in time and space on behalf of data based decision making. The new architecture fixed in the conception succeeded in solving database versioning problems concerning countrywide statistics of protected areas.
2. The author worked out a license proposal in transformation in shapefile – geodatabase data storage with the help of ESRI Conservation Program, which enabled the unification and further improvement of the GIS environment of Hungarian nature conservation. Use of geodatabase enables countrywide analyses resulted in better solutions in quality and higher numbers of results in quantity.
3. In the case of the elements of Nature Conservation Information System the author set down limiting factors of applicability of primary databases, described the method of KÜVET (digital cadastral map – in Interactive Mapping System –ITR– format) data conversion to geodatabase. Remarkable (80%) storage saving and data efficiecy can be obtained with datamodel transformation of ITR files – geodatabase conversion.
4. The thesis describes the dataflow processes of modules of TIR. The author stated that efficiency of conservational property management can be significantly increased with the initiation of map basics of conservational property management. Size of lands leased out, occasional overlaps, and location of accidentally intermitted lands can be supervised.
5. Comparing with other European habitats, the author participated in the characterization of ecological demands of *fen orchid*, which was rediscovered subsequent to twenty years of latency in the year 2000 on floating fans of Lake Velence. He demonstrated conservational applicability of GIS toolset in spatial zonal modeling of biological characteristics (the potential reproductive zone of *fen orchid* characterized by the germination ability).
6. The thesis comprehensively reviewed the scientific literature of the frontiers of knowledge.

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