THE USE OF GIS METHODS IN TSES PLANNING

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Abstract

The aim of the article is to introduce the practical use of GIS methods in the territorial system of ecological stability of landscape (TSES) establishment. One of the goals of this methodology is to eliminate a subjective access at the territorial system of ecological stability of landscape planning and establishment. It has been developed and tested at the local TSES proposal in a part of Bartosovicky stream-basin area in the north-eastern Moravia. One of the important qualities of the landscape is its ecological stability according to Míchal (1992). The need to conserve fundamental landscape capacity, as an important donator of renewable resources, is the widest contemporary conscious process leading to the straightening of the ecological landscape stability. The completion of the TSES is one of its compounds as well.

KEY WORDS: ecological stability, GIS, landscape, TSES

1. INTRODUCTION

An idea of territorial system of ecological stability has emerged from the biogeographic island theory. Human activities result in the fragmentation of the natural environment life of other organisms and in the reduction of natural and nature close ecosystems in the landscape. Only a small part created "islands" - residual nature patches - is large enough and it contents such biodiversity to support possible survival and development of the distinctive species, its populations and societies. Occasionally, a species can extinct at one/more limited patch/es. To ensure this species re-colonisation from other residual patches, it is necessary to conserve a sufficient amount of large "islands" and to ensure the possibility of migration among those "islands". Different species are bound to specific abiotic environments. Therefore, it is important to conserve a wide range of such environments. The objective of the landscape ecological stabilisation is clear, however, the issue is what ways should be used to achieve the stage proposed. The recent methodology is based mainly on the intuition and the relation to the landscape. Nevertheless, the nowadays approaches should be more based on the scientific data (e.g. the landscape and its patterns condition). This attitude is compatible with the landscape synthesis process according to Kolejka et Pokorný in Voženílek (1999). At the same time, it is important to include the geo-informational technologies, which are suitable for the analysis of a big amount of the space data and other synthesis.

2. METHODOLOGY OF TSES PLANNING WITH THE USE OF GIS

2.1 Analysis and visualization

The methodology is based on the technology of the GIS. Tuček characterizes geographic informational systems as an organized system of hardware, software and geographical data to achieve an effective collection, storing, actualizing and visualization of the time-space information. Preparation of digital data is time-consuming stage and means conversion of all printed maps to digital layers (maps) in the environment of system PC ARC/INFO 3.5.2. Alternatively, it is possible to digitize scanned maps in the system ArcView. Analysis and other visualization of results have been done in software ArcView GIS. Data got during the fieldwork was implemented to an attribute table. On the base of an ortophoto were modified outlines and accurate position of a current landscape segment. Area of such modified segments was consequently recount. Final maps were completed in the scale layouts with all the components of a map.

2.2. Theoretical base

Theoretical basis of establishing local TSES using GIS were created on the ground of methodology Kolejka et Pokorný in Voženílek, 1999, with use of same techniques from Metodika vymezování místního ÚSES/Methodology of local TSES identification (Löw et al., 1995).

Main principles of TSES completing:

1. To comply with natural landscape structure and its predisposition for a certain risk processes as a basis for an evaluation of landscape human modification and analysis of the requirements for ecological stabilization.
2. To take the abundance of valuable landscape segments in the landscape matrix into account.
3. To ensure the sufficiency of existing elements of the system.
4. To prefer poly-functionality of all elements of the system.

The most suitable method for the TSES establishment is a process of the landscape synthesis. Therefore, the essential is prior landscape diagnosis. This part involved primary (natural) landscape structures inventory and location of secondary (existing) landscape structure. The evaluation part of the diagnosis consists of the eco-stability function determination of both natural and secondary landscape structure and their integral display into the actual landscape segments condition from the ecological stability viewpoint.

2.3. Identification of the primary landscape structure

Identification of the primary landscape structure is the main starting point for the impact evaluation of human landscape modification and the analysis of the need for ecological stabilization. A prior step for the location of primary landscape structure is to create layer (map) of geobiocen type groups (GTG). A geobiocen type consists of natural geobiocenose and all other transformed geobiocenose derivate and developed from natural geobiocenosis and its development stages. Detection process of natural landscape stage includes a geobiocenosis classification and geobiocen classes specification. Basic application unit of this typification are geobiocen type groups (GTG). Their names are derived from the terms of predominant temperate woody species from original forestal geobiocenose. The geobiocen type groups (GTG) as a frame of specific ecological conditions and therefore potential biocenosis are specified by biocenological code. The first symbol in the code (a number) represents altitudinal vegetation zone, the second symbol (a letter) represents the soil conditions (trophic level) and finally the third letter presents hydric level (Löw at al., 1995). The GTG associates areas with similar lasting ecological conditions without a reference to their existing situation. Nevertheless, these areas have similar conditions for the using in forestry, agriculture, water management and nature conservation.

The GTG for the forest land have been specified by the conversion from STL forest type group derived from the forest typological map. A conversion table has been used for the purpose of a conversion of a HPJ (hlavní půdní jednotka) to the GTG. More options, how to BPEJ data interpret, exist as the reason that in BPEJ (bonitovaná půdně ekologická jednotka) key does not always mention its pedogenic substrate. As a consequence, a final verdict for the soil condition (trophic level) has depended on the soil parent material inferred from the geological map.

The GTG for the agricultural land were specified by the conversion from HPJ derived from BPEJ, where the second and the third position of the five-symbol code has simply defined the soil type, sort and hydrological regime (Kynčl, 1994).

The final result of the process was the GTG digital coverage (map) with the corresponding attribute tables.

2.4. Identification of secondary landscape structure

The current landscape structure condition has been found out by the field environmental mapping in the growing season. The field mapping was completed according to the methodology Mapování krajiny SMS (Vondrušková, 1994). Each uniform landscape segment in structure and function was confined and specified with the ordinal number. In the table, these attributes have been recorded: the ordinal number, corresponding special segment type data code (účelový typ segmentu), actual size, ecological stability level and basal parameters. The basal parameter contents the description of the landscape, vegetation cover, and other notes.

The secondary landscape structure was confronted with the ortophoto map (to achieve the accuracy), digitized and visualized. Special segment type data code, actual size, ecological stability level and basic parameters were added to the attribute table.

2.5. Determination of the natural stability

The natural stability was inferred from the theme of the geobiocen type groups (GTG). The natural stability was determinate for each entity within the frame of GTG, in the case of particular GTG was compounded from a several area separated segments (entities). This technique has prevented an unduly generalization of weighted average effect of inclination and geological substratum. To the each GTG segment were assorted point values representing nature factor influences. The bioclimate, soil conditions (trophic level) and soil humidity (GTG code) are in the frame of GTG uniform. The influence of the inclination and the geological substratum was determinate separately for each GTG segment as point values weighted average inferred from real natural components. The final natural stability level was derived from the summary point valuation acquired as a sum of partial point values of particular nature factors. The essential step to learn a geological substratum impact was the creating of digital geological coverage and attribute tables with point values for particular geological substratum. This theme (coverage) was united together with the primary landscape structure theme (coverage) to simplify a new polygonal theme. Weighted averages were counted in the attribute tables.

The essential step to create the geo-relief inclination theme was a contour line digitalization. Consequently, a fully dimensional digital model was created in the module of the ArcView 3D Analyst. Simultaneously, the slope categories were redefined: 0–3° for flatlands and very gentle slopes, 3–15° for gentle slopes and over 15° for steep slopes. The final 3D digital model was converted to the shapefile polygon coverage. The subsequent union with a primary landscape structure theme was analogical to the process with geological substratum theme.

The final step in this part of process was uniting primary landscape structure theme competed with nature stability values and secondary landscape structure theme. The secondary landscape structure units are for a particular GTG homogenous also in their natural quality.

2.6. Determination of the functional stability

By the uniting primary and secondary landscape, structure themes were creating a theme containing units uniform in their natural character and purpose utilization. The functional stability of individual natural landscape units (entire GTG) was determinate as a weighted average of ecological stability levels of purpose segment types in the frame of the GTG geosystem. Ecological stability levels of purpose segment types were determinate in accordance with the methodology Mapování krajiny SMS (Vondrušková, 1996). The functional stability level was determinated in terms of point values in Tab. 1.

Tab. 1: Determination of natural and functional stability (Kolejka et Pokorný, 1999)

Stability value	Abbreviation	Point values of natural stability	Point values of functional stability
Very high	VH	12–15	4,500–5,000
High	H	9–11	3,500–4,499
Average	A	7–8	2,500–3,499
Low	L	4–6	1,500–2,499
Very low	VL	0–3	0,000–1,499

2.7. Determination of the ecological stability

The ecological stability values of individual GTG were derived using the means of matrix (Tab. 2).

The ecological stability level is an aggregate indicator of real eco-stabilization status or area condition of an entire natural landscape unit (entire GTG) and, therefore, also a condition of purpose segment type within a specific GTG. The condition is impacted by the current land use (functional stability) and by the natural resistance against destabilization processes (natural stability).

Tab. 2: Decision matrix for ecological stability determination (Kolejka et Pokorný, 1999)

		Functional stability				
		VH	H	A	L	VL
Natural stability	VH	5	5	4	3	3
	H	5	4	3	3	2
	A	4	3	3	2	2
	L	3	3	2	2	1
	VL	3	2	2	1	1

2.8. Planning of the landscape ecological stability structure

Realized ecological stability levels are main base for delimitation of ecological stability structure. Ecological stability structure integrates existing ecologically significant landscape segments. Ecologically landscape segments are created by ecosystems with relatively a higher ecological stability with preponderance of these ecosystems (Löw et al., 1995).

The incorporating landscape segment priority rate of particular purpose segment types of GTG into ecological stability structure depends on the confrontation of entire ecological stability of particular GTG with an area condition within the purpose segment type. If an area of a certain GTG was stabile and concurrently the particular purpose segment type within this GTG was stable too, than the importance of the incorporating of this stable landscape segment was relatively low. Reversely, if an area of a certain GTG was instable but the particular purpose segment type within this GTG was stabile, than the priority of incorporating of this stabile landscape segment was maximal. The priority determination of ecologically significant landscape segments incorporation into the ecological stability structure was managed within matrix (Tab. 3).

Tab. 3: Decision matrix for priority determination of significant landscape segments incorporation into ecological stability structure; 5 – max. priority, 1 – min. priority (Kolejka et Pokorný, 1999)

		Ecological stability of purpose segment type in the background of GTG				
		VH	H	A	L	VL
Ecological stability of GTG	VH	4	3	2	1	1
	H	4	3	2	2	1
	A	5	4	3	2	1
	L	5	4	3	3	1
	VL	5	5	4	3	1

2.9. Planning of the local TSES

All the ecologically significant landscape segments are concurrently existing structural segments of the TSES. In the process of TSES planning, these existing segments should be preferred especially. Newly established segments have to be created in the field, these will be fully functional after many years. The reorganization of ecological stability structure is not possible until the TSES are in the full and optimal capacity. According to the prevailing function and parameters are the structural segments distinguished into biocentres, biocorridors and interactive components (Löw et al., 1995).

The priority determination of the existing biocentre from the proposal of other biocentres into the TSES structure was managed with the decision matrix (Tab. 3). The concrete selection from the amounts of equivalent segments was managed through the use of spatial requirements listed in Tab. 5.

The principle of such a selection is to conserve with the minimal spatial equivalent existing GTG in the landscape structure.

The priority determination of new bio-centres localization (will be established in instable areas) was done the opposite way. The determination of a suitable purpose segment type (or a concrete segment type in its area) to form a new bio-centre and was managed through the use of the decision matrix (Tab. 4). The priority rate of a certain purpose segment type incorporating (or a concrete segment in its area) depended on the situation confrontation in a concrete purpose segment type in the frame of a certain GTG with the condition of the whole GTG area. After the confrontation with the primary landscape structure map were separated out ineligible locations impossible or uneconomical to create the new bio-centre (e.g. build-up an area, an urban area)from the segments selected.

Tab. 4: Decision matrix for the priority determination of landscape segments to completion of biocenter; 5 – max. priority, 1 – min. priority (Kolejka et Pokorný, 1999)

		Ecological stability of purpose segment type in the background of GTG				
		VH	H	A	L	VL
Ecological stability of GTG	VH	1	1	2	2	3
	H	1	2	2	3	3
	A	2	2	3	3	4
	L	2	3	3	4	5
	VL	3	3	4	5	5

The final conceptual objective of the TSES planning was the selection of optimal interconnections between bio-centre concepts. The bio-corridors should be created with the minimal migration barriers for keeping its effective function. These barriers are GTG divisions and disturbance corridors (e.g. motorways), which form a barrier for species migration. It is necessary to ensure the sufficient capacity to enable the migration of multitude species. Minimum area requirements for migration corridors are listed in Tab. 5.

Tab. 5: Area parameters of local biocentre and biocorridor parameters (Löw et al., 1999)

canopy type	Min. area of biocentre [ha]	Biocorridor	
		Max. length [m]	Min. widht [m]
Forest canopy	3	2 000	15
Wetland canopy	1	2 000	20
Meadow canopy	3	1 500	20
Steppe canopy	1	2 000	10
Rock canopy	0.5	–	–
Combined canopy	3	2 000	–

It is rational to assume, that a higher variability in conditions of landscape segments (in the frame of GTG) imply a stronger barrier character. Fewer amounts of species will cross this barrier and will migrate along the barrier. Therefore, the best option is to plan the migration corridor along the GTG division. Theoretically, such a corridor can use different species bounded to both environments concerned to bordering the GTG. GTG divisions are the prime option to plan a biocorridor.

The economic efficiency of the biocorridor planning (and constructing) is directly proportional to the quantity of the existing or partially existing functional sections between two preliminary selected biocentres. The real situation in the area of potential biocorridors was located after covering the GTG division network coverage and secondary landscape structure coverage.

2.10. Selecting and proposition of the TSES components

Basic TSES components are biocorridors, biocentres and interactive components. These components can be divided according to the functionality into the existing (functional), semi-functional (partially functional) and absent (non-functional) biocentres and biocorridors.

The existing biocentres should be selected from the sum of equivalent ecologically significant landscape segments according to their area parameters. The evaluation of landscape segment ecological stability on the background of the GTG has required a high fragmentation to ensure the character homogeneity of the each segment. A certain amount of such segments was not in compliance with the requirements to the minimal local (or regional) bio-centre size. Therefore, the final existing biocenter selection was in some cases affected by a sequential synthesis of neighboring segments with similar phytocoenose, eventually the synthesis of segments with different vegetation cover, but it belonged to the same or affinitive GTG. All the times, their area parameters were verified. In the case the requirements were not fulfilled, such biocentres were classified as a semi-existing (semi-functional) bio-centre. Absent areas usually on arable land were recommended for tree species planting (tree species must correspond to the potential nature biocoenose). All the recommendations together with other attributes (characteristic of current condition, area parameters, GTG code and segment sequence number) were written into the tables. The biocentres with sufficient area parameters (however, their vegetation cover does not correspond to potential nature biocoenose – artificially modified natural species composition with preponderance of allochtonous species) were also included into the semi-functional bio-centre category. Such areas were recommended for a gradual replacement from the allochtonous species to the autochtonous. The existing biocentres are devised to conserve its biocoenose.

In the process of a non-existing bio-centre determination were found many large segments suitable for the stabilization. The final selection was done in the consideration of greatest distance admissible for the bio-corridor connecting different biocentres. Therefore, a new biocentre was selected on the biocorridors usually on the crossings of biocorridors.

The existing functional biocorridors formed a full connection between biocentres and met all the area parameter requirements (length, width, disconnections) and are compounded from the species corresponding to the potential nature biocoenose. The main function of the corridor is the interfered biological information flow in the landscape.

Semi-functional biocorridors represent usually a non-interrupted connection of two biocentres, however, some of these segments do not meet area parameter requirements and in addition, the vegetation cover is composed of rellativelly instable biocoenose. These segments are recommended to be extended and species should be changed in the sense of potential natural ecocoenose. The last sort of semi-functional biocorridors are those with non-functional segments on an arable land.

Non–functional absent bio-corridors or their parts are recommended for plantion in the strip attached to both sides of the GTG borders. The recommended tree-species should be adequate to both GTG – the objective ecocoenose is supposed to represent a transition zone.

The interactive components are remaining landscape segments, which were not included in the TSES for the reason of substandard area parameters or unsuitable position, however, they are important for conserving and increasing of the eco-stability and biodiversity of the landscape. Other typical segments classified as interactive components are significant lineal canopies, which are not eligible for the biocentre tracking.

SUMMARY

Although the territorial system of ecological stability of landscape theory is sometimes criticized, currently represent the best practical system of landscape conservation. The methodology introduced in this article is based on the methodology Kolejka et Pokorný (1999) and its main goal is eliminate a subjective access at the territorial system of the TSES planning and establishment as an most criticized point of the TSES theory. The GIS technology afforded multifunctional analysis and synthesis of natural or human-influenced components of the landscape.

SOUHRN

Využití metod GIS v územním plánování

Územní systém ekologické stability (ÚSES) krajiny představuje v současnosti hlavní nástroj ochrany přírodních a přírodě blízkých segmentů krajiny a celkové krajinné struktury. Využití geografických informačních systémů umožňuje eliminovat subjektivní přístupy při stanovování ÚSES. Popsaná metodika vycházející z metodiky Kolejka et Pokorný (1999) byla vyvinuta a ověřena při vytyčení lokálního a (částečně) regionálního ÚSES v severní části Bartošovického potoka na severovýchodní Moravě.

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