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ECOLOGICAL NETWORK DYNAMICS AND ENVIRONMENTAL CONSIDERATION IN PLANNING FOR RENEWABLE ENERGY

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An ecological network is a set of ecosystems linked into a spatially coherent system, which might change over time but needs to keep its conservation and stabilizing potential. The aim of the paper is to show how an ecological network in the study area of Záhorie changed over fifty years, to analyse former and remaining ecological connections in the landscape and to highlight current barriers to network operation. The following aim is to outline the potential negative environmental effects of renewable energy sources and the necessity to locate renewable energy installations under the constraints of nature conservation. Land cover databases representing the state of the landscape in 4 time horizons (1954, 1979, 1992 and 2003) were used for the analysis of landscape changes. Ecologically important segments identified in the land cover maps represent the most ecologically valuable areas and form the basis of the ecological stability system. The study focused on changes in stabilizing elements and changes in the ecological stability of the landscape system as they are important for the planning of any human activity. The present trends in energy management point to the fact that renewable energies will gain a more important position in the energy structure of the individual European Union (EU) countries. Assuming further expansion of renewable energy sources (RES) in the landscape, it is also expected that the anthropogenic impact on the landscape will increase. It may result in changes to the original geo-

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systems. Territories primarily suitable for the development of RES represent a significant developmental potential and their environmental limits must be considered in relation to the existing anthropogenic layer, human interests and the protection of nature.

Key words: ecological network dynamics, ecological stability, landscape protection, renewable energies

INTRODUCTION

Exploration of the essence of stability, balance of the landscape systems and their changes is central to landscape ecological studies. The aim of the research is connected with the requirement to conserve stable landscape systems, as a prerequisite for the functioning of human society. This implies that in decision-making about a future landscape a balance is achieved between ecological, cultural and economic functions (Huba 1995, Huba and Ira 1996, Linehan and Gross 1998). The landscape system should afford conditions that allow natural populations to recover in time from environmental, political and socio-economic perturbation. The landscape is ecologically sustainable if the following conditions are fulfilled: spatial pattern of the landscape with resilient populations, development changes in the spatial pattern without deteriorating the conditions for target species. Moreover, the local and regional actors should be able to incorporate these conditions in a planning and design process (Opdam et al. 2006). Ecological networks are defined as a set of ecosystems linked into a spatially coherent system through flows of organisms and interacting with the landscape matrix. The author of this paper agrees with Opdam et al. (2006) that key features of an ecological network can have different configurations and still serve the same goal. In the case of intensively exploited landscape, habitat fragmentation is one of the most serious threats to species as it leads to their extinction and the loss of biological diversity (D'Eon et al. 2002, Mayers 2003). A solution to this problem is based on the spatial cohesion of the habitat networks in the landscape. Opdam et al. (2006) emphasized that an ecological network might change in area, shape and location without losing its conservation potential. An ecological network depicts the ecologically important part of the landscape and helps the multi-actor decision-making and planning process.

Ecologically significant elements are interpreted as the landscape-forming ones with a positive (stabilizing) effect on the surrounding landscape. They constitute the basis for the proposal of elements within the Territorial System of Ecological Stability – TSES (Hrnčiarová and Ružička 1997, Izakovičová et al. 2001). The TSES represents the most important projection of the landscape-ecological principles into real environmental policy and spatial planning. It is an integral part of legislation, and a general ecological regulator of various plans and projects and has become a compulsory part of the decision-making processes. While designing the landscape ecological network, it is also beneficial to account for the changes in landscape elements during recent decades. Principles of restoration ecology can be applied by complementing the missing segments and links of the ecological network based on the landscape change (Straka 2002).

The ecological network of a particular territory is a dynamic system that changes depending on changes of the landscape elements, their spatial arrangement and relationships between them. The land cover database CORINE Land Cover (CLC) sufficiently represents the material elements of the contemporary landscape structure. CLC classes (Feranec and Oťaheľ 1999) distinguish the landscape elements with respect to the degree of anthropogenic impact, to its dependence on human (the highest dependence is in the artificial anthropogenic areas) and to the degree of their eco-stabilizing capacity (it increases from semi-natural towards natural classes). Analysis of land cover changes makes it possible to identify the particular changes of natural and semi-natural elements in the landscape, its network and to discover landscape-ecological problems of the present land use. Ecologically important landscape segments comprise the positive elements in the territorial system of ecological stability.

Landscape protection and its most valuable parts are important limitations for the location of renewable energy technologies. To avoid conflicts with landscape protection in future, it is necessary to analyse the spatial information on local ecosystems during the analysis of the potential use of renewable energies. Land cover with the identified ecologically important landscape elements represents one of the important information layers used for the delineation of areas suitable for renewable energies.

The author of this paper focuses on the ecological network dynamics in sustainable conditions. The aim of the paper is to show how an ecological network changed over fifty years in the study area Záhorie, to analyse former and remaining ecological connections in the landscape and to highlight current barriers to network operation. Assessment of the contemporary landscape structure in work represented by land cover is a fundamental step within the procedure of ecological network analysis. The following aim is to outline the potential negative environmental effects of renewable energies and the necessity to locate renewable energy installations under the constraints of nature conservation.

DATA AND METHODS

Study area

The study area (extent 131.57 km^2) is situated in the southern part of the Borská nížina lowland and Malé Karpaty mountains (Fig. 1). The altitude ranges from 136 m a.s.l. (floodplain of the Morava river near the Devínska Nová Ves) to 514 m a.s.l. (Devínska Kobyla). The study area spreads over the administrative territory (or its parts) of the capital Bratislava, and also communes Marianka, Stupava, Vysoká pri Morave, and Zohor.

The spirit of Bratislava and the adjacent smaller settlements started to change with the onset of socialist industrialization in the 1950's. The city's development accelerated, massive investments and production influenced the population increase (Cebecauerová 2007). From the 1970's, the development of urban areas with prefab constructions and uniform multi-storey buildings and large industrial plants prevailed. This type of development completely changed the original rural character of the city wards Dúbravka, and later of those of Lamač and Devínska Nová Ves. The development of the city and its surrounding area has been considerably influenced by international contacts with neighbouring countries: Austria, Hungary after 1989 and, with the Czech Republic after 1993.

Fig. 1. Location of study area in the Slovakia

Bratislava boasts a well-developed poly-functional structure of industry. Numerous other infrastructure areas such as services, schools, hospitals, administrative complexes, sport, leisure and recreation areas are related to the position of Bratislava as the principal urban centre of the country. New construction of residential and prefab buildings as well as industrial plants modified the spirit of Stupava and other satellite settlements.

Land cover analysis and identification of changes

The contemporary landscape structure was primarily analysed according to the real physical state represented by land cover (Oťaheľ 1999, Feranec and Oťaheľ 2001). Panchromatic aerial photographs of the study area from 1954, 1979, 1992 and 2003, the topographical maps with the scale of 1:50 000 from 1953 and 1987, thematic maps and information acquired by field mapping were used in this study. The modified CLC nomenclature for scale 1:50 000, presented by Feranec and Oťaheľ (1999), was used for identification of classes (Cebeceuarová 2007). This nomenclature is based on the CORINE land cover nomenclature for the scale of 1:100 000 (Feranec and Oťaheľ 2001), which was extended with the aim of respecting national particularities and scale differences. The nomenclature is composed of 4 hierarchic levels, it is divided into 5 classes at the first level and at the fourth level it is divided into 77 classes, including 37 which were identified in the study area.

Land cover databases representing the state of the landscape in 4 time horizons were used for the analysis of landscape changes. The first step of the analysis consisted of land cover databases integration by overlay operation and identification of individual areas of land cover changes (LCC). Based on comparison of individual land cover states for 1954, 1979, 1992 and 2003, summary characteristics of land cover classes for each time horizon and hierarchic level were derived and accompanied by analysis of the mutual changes of two time horizons by the use of contingency tables and analyses of areas with the same land cover class in the 1st (1954) and the 4th (2003) time horizons and with change in 1979 and/or 1992.

Analyses of the ecological network and its changes

Changes of landscape elements during the development affected the whole landscape structure as well as its ecological stability. CLC classes were treated as elements of the landscape structure under the concept of the landscape eco-stabilizing assessment. The morphostructural and physiognomic properties of land cover correspond to the basic functional features and indicate spatial organization of the cultural landscape in the regional dimension (Feranec and Oťaheľ 2001, Oťaheľ et al. 2005). Hence, the land cover database sufficiently represents the material elements of the contemporary landscape structure. CLC classes (Feranec and Oťaheľ 1999) distinguish the landscape elements with respect to the degree of anthropogenic impact, its dependence on human (the highest dependence exists in artificial anthropogenic areas) and to the degree of their eco-stabilizing capacity (it increases from the semi-natural towards natural classes).

Ecologically important segments of the landscape identified in the landscape structure represent the ecologically most valuable areas and form the basis of the ecological stability system. They are parts of the landscape formed by ecosystems with relatively higher ecological stability or parts where such ecosystems prevail. They are characterized by the stability of biota and ecological conditions that allow the existence of species belonging to the natural gene pool of the landscape. The existing ecologically important segments form the background for designers of biocentre and biocorridor networks. Identification of biocentres and biocorridors is associated with cognition of biota in the study territory, its ecological quality, diversity, existential demands and functions in relationship to humans (Oťaheľ and Feranec 1997).

In our work assessment of the contemporary landscape structure represented by land cover is a fundamental step in drafting the territorial system of ecological stability. We analysed the ecological network for four time horizons and differentiated ecologically important landscape segments. Selected land cover classes were divided into two groups: ecologically important segments with higher eco-stabilizing capacity – woody vegetation, grassland, water bo-dies, selected agricultural areas (orchards with natural vegetation, complex cultivation patterns), ecologically important segments with lower eco-stabilizing capacity which also exert positive effects on their environs – orchards without natural vegetation, vineyards, green urban areas – parks, cemeteries, some sport and leisure areas.

The assignment of the individual coefficients of the eco-stabilizing capacity (Tab. 1) to the individual land cover classes was based on the results of Miklós (1986). In our previous work (Cebecauerová 2006) we proposed the distinguishing of eco-stabilizing important coefficients for different time periods (in this paper, the term coefficients of the eco-stabilizing capacity is preferred according to Oťaheľ et al. 2004). This coefficient emphasizes the ecological value of a natural association compared to artificial elements; it prefers their ecological importance, self-regulation and soil conservation functions. The values of this coefficient were modified for each individual year in order to take into account the factor of time. Higher values of the eco-stabilizing capacity coefficient were assigned to some landscape elements in 1954 as the anthropogenic pressure on

Tab. 1. Coefficients of the eco-stabilizing capacity of landscape elements

Landscape elements—Land cover classes		Coefficient of the eco-stabilizing capacity		
		1954	1979, 1992	2003
112 – discontinuous urban fabric	without gardens (1121)	0.20	0.10	0.00
	with gardens (1122)			0.15
121 – industrial or commercial units		0.00	0.00	0.00
122 – road and rail networks and associated land		0.00	0.00	0.00
132 – dump sites			0.00	0.00
133 – construction sites		0.00	0.00	0.00
141 – green urban areas		0.40	0.30	0.30
142 – sport and leisure facilities	sport facilities (1421)	0.14	0.14	0.14
	leisure facilities (1422)			0.30
211 – non-irrigated arable land		0.20	0.14	0.14
221 – vineyards			0.29	0.29
222 – fruit trees and berry plantations	without vegetation	0.55	0.43	0.43
	with natural vegetation			0.50
231 – pastures	protected	0.75	0.65	0.75
	non-protected			0.65
242 – complex cultivation patterns	without scattered houses – crofts (2421)	0.60	0.50	0.45
	with scattered houses – gardens (2422)			0.55
311, 312, 313 – all forests	protected	1.00	1.00	1.00
	non-protected			0.85
324 – transitional woodland-scrub		0.80	0.75	0.75
411 – marshes	natural	1.00		1.00
	under human impact		0.90	0.90
511 – water courses		0.90	0.79	0.79
512 – water bodies		0.90	0.79	0.79

all natural and semi-natural elements in this period was markedly lower than in the following years. The coefficient of the eco-stabilizing importance in 2003 was elaborated in more details using the knowledge of local conditions and historical development of studied area, more reliable land cover layer supplemented by field mapping and consideration of contemporary nature protection measures. Moreover, some classes at 4th hierarchic level might differ in space in terms of their biotic part proportion (share of trees and shrubs, start of natural succession association) and in nature and landscape protection (areas legally protected or not protected).

Identification of the landscape structure elements and quantification of its ecological stability allowed an overall ecological stability analysis of the study area. Ecological stability is computed according to two common approaches - the 1st coefficient of ecological stability of Míchal (1982), see also Karlubíková (1993), Streďanský and Šimonides (1995), Lipský (2000), and the 2nd coefficient of ecological stability after Miklós (1986), or the coefficient of landscape structure quality of Izakovičová (1999). The landscape structure is assessed through the quantitative evaluation of landscape structure elements, while the relations between them and their spatially varying structure are neglected.

Coefficient of ecological stability (KES1) after Míchal (1982):

$$KES\ 1 = \frac{\sum_{1}^{n} PK_p}{\sum_{1}^{m} PK_n}, \tag{1}$$

where: *KES* 1 – coefficient of ecological stability, PK_p – the area of elements with stable or positive influence (woody vegetation, grassland, orchards, vineyards, gardens, urban vegetation, recreational and leisure areas, water bodies), PK_n – the area of elements with unstable and negative influence (arable land annually ploughed, built-up areas without green urban areas and leisure areas), n – number of elements with positive influence, m – number of elements with negative influence in the landscape.

Coefficient of ecological stability (KES 2) after Miklós (1986):

$$KES\ 2 = \sum_{1}^{n} \frac{p_i \cdot k_{pi}}{p}, \tag{2}$$

where: *KES* 2 – coefficient of ecological stability, p_i – the area of individual elements (our land cover classes), k_{pi} – coefficient of the eco-stabilizing capacity of individual elements for each year, p – the area of elements, n – number of polygons of elements.

Changes, where the reconstruction of the original properties from the former periods were identified were also studied in more detail. Interpretation of such changes, i.e. development of the area type X (1954), Y(1979 and/or 1992) and Z (2003) together with supplementary information may contribute to issues of the reconstruction of the historical landscape structures. The share of such changes in all changes in the 1954-2003 period at the fourth hierarchic level was 6 %.

RESULTS

Land cover changes

The intensive landscape dynamics induced above all by human pressure, was the characteristic feature of the study area in recent 50 years. The landscape dynamics are analysed by comparison of the initial and final states of the landscape for the following time periods: 1954-1979, 1979-1992, 1992-2003, and 1954-2003. The overall period studied (1954-2003) shows a significant landscape transformation. During this period, the class of artificial surfaces increased from 5 % to 14 % of the total extent of the study area (Fig. 2), the extent of agricultural areas decreased by 12 % to final 57 % in 2003. Especially during the first period (1954-1979), the growth of the Bratislava city was noticeable, above all due to construction of new residential areas (housing estates), industrial facilities with associated transport and technical infrastructure. In the succeeding periods, the growth of artificial surfaces continued, but with lower intensity.

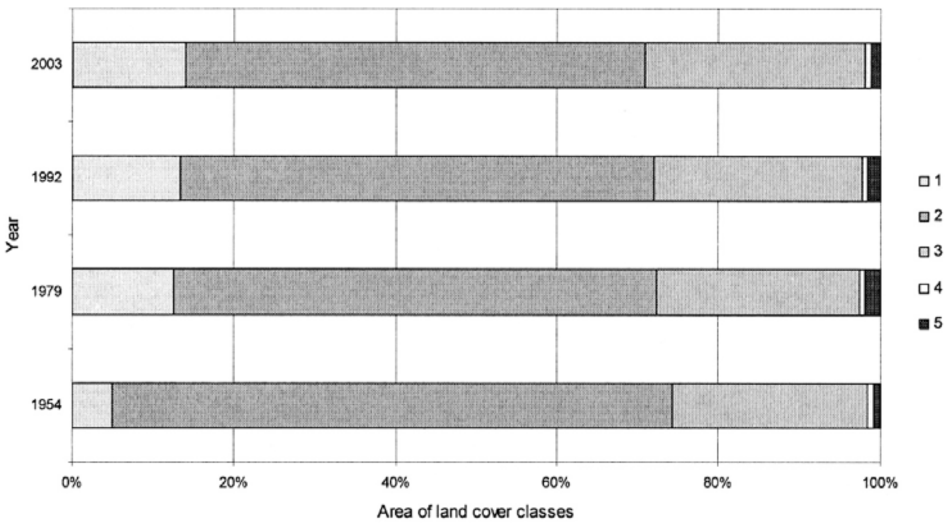

Fig. 2. Changes in area of five main land cover classes in the years 1954, 1979, 1992 and 2003

1 – artificial surfaces, 2 – agricultural areas, 3 – forest and semi-natural areas, 4 – wetlands, 5 – water bodies.

The extent of the agricultural areas decreased in the course of all studied periods as a result of increasing artificial surfaces and a moderate change of forest and semi-natural areas, but the most intensive decrease were during the first period (1954-1979). The vast changes taking place in agricultural areas changed the image of the landscape. Collectivization and modernization of agricultural production induced extensive changes especially during the first period. The mosaic of small plots of arable land and pastures cultivated by individual farmers was replaced by large plots of arable land cultivated by co-operatives and state farms and the extent of pastures considerably decreased. Only in the last period (1992-2003), the reverse processes started, the extent of arable land decreased and the area of pastures increased. This trend is the result of political and economic transformations that started in 1989 and the actual influence of the EU agropolicy – the trend to limit intensive agricultural cultivation to the most productive areas only (Bastian and Steinhard 2002, Lipský and Kvapil 2000).

The original agricultural landscape, with rural settlements was transformed under the effect of the widespread urban and industrial growth of Bratislava with modern agricultural production in its vicinity. The study area currently represents the landscape, with dominant industrial, commercial and transport functions with built-up areas and, with a secondary agricultural function in the vicinity of the city. The study area has undergone rapid development with fundamental social and economic changes after 1948 and 1989 (the beginning and end of the communist regime) that influenced the original land cover structure and affected all its components. Urbanization, industrialization, collectivization and modernization of agriculture and forestry changed the landscape structure during the first and partially during the second periods. During the second and mainly the third periods, other new factors drove the landscape changes. The most important ones include the introduction of the market economy, changes in international relationships, approximation to the European agricultural policy and observation of international commitments related to the protection and conservation of nature.

Ecological network and its changes

Ecologically important segments with higher eco-stabilizing capacity

The woody vegetation is represented in the study area by classes of forest and transitional woodland-shrubs (including forest nurseries and young stands after cutting). Continuous forest is the most important element of the eco-stabilizing network, especially that protected by law. In these areas human activities are regulated according to the degree of protection. The study area partially extends over two protected areas: the southern part of the Protected Landscape Area (PLA) Záhorie and the PLA Malé Karpaty. The non-forest woody vegetation is represented by small patches of forest and shrubs in the landscape, narrow strips of trees along the watercourses and roads and in the valleys of hilly land. The narrow strips of forest along the Morava river belong to the protected site Devínske alúvium Moravy.

The size of forest and semi-natural areas (class 3 of the CLC nomenclature) slightly increased over all the studied periods. Regarding preservation of ecological quality, this development can be considered positive (Tab. 2). The study area was utilized intensely for agriculture in all suitable areas for a long time and forest remained only on the inaccessible slopes of the Malé Karpaty mountains and less fertile soils of the Borská nížina lowland. The increase of forest and semi-natural areas was induced by different processes: division of the big areas of coniferous and mixed forests into smaller plots with higher spatial heterogeneity, increase of the number and extent of the transitional woodland-shrubs and emergence of linear vegetation along small water courses (canals) during the last period.

Tab. 2. Extent of ecologically important segments and stress elements of the landscape identified in land cover in 1954, 1979, 1992 and 2003

Landscape elements	Land cover classes	Area (ha)			
		1954	1979	1992	2003
Ecologically important segment with higher eco-stabilizing capacity (selected classes on 3rd level)					
Woody vegetation (forest and non-forest)	311, 312, 313, 324	3 158.3	3 283.9	3 353.4	3 556.3
Grassland (pastures and meadows)	231	1 747.9	1 390.2	1 173.5	2 091.6
Wetlands	411	108.7	101.6	87.4	110.5
Water bodies	511, 512	97.7	245.1	219.1	152.0
Complex cultivation pattern	242	5 389.8	752.8	831.5	799.2
Ecologically important segment with lower eco-stabilizing capacity (selected classes on 4th level)					
Orchards	2221	144.1	228.5	186.7	192.7
Vineyards	2211	-	149.6	199.6	183.9
Parks	1411	15.6	14.2	22.1	40.2
Cemeteries	1412	0.7	12.3	12.5	14.3
Leisure and relaxation areas	1422	-	4.5	7.6	5.5
Stress factors					
Artificial surfaces (without parks, cemeteries and leisure areas)	112, 121, 122, 131, 1321, 133, 1421	648.7	1 633.3	1 710.4	1 777.6
Arable land without dispersed vegetation	2111	1 562.1	5 334.3	5 280.0	4 233.7

The group of the permanent grassland areas (meadows and pastures) is represented mainly by meadows situated on the alluvial plain of the Morava river and less by meadows on the slopes of the Malé Karpaty mountains. The ecological spectrum of the occurrence of fields is wide and ranges from wet to dry stands (with high seasonal dynamics of water regime). The species composition depends on the ecological characteristics of stands and local cultivation practices (Stanová and Valachovič 2002). Wet meadows in terrain depressions (tall-sedge beds) and old river oxbows are mapped as the land cover class of freshwater marshes. They form important biotopes for fauna, above all waterfowl and amphibians. The field complexes containing terrain depressions with wetland vegetation are preserved next to the point where the Malina river joins the Morava river (Ružičková 1994). The majority of the larger areas of fields on the alluvial plain of the Morava river extends in the PLA Záhorie and the protected site of the Devínske alluvium of the Morava river. Smaller areas of fields situated on the slopes of the Malé Karpaty mountains belong to the PLA Malé Karpaty.

Due to the intensification of agriculture with the aim of maximizing the area of arable land, the extent of the grassland dramatically decreased during the first and second periods. During the third period, this trend was reversed and the total area of class 231 was biger in 2003 than in the initial year 1954. The main reasons for this change are related to the introduction of the market economy in agriculture resulting in the cultivation of the most fertile areas only and, to the decrease of the total number of employees in this sector (extensification of agriculture). The field survey carried out recently confirmed this trend and several new areas of grassland mainly on the Morava river alluvium were identified.

The total area of wetlands had also slightly decreased during the first two periods and then increased during the last, reaching its initial area. Patches of wetlands were small and of irregular shape in the past. In the last time horizon, they became larger and their boundaries more regular. Many areas of wetlands in 1954 were later transformed into agricultural areas, mainly arable land and pastures. During the last period, the area of wetlands increased in the northern part of the Morava river alluvium and was formed by reverse transformation of the agricultural areas. This process is linked to the transformation of agriculture mentioned above.

Grasslands and open weed and ruderal vegetation close by settlements and other artificial areas have also had an ecostabilizing function, and often act as interactive elements of TSES. Resistance of grasslands, intensely exposed to human activity, to some negative impact may be higher than that of biotopes with a natural composition of species.

Watercourses and their areas represent inherent elements of the natural landscape. Modification and regulation of small watercourses, which proceeded mainly during the first period, resulted in large negative changes in the original composition of the riparian vegetation. The original spatial structure of the canal network was preserved and expanded by many new canals in the agricultural landscape. The network of drainage canals was built in the Záhorská nížina lowland with the aim of regulating the drainage of watercourses coming from the Malé Karpaty mountains and setting up a more balanced water regime in the lowland area. Processes like densification, canal straightening, and diminishing of the vegetation along canals are observable on land cover maps. The part of the canals, which was later overgrown by continuous woody vegetation, was interpreted as forest and semi-natural landscape (class 3).

Small fields, pastures, vineyards, orchards and fruit tree plantations with traditional cultivation practices without the use of herbicides, allow the development of weed vegetation. Due to the changing natural conditions, their species composition is spatially diversified. These patches are represented in land cover maps by heterogeneous agricultural areas forming a varied mosaic of fields, pastures and permanent crops. This rich mosaic of small fields and pastures of individual farmers (visible on aerial photographs from 1954) was mostly replaced by large-area arable plots and less by grasslands and pastures cultivated by collective farms. Only small patches of the original mixed mosaic survive in the vicinity of settlements. Garden colonies were established near the settlements and their extent slightly increased during the second and third periods.

Ecologically important segments with lower eco-stabilizing capacity

The large-area fruit tree plantations and vineyards, intensely cultivated with the application of herbicides eliminating the growth of weed vegetation, have left a few of the most resistant synantropic plant species that are tolerant to extreme conditions. Thus, these areas were classified as the ecologically less important landscape elements. Artificially vegetated areas are classified as elements with lower eco-stabilizing capacity among classes of artificial surfaces (CLC class 1).

Since vineyards were parts of the heterogeneous agricultural mosaic in 1954, they are not present as an individual class in land cover map for this time horizon. Big changes also took place in the class of fruit plantations, where almost all original areas from 1954 disappeared and emerged in new places concentrated into big parcels and cultivated by modern intensive practices. In the last time horizon, a significant part of fruit tree plantations was abandoned without any further cultivation. The onset of plant succession and natural restoration of the landscape after the direct human impact finished is apparent in these areas. This development is the consequence of the overall drop of agricultural production intensification as well as of other economic changes after 1989.

The overall extent of forests and semi-natural areas was increased slightly during all periods positively influencing the ecological quality of the whole territory. The spatial structure of large forest complexes is one of the most stable landscape elements; the changes of forests took place predominantly in the form of transition to agricultural areas with the gradual transformation of pastures into forests. The increase of forest and semi-natural areas in the agricultural landscape was connected above all with the growth of riparian vegetation along the drainage channels.

The comparison of land cover in the territory studied over the years reveals that although the landscape segment with high eco-stabilizing capacity (mostly that of forest classes) did not change significantly , anthropogenic pressure upon the territory as a whole increased due to the global human impact. Connectivity of biocentres was especially threatened and extensive development of urban parts of Bratislava, construction of the motorway (a big barrier) and distinct increase of transport only contributed to it. Connection of large forest complexes of the mountains ranges Devínske and Pezinské Karpaty was ensured by the network of interactive elements (meadows and pastures) in 1954. These were completely removed later and the furrow of Lamačská brána gate changed into urban fabric with a developing infrastructure.

Change in ecological stability

Changes of landscape elements during the development have an impact on the whole landscape structure as well as its ecological conditions and stability. The first assessment of ecological stability lies in compilation of the ecological stability coefficient KES 1 by the ratio of stabilizing and destabilizing landscape elements for the given spatial unit (Míchal 1982). Ecological stability assessment according to Míchal emphasizes the presence and scope of positive elements in the landscape regardless of their varied ecostabilizing properties. The change of the study area in the course of 50 years was very dramatic. Areas of positive elements declined and, on the contrary, those of negative elements increased. As the graph (Fig. 3) shows, ecological stability has increased slightly in the recent period above all through the transition from intensive farming to extensive use. The higher level of temporal stability – momentum, characterizes anthropogenic elements that appeared in the landscape.

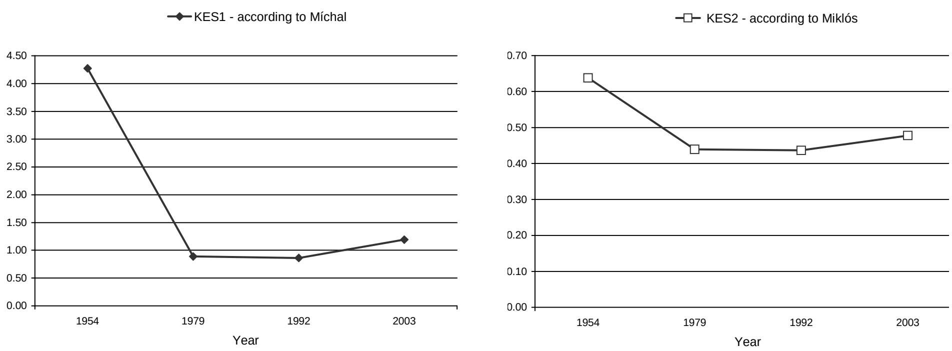

Fig. 3. Development of coefficient of the ecological stability KES 1 according to Míchal (1982) and KES 2 according to Miklós (1986) in the study area from 1954 to 2003

The ecological stability coefficient KES 2 (Miklós 1986), or that of ecological quality of the landscape structure (Izakovičová 1999) is the function of area representation of landscape elements and their different ecostabilizing importance. It reflects the natural character and ecological quality of the landscape structure. Miklós' curve of the ecological stability coefficient from 1954 to 2003 is similar to Míchal's. The maximum KES value in the first period has dramatically dropped; it did not change until 1992 and slightly increased in the recent period.

Analysis of transient changes in land cover during the 1954-2003 period

Changes, where the reconstruction of the original properties from the former periods was identified, were studied in more detail. Interpretation of such changes (development of the area type X (1954), Y(1979 and/or 1992) and Z (2003) – the same land cover class in the 1st (1954) and 4th (2003) time horizons and with change in 1979 and/or 1992) together with supplementing information may contribute to the issues of the reconstruction of historical landscapes. The share of such changes in all changes realised during the 1954-2003 period was 6 % (Tab. 3).

Tab. 3. Types of the development of areas 1954 → 1979 → 1992 → 2003 (4th hierarchic level)

Types of the development of areas 1954-1979-1992-2003		Area	
		(ha)	(%)
1	x - x - x - x	3 936.07	29.92
2	x - x - x - y	394.96	3.00
3	x - x - y - x	206.19	1.57
4	x - x - y - y	315.44	2.40
5	x - x - y - z	155.57	1.18
6	x - y - x - x	262.55	2.00
7	x - y - x - y	42.70	0.32
8	x - y - x - z	73.60	0.56
9	x - y - y - x	225.78	1.72
10	x - y - y - y	5 072.79	38.56
11	x - y - y - z	965.68	7.34
12	x - y - z - x	114.03	0.87
13	x - y - z - y	140.60	1.07
14	x - y - z - z	825.49	6.27
15	x - y - y - w	425.19	3.23
Total		13 156.63	100.00
Stable (type 1)		3 936.07	29.92
Total changed (from 2 to 15)		9 220.56	70.08
Stable in 1st and 4th year (3+6+9+12)		**808.55**	**6.15**
Changed in 1st and 4th year (2+4+5+7+8+10+11+13+14+15)		8 412.01	63.94

x – original land cover class of area, y – 1st change of land cover class of area, z – 2nd change of land cover class of area, w – 3rd change of land cover class of area

More precisely the ecologically important segments form the major group of classes belonging to these transient changes – above all changes of forest into the transitional woodland-shrubs and then back to forest (classes 31x→32x→31x), changes of the heterogeneous agricultural areas into arable land or pastures and back (242→211 or 231→242) and the change of pastures into arable land and back (231→211→231). Some of these changes stand for restoration of the original agricultural structures, others represent the usual cycle in the forest landscape, where classes of the forest changed into the transitional woodland-shrubs as a result of timber production.

Identification of biocentres is closely related to the understanding of biota in the study area, their ecological quality, existential requirements as well as their functions for humans (Oťaheľ and Feranec 1997). Biocentres represent the ecosystems, providing stable conditions for organisms and ensure conditions for their development. Biocorridors, as spatially connected ecosystems, provide interconnection of biocentra and enable migration and exchange of genetic information. Therefore these interconnections providing the pathways for migration of organisms should be maintained.

Fig. 4 shows elements of the ecological network and stress factors analysed using land cover maps. Anthropogenic stress elements are represented by classes of artificial areas in the study area: urban fabric, industrial, commercial and transport units, dumpsites, sports facilities and areas of intensive agricultural production with hydro-meliorations (arable land). Their extent increased threefold during the studied 50 years (from 2 211 ha in 1954 to 6 011 ha in 2003). The land cover map from 1954 shows the landscape before extensive expansion of settlements and before collectivization of agriculture. Stress elements were represented only by the rural settlements with sparse traffic network and their negative influence was compensated by positive landscape elements (natural and semi-natural elements, mosaic of the heterogeneous agricultural areas). The larger biocentres were interconnected by many interactive elements. The landscape was open for migration of organisms without any major linear barriers.

Nowadays, the cores of stress elements are settlements with high concentrations of residential, manufacturing and commercial activities and the linear elements of the traffic system. The negative impact of these elements on the landscape are manifest in the soil, water and air contamination, transformation of the original ecosystems, the barrier effect for migrating organisms, devastation of the natural and semi-natural biotopes by sport and recreation activities. The large-scale stress elements are also represented by arable land lacking scattered vegetation that emerged after collectivisation. A completely isolated area of arable land emerged between localities Dúbravka, Devínska Nová Ves and the motorway heading north of Bratislava. The arable land in this isolated area is under heavy pressure from the surrounding anthropogenic elements; water canals are without vegetation and there are no interactive elements in this landscape. The north-south oriented motorway is a significant barrier that might have been mitigated by biocorridors passing over the motorway. The original natural interconnections of biocentres in the Devínske Karpaty mountains and the Malé Karpaty mountains were destroyed and migration pathways are now entirely closed for some groups of animals.

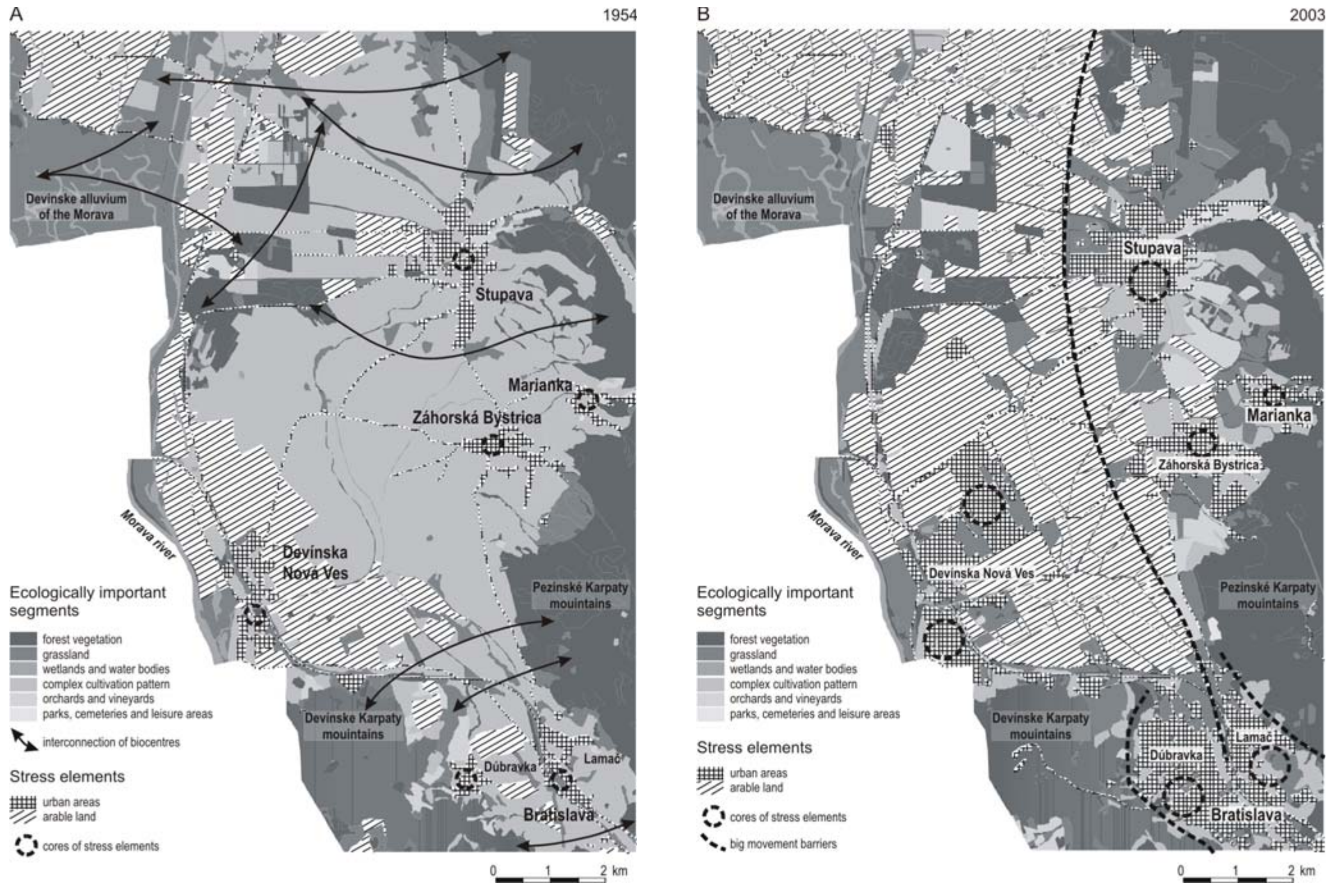

Fig. 4. Ecologically important segments of the landscape and stress elements identified in land cover in 1954 and 2003

RENEWABLE ENERGIES PLANNING

A longer observation of changes of landscape elements makes possible the evaluation of qualitative changes of the whole landscape system and identification of the present processes. Succession and stabilizing processes in the natural landscape induced by the anthropogenic impacts (tangible and intangible) require time to manifest themselves in the form of new elements or whole structures. The focus on changes to stabilizing elements and changes in the ecological quality of the landscape system is important for the planning of any human activity. The present trends in the energy sector point to the fact that the renewable energies (RES) should gain a more important position in the energy structure of the individual EU countries. One of the characteristics of RES is their relatively high demand for the production area due to their low energetic density in space. Assuming further expansion of RES, it can be expected that the anthropogenic impact on the landscape will change resulting in changes to the original geosystems.

The leaders of the EU countries agreed, in March 2007, to adopt a binding target to use 20 % of the total energy consumption from renewables (EurActiv 2007). National Action Plans (NAPs) will be drawn up in the near future. They should outline targets for each RES – electricity, biofuels, heating and cooling. The overall target will have to be further specified for individual countries depending on their potential for development of RES. The share of consumed fossil and nuclear fuels should decrease in future.

The Government of the Slovak Republic approved the „*Stratégia vyššieho využitia obnoviteľných zdrojov energie v SR*" (Strategy for higher utilization of renewable RES in SR) in April 2007 (MH SR 2007). The document identifies as RES the biomass including biofuels and biogas, sun, water, wind and geothermal energies. These are technologically exploitable in Slovakia for production of electricity, heat and transport fuels. The aim of this document is to formulate the strategy haw to increase the use of RES in accordance with the aims established until 2010 or 2015. These aims have been established drawing on the potential of individual RES, the existing use of these sources and their anticipated usage and presumed use in the future. Targets for 2010 a 2015 offer Slovakia the real opportunity to increase the present 4 % (big water power stations are not considered RES) of their overall consumption to 12 % in 2020. The increase of individual types of RES requires first the identification of the spatial potential for utilization at the national level and then the development of the RES focusing on the analysis of sources, environmental factors and impacts, technological possibilities and their applications.

In spite of the well-acknowledged benefits of renewably energy (abundant reserves, dispersed production bases, vulnerability, disruption and breakdown due to the present centralization of technological facilities, shortening of the distance between places of energy production and consumption – reducing the need for energy transport, energy solutions for developing countries as well as countries with fast growing economic development – India and China, moderating of climatic changes and others), there are also negative effects on people and the landscape. Possible major and medium adverse environmental impacts of renewable energy sources of big centralized systems are (Abbasi and Abbasi 2000, Krewitt and Nitsch 2003, Šúri 2004):

- biomass production – exploitation of forests and their modification to large-scale plantations, degradation of native ecosystems and soils, stress on the ecosystems, increase of consumption of water and its degradation, air pollution due to combustion of biomass, pollution resulting from biofuel production,
- solar energy – loss and degradation of soil and ecosystems, pollution produced by manufacture and decommission, impact on microclimate,
- wind energy – impact on ecosystems – mainly birds and bats, noise, decrease of the aesthetic value of the landscape,
- hydroenergy – loss of soil and ecosystems, changes of water regime and ecosystems, decrease of water quality,
- geothermal energy – land subsidence, noise, thermal air and water pollution.

Some of these negative effects are negligible in the case of small renewable energy installations. The topic of renewable energy is broad and the negative effects differ according to the type and size of the project. The location of individual renewable energy installations in the landscape varies and the increase of the number of installed systems will presumably trigger changes in the existing landscape structures. Abbasi and Abbasi (2000) rate large centralized renewable energy projects among those with an adverse environmental impact of a major magnitude. Family (or house)-scale or highly dispersed renewable energy systems (such as roof-mounted or building integrated solar systems) produce a medium or minor environmental impact and fit better with the image of “clean” and “benign” energy.

It is necessary to take into account all aspects of the protection of nature for the whole RES project cycle starting with project implementation and ending with the long-term effects of the new energy system in the landscape. Territories primarily suitable for the development of RES have significant potential for substantial landscape changes. Such development plans must be considered in relation to the environmental limits of the area, that reflect an existing anthropogenic layer and human interests, and the protection of nature.

The environmental aspects of RES exploitation are assessed with concern in protection of the landscape, population and sustainable development of regions. Environmental risks and pressures differ with types of the individual RES, therefore their assessment has to be done separately for each RES. *Clause of effects of the strategic document with the national impact on the environment* of the Ministry of Environment of the Slovak Republic highlights:

– The necessity of a comprehensive assessment of the location and operation effects of the individual RES activities on protected areas, protected species and biotopes. Measures to mitigate these effects on the landscape should be proposed and accompanied by the SWOT analysis of the individual RES for possible conflicts with the nature protection interests.

– Evaluation of the construction of wind power plants from the point of view of utilization efficiency, and their location, which is conditioned by the natural potential of landscape also considering the impact on the landscape (landscape structure, landscape utilization, landscape image) outside the protected areas – under the 1st level of territorial protection.

The ecologically most important segments of regions (ecological network) and protected areas (under the 2nd to 5th levels of protection) are the territories unsuitable for location of the selected types of RES (above all the wind and hydro energy) or with some restrictions depending on the type of RES, project size, technological aspects, etc. One of the possibilities how to identify the contemporary ecological network quickly and effectively is the use of the land cover map that contains the detailed and topical data. The land cover database allows for identification of ecostabilizing landscape elements. The knowledge of their spatial differentiation is inevitable for the construction of the landscape ecological network. Along with the layer of territorial landscape protection they exclude the delimitation of territories suitable for utilization of the individual types of RES.

The assessment of agricultural land and forests changes that took place after the introduction of private economy and implementation of the European agricultural policy is important for the identification of potential areas for biomass utilization in production of biofuel or biogas. Extensification of agriculture and existence of areas for biomass production increases the exploitation potential of this type of the RES. Monitoring of landscape changes becomes a tool guiding the decisions in the regional development of the RES utilization and later a tool for the long-term impact assessment of RES installation in the landscape (structural changes, ecological network connectivity, etc.).

CONCLUSION

Land cover sufficiently represents the material elements of the present landscape structure and land cover classes are treated in the further assessment as landscape elements in its further assessment. A Land cover map complemented by line anthropogenic elements is a suitable tool for cognition of the anthropogenic layer in the landscape. Networks of ecologically important landscape segments can be identified in the land cover map (Oťaheľ et al. 2005), which, along with the map of the territorial landscape protection, represents the natural limits for location of RES.

The geographical information system (GIS) is a useful tool for quantifying the renewable energy potential. Identification of potential territories for RES requires the integration of several information layers (land cover/land use, layer landscape protection and natural resources layer, climatological and hydrological data, etc.). Delimitation of the territory suitable for the development of RES for long-term planning must be drawn with regard to the protection of its most valuable parts.

Analysis of land cover changes facilitates identification of changes in natural and seminatural landscape elements, their ecostabilizing network and the overall quality of the ecological landscape. The proposed methodological procedures and assessment can be used as a step in the compilation of the TSES proposal which respects the original linkages in the landscape (in the form of the reconstruction of the biocentres and biocorridors that existed in the past), in proposing the optimum land use and location of selected social activities (intentions) based on the existing reserves of present land use. In the case of RES projects (depending on the type and size of the project), it is possible to identify potentially suitable territories for their location, to simulate their future impact on the ecological stability of the particular territory and to assess the potential fragmentation of the landscape and change in the connectivity of its elements.

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Martina C e b e c a u e r o v á

DYNAMIKA EKOLOGICKEJ SIETE A ENVIRONMENTÁLNE ÚVAHY PRI PLÁNOVANÍ VYUŽITIA OBNOVITEĽNEJ ENERGIE

Ekologické siete chápeme ako vybrané skupiny ekosystémov poprepájaných do koherentného priestorového systému cez toky organizmov a ich interakcie s krajinným systémom. Ekologická sieť prezentuje ekologicky významné prvky, ktoré sa chápu ako krajinotvorné s pozitívnym (stabilizujúcim) vplyvom na okolitú krajinu a tvoria základ pre návrh prvkov územného systému ekologickej stability – ÚSES (Hrnčiarová a Ružička 1997, Izakovičová et al. 2001). Opdam et al. (2006) zdôrazňuje, že ekologická sieť môže meniť plochu, tvar a priestorové usporiadanie, avšak nesmie strácať svoj stabilizačný a konzervačný potenciál.

Ochrana krajiny a jej najhodnotnejších častí je dôležitým obmedzením pri určení potenciálne vhodných území pre lokalizáciu systémov obnoviteľných zdrojov energie (OZE). S cieľom predísť budúcim konfliktom s ochranou prírody je nevyhnutné analyzovať priestorové informácie o lokálnych ekosystémoch už v procese analýzy potenciálneho využívania OZE. Krajinná pokrývka, spolu s identifikovanými ekologicky významnými prvkami krajiny, je jednou z dôležitých informačných vrstiev pri vyčlenení území potenciálne vhodných pre ich využitie pre OZE.

V tomto príspevku sústredíme našu pozornosť na dynamiku ekologickej siete a hodnotenie jej zmien za posledných 50 rokov na vybranom území na Záhorí (obr. 1 – južná časť Borskej nížiny a Malých Karpát). Fundamentálnym krokom v procese identifikovania ekologickej siete a sledovania jej zmien je analýza zmien krajinnej pokrývky územia od roku 1954 do roku 2003.

Vrstvy krajinnej pokrývky územia v rokoch 1954, 1979, 1992 a 2003 boli vytvorené v súlade s nomenklatúrou CLC, prezentovanou v práci Feranca a Oťaheľa 1999. V rámci územia bolo vyčlenených 37 tried krajinnej pokrývky na 4. hierarchickej úrovni. Po naložení vrstiev krajinných pokrývok boli vytvorené databázy zmien. Väčšiu pozornosť sme venovali zmenám, ktoré predstavujú typ vývoja, kde sa obnovila pôvodná trieda krajinnej pokrývky (tab. 3). Niektoré premeny predstavujú obnovu pôvodných štruktúr, iné premeny zachytávajú prirodzený cyklus v krajine (napr. ťažba lesov a následná výsadba a vývoj lesa). Interpretácia takýchto zmien, spolu s ďalšími doplňajúcimi informáciami môže hlbšie prispieť ku problematike obnovy historických krajinných štruktúr.

Aby mohli byť následne porovnávané stavy krajinnej štruktúry z ekostabilizačného hľadiska, triedy krajinnej pokrývky boli klasifikované podľa stupňa prirodzenosti, stability a miery antropických zásahov.V ekostabilizačnom hodnotení krajiny ich považujeme za krajinné prvky. Diferenciácia ekostabilizačnej schopnosti prvkov krajinnej pokrývky v jednotlivých rokoch 1954, 1979, 1992 a 2003 umožňuje sledovať premeny ekologickej stability územia (Cebecauerová 2006).

Ekologickú stabilitu krajiny sme hodnotili podľa dvoch používaných postupov: 1. podľa koeficientu ekologickej stability podľa Míchala (1982), kde miera ekologickej stability je určená pomerom rozsahu stabilizačných a nestabilizačných krajinných prvkov pre danú priestorovú jednotku, 2. podľa koeficientu ekologickej stability podľa Miklósa (1986), v ktorom je ekologická stabilita funkciou plošného zastúpenia krajinných prvkov a ich rôznej ekostabilizačnej významnosti.

Krajinná štruktúra je odrazom pôsobenia ľudskej činnosti na biotické a abiotické zložky krajiny a zároveň odzrkadľuje stupeň antropogénnej premeny krajiny. V tomto kontexte sme sa pokúsili analyzovať krajinnú pokrývku študovaného územia a diferencovať ekologicky významné segmenty krajiny. Triedy prírodnej a poloprírodnej krajiny (krajinné prvky) boli rozdelené do dvoch skupín: ekologicky významné segmenty s vyššou ekostabilizačnou schopnosťou a ekologicky významné segmenty krajiny s nižšou ekostabilizačnou schopnosťou. Stresové prvky v krajine predstavujú všetky antropogénne umelé areály a veľkoplošná orná pôda. Ich rozloha narástla za 50 rokov takmer trojnásobne (tab. 2). V roku 1954 tvoriili stresové prvky len vidiecke sídla s riedkou dopravou sieťou a ich negatívne vplyvy boli eliminované pozitívnymi prvkami v krajine. Spojenie medzi väčšími biocentrami vytvárali mnohé interakčné prvky a krajina bola otvorená pre migráciu organizmov.

V súčasnosti tvoria jadrové stresové prvky sídla s vysokou koncentráciou výrobných, obytných, komerčných a iných aktivít, ďalej líniové prvky dopravného systému. Vplyvy týchto prvkov sa negatívne prejavujú v okolitej krajine kontamináciou pôdy, vody a vzduchu, premenou pôvodných ekosystémov, bariérovým efektom pre živé organizmy. Pôvodné prirodzené prepojenia biocentier Devínskych a Pezinských Karpát boli odstránené a migračné cesty zostali pre určité skupiny živočíchov úplne prerušené.

Upriamenie našej pozornosti na zmeny stabilizujúcich prvkov a zmeny ekologickej kvality krajinného systému je dôležité z hľadiska plánovania akýchkoľvek ďalších aktivít človeka. Súčasné trendy v energetike ukazujú, že obnoviteľné zdroje energie zaujmú významnejšie postavenie v energetickej štruktúre jednotlivých štátov EÚ. Vychádzajúc z tohoto predpokladu očakávame, že v pôvodných geosystémov nastanú zmeny. Stabilizačné a sukcesné procesy v prírodnej krajine potrebujú dlhší čas od začiatku pôsobenia antropogénneho impaktu (hmotného aj nehmotného), kým sa prejavia v podobe nových prvkov alebo celých štruktúr.

Napriek mnohým pozitívnym stránkam využívania OZE stoja proti aj negatívne vplyvy na obyvateľstvo a krajinu. (Abbasi a Abbasi 2000, Krewitt a Nitsch 2003, Šúri 2004). Téma OZE je nesmierne široká a negatívne vplyvy sú veľmi rozdielne v závislosti od druhu a rozsahu – veľkosti systému OZE. Jednotlivé OZE sú v krajine rozmiestnené rôzne a s rastom ich počtu v krajine sa budú meniť aj existujúce krajinné štruktúry.

Prihliadať na aspekty ochrany prírody je nevyhnutné od procesu realizácie určitého projektu až po dlhodobé pôsobenie nového energetického prvku/systému v krajine. Územia primárne vhodné pre rozvoj OZE z hľadiska svojich prírodných podmienok predstavujú významný potenciál rozvoja a musia byť v ďalšom procese konfrontované s environmentálnymi limitmi rozvoja, ktoré vyplývajú z existujúcej antropogénnej vrstvy a záujmov človeka, ako aj z ochrany prírody.

Analýza zmien krajinnej pokrývky umožňuje identifikovať ekostabilizačnú sieť a ekologickú kvalitu krajiny. V prípade projektov OZE (podľa druhu a veľkosti daného projektu) je možné určiť potenciálne vhodné územia pre ich lokalizáciu, simulovať budúci vplyv na ekologickú stabilitu územia, hodnotiť potenciálnu fragmentáciu krajiny a zmeny spojitosti jej prvkov.