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The evaluation of anthropogenic impact on the ecological stability of landscape

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Abstract

The model area is the northern surrounding of the water reservoir Zemplínska šírava in the east of Slovakia. Selection of the examined territory and the time horizons was not random. The aim was to capture the intensity level of anthropogenic impact on the values of the coefficient of ecological stability after the construction of water reservoir, Zemplínska šírava. The contribution evaluates ecological stability of landscape in the years 1956 and 2009 by GIS technology, using two methods. The first method determines the rate of ecological stability of landscape on the basis of the significance of land cover classes in the regular network of squares (the real size of the square is 0.5 square km). The second method determines the ecological stability of landscape secondary on the basis of the man influence on the landscape. A comparison of two methods has been made, as well as interpretation of the output data (eg. monitoring the impact of marginal land cover classes with the minimal surfaces in the grid of square at the fluctuation of the index of ecological stability, respectively, it considers the possibilities to streamline the research results using homogeneous spatial units) and it also allows to track the changes in the ecological stability of the landscape in chronological development.

Key words

Anthropogenic impact, Ecological stability, GIS (Geographical Information Systems), Land cover

Introduction

The ecological stability is the ability of ecological systems to persist during the course of disturbance and reproduce its essential characteristics in terms of external disturbing. This ability is manifested by minimal change during the course of disturbance or spontaneous return to the default state. If the landscape returns to its original state it is regarded as more stable.The main aim of this paper was to characterize the anthropogenic impact on ecological stability in the time horizon 1956 - 2009 in the natural contrast region on the contact zone of mountain and lowland. Although different authors (Míchal *et al.*, 1994; Forman and Godron; 1993) have expressed the ecological stability in terms of resistance, persistence, amplitude, elasticity, plasticity, recovery, flexibility, delays and yaw. Their definitions are close to the generally accepted concept of ecological stability, which can be characterized by the operation of self-regulatory mechanisms and according to the amount of energy needed for their retention. The last few years have experienced an increase in the landscape-ecological research used for the evaluation of ecological stability through analysis of secondary structure of the landscape (land cover classes). It indirectly reflects the intensity of anthropogenic intervention in the country. From this aspect, it was considered important for monitoring land cover classes in the space-time context, especially those whose anthropogenic impact on the landscape mosaic can have irreversible, permanent negative consequences.

Materials and Methods

Study area : The area of research is situated in the eastern part of Slovak Republic, at the interface of two subsystems: the Carpathians and the Pannonian Basin, more specifically on the intercourse of two subprovinces: Inner Eastern Carpathians and the Great Danube Basin. The northern part of the territory belongs to Vihorlatská-gutínska area and southern part to East-Slovakian lowland (Mazúr and Lukniš, 1986). The area of research is defined by the cadastral borders of five municipalities: Vinné, Kaluža, Klokočov, Kusín and Jovsa (Fig. 1).

Geological structure of the area is relatively varying. It consists of two different age groups of rocks. The oldest from the Miocene (Upper Sarmatian and Lower Pannonian) consisting of volcanic lava flows of clinopyroxene andesites and breccias (Vass *et al.,* 1991), which occur at the surface in the northern part of the territory. The second group is represented by the Neogene sedimentary formations of East - Pannonian Basin. The surface of these formations is covered with the quaternary sediments: medium-grained sands, fine sandy clays and proluvial gravels, loesses and eolian sands and organic sediments (Baňacký *et al.*,1987, Baňacký, 1988).

In the climatic classification of Slovak Republic (Lapin *et al.,* 2002), investigated territory belongs to two climatic regions: warm and moderately warm. Warm climate region in the Podvihorlatská pahorkatina - Hills on the slopes which are south oriented, with warm, slightly humid and mild winters. The moderately warm region with slightly warm, slightly humid climate is in the northern part of the territory (Vihorlatskévrchy Mts.). The hydrological regionalization includes surface flows into the river basin Laborec. The sources of brooks are at an altitude of 600 - 1000 m and flow into the water reservoir called Zemplínska šírava.

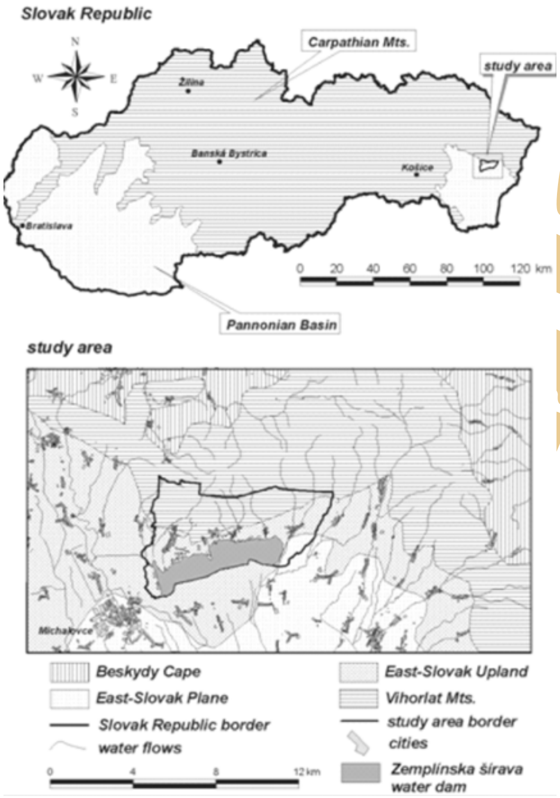

Fig. 1 : Location map of the study area

The soil types are represented by Lithosols, Fluvisols, Luvisols, Cambisols, Andosols, Planosols and Gleysols. At places with a stronger influence of anthropogenic activity (Fazekašová, 2012) some of the Anthrosols and Urbi-Anthropic Regosols are visible.The original vegetation cover of the territory accounts largely for the forest communities, which mainly consist of Oak-hornbeam and Beech forests. There are floodplains (in the areas with frequent flooding and lowland forests at the floodplains of rivers (Michalko *et al.,* 1986a, b). Most of the primary floodplain lowland forests and the Oak-hornbeam Panonian forests have been removed and the territory transformed into a cultural steppe. Secondary communities are grassland, pasture, arable culture, orchards and vineyards. At places of Oak-hornbeam-Carpathian forests have been replaced by vineyards creating conditions for overall economic development of municipalities.

Materials for landscape ecological stability assessment : Evaluation of the ecological stability of the landscape based on the underlying land cover maps, georeferenced and vectorization military topographic maps at scales 1: 25 000 from the year 1956 and vectorization of orthophoto with an accuracy the 5 m in the grid squares for year 2009, as well as on the basis of our own field research was obtained. The obtained polygons were included into land cover classes according to the legend CORINE Land Cover (Boltižiar, 2007, Slolár, 2012), developed for the purpose of landscape-ecological research for the country under PHARE work of Feranec and Oťaheľ (1999). The legend divides each of the land cover classes to 4th hierarchical levels, which is in contrast to traditionally used CLC methods (Feranec and Oťaheľ, 2001), and is better suited for work in the micro-regional scale.

Methods of research : Ecological stability of the region was evaluated using ArcView 3.2 GIS software in the network of regular square size 0.5 km^2. The layers of land cover classes were covered with the network of grid squares, in which the occurrence and acreage of the land cover classes were investigated. In the first method, the Miklós(1986) formula, based on the significance of land cover classes was applied:

$$Ks = (\sum_{i=1}^{n} p_i k_i) / p,$$

where: pi is the i-th surface forms of land cover, ki is the weighting coefficient, p is the total area of each analyzed spatial units (a squares, or the parts of squares).

Range of weighting coefficients (Table 1) was taken from the work of Oťaheľ *et al.* (2004) and slightly modified with respect to the ecological ability of the landscape of the investigated region. The coefficient respects the biotic share of the individual

Table 1 : Coefficients of ecological ability of land cover k_i

i	**Classes of land cover**	k_i
1	1.1.2.2 Discontinuous urban fabric with single-family house and gardens	0,08
2	1.2.1.1 Industrial and commercial areas	0,01
3	1.2.2.1 Road networks and associated land	0
4	1.2.3.4 Sport and recreation ports	0
5	1.2.4.1 Dike with communications	0
6	1.2.4.2 Dike with woods vegetation	0,6
7	1.3.1.2 Stone quarries	0
8	1.4.1.1 Parks	0,45
9	1.4.1.2 Cemeteries	0,08
10	1.4.2.1. Sports areas	0,4
11	1.4.2.2. Leisure areas	0,20
12	2.1.1.1 Arable land mostlywithout dispersed(linear andsolitary)vegetation	0,14
13	2.1.1.2 Arable land with dispersed(linear andsolitary)vegetation)	0,20
14	2.1.1.3 Deserted areas on arable land	0,20
15	2.2.1.1 Vineyards	0,29
16	2.2.2.1 Orchards	0,43
17	2.3.1.1 Permanent grassland mostly without dispersed trees and scrubs	0,65
18	2.3.1.2 Permanent grassland with dispersed trees and scrubs	0,70
19	2.4.2.2 Mosaic of fields, meadows and permanent crops with scattered weekend houses	0,50
20	3.1.1.1 Broad-leaved forest with continuous spacing of trees	1,00
21	3.1.1.2 Broad-leaved forest with not continuous spacing of trees	0,90
22	3.1.2.1 Coniferous forest with continuous spacing of trees	1,00
23	3.1.3.1 Mixed forest with continuous spacing of trees	1,00
24	3.2.4.2 Natural hopped wort	0,85
25	3.2.4.3 Shrubby (forests) vegetation	0,75
27	3.3.1.3 Lake and rivershorelinesandbenches	0,43
28	5.1.1.1 Rivers and brooks	0,79
29	5.1.1.2 Channels	0,79
30	5.1.2.2 Artificial water bodies	0,79

land cover classes and indicates the level of the self-regulatory capacities of the given class.

The second method aimed to evaluate the intensity of human impact on the landscape and its evolution by calculating the coefficient rate of anthropogenic influence on the landscape (Kupková, 2001):

$$CAI = \frac{(A + B + C)}{(D + E + F + G)'}$$

where: A- area of arable land, B - built-up area, C - area of other surfaces, D - meadows, E - pastures, F-forest and G -an area of water bodies.

Coefficient value was greater than 0 and there was no upper limit. The value of 1 is reached if area with high intensity of utilization is in equilibrium with the area with less degree of anthropogenic disruption. Values greater than 1 indicated predominance of area with a high concentration of anthropogenic activities. For additional information on the causes of fluctuations in index of the ecological stability in the chronological development of the landscape, some changes in the land cover classes were also observed. They were obtained from the loaded layers of land cover classes from the year 1956 and 2009. The research results were supplemented by analysis of indices of the spatial structure of the patches (land cover classes), as described by Ivanová (2013).

Table 2 : Number of squares classified to the selected interval of the coefficient of the landscape ecological stability

Interval of coefficients	**Year 1956**	**Year 2009**
(0;0,2077>	25	12
(0,2077;0,4706>	44	23
(0,4706;0,6894>	36	24
(0,6894;0,8754>	15	56
(0,8754;1>	79	84

Table 3 : Number of squares classified to the selected interval of the coefficient anthropogenic impact on the landscape

Interval of coefficients	**Year 1956**	**Year 2009**
(0;3>	163	171
(3;15>	26	17
(15;66>	6	8
(66;199>	1	2
(199;118735,716>	3	1

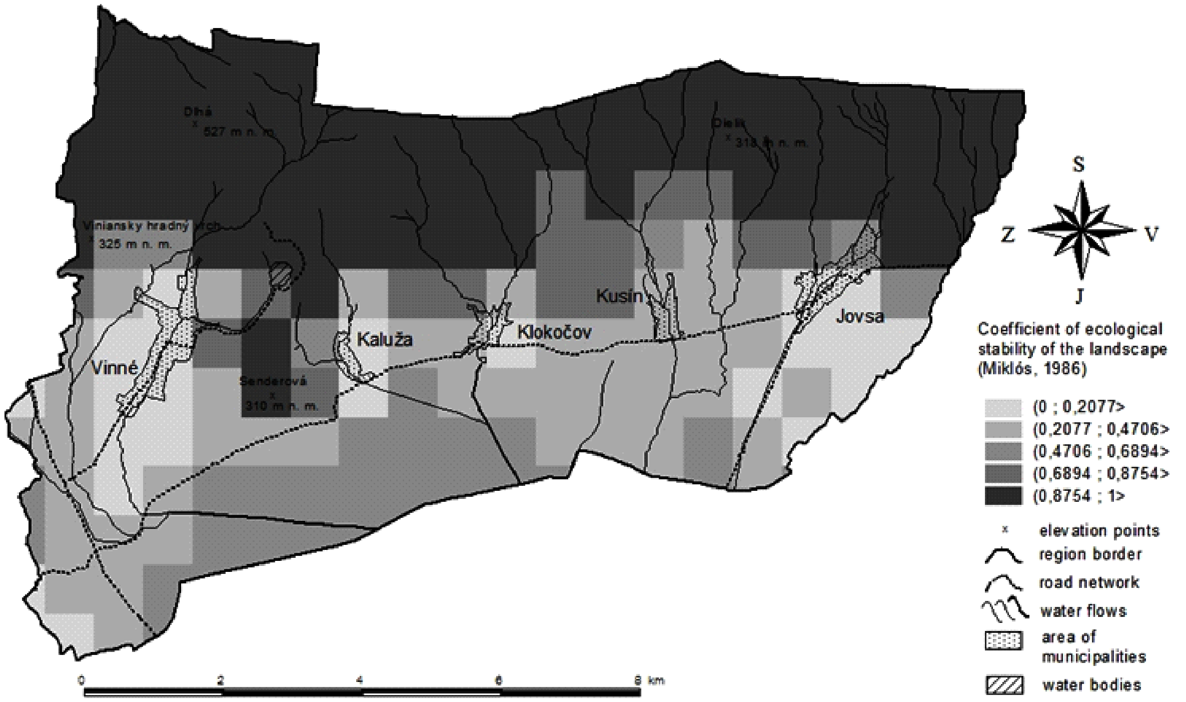

Fig. 2 : Ecological stability of the landscape (year 1956)

Results and Discussion

Ecological stability was evaluated by two methods. Both methods were based on the overlapping maps of the land cover classes with a regular network of squares of size 0.5 km^2 (Miklós, 1986;Kupková, 2001).The values of ecological stability coefficient of the country were divided into 5 intervals. For each interval, it was found that the number of squares belonged to the interval and the changes in the ecological stability of the landscape for two time horizons were compared (1956 and 2009). Comparison of the changes in ecological stability of the landscape in the chronological development were established on the basis of numbers of squares at each interval, taking into account the level of landscape ecological stability coefficient. Based on the identified values, it was concluded that there was a significant difference in ecological stability between 1956 and 2009. This was due to the construction of Zemplínska šírava water reservoir which decreased the area of arable land and permanent grasslands significantly with lower eco-stabilizing ability (more than 700 ha of arable land and more than 1000 ha of permanent grassland was transformed in surface backwater areas). The increase of eco-stabilizing ability of the landscape is also documented in Table 2, where in 1956 about 105 squares belonged to first three intervals while in 2009 there were only 59. On the contrary, the number of squares in the last two intervals increased from 94 to 140 squares.

Causes of changes in the ecological stability of the landscape are connected with the transformation of agriculture (abandonment of the landscape in connection with the abandonment of the original agricultural land, overgrowing of permanent grassland by the scrubs and the transformation of deciduous forest with larger spacing of trees into deciduous forests with continuous spacing of trees) after 1989. From 1956 to 2009, the number of patches of permanent grassland with dispersed vegetation increased from 15 patches to 28, and the number of patches of deciduous forest, with continuous spacing of trees, increased from 8 patches to 22. In 2009, a new class of land cover appeared - deciduous forest with larger spacing of trees that included of 35 patches.

The aim of the second method was (Kupková, 2001) to study the impact of human intervention on the values of landscape ecological stability coefficient. For comparison of results in the chronological development, the number of squares belonging to interval characterizing the anthropogenic load of landscape was again investigated. In the legends of maps 4 and 5, the coefficients of anthropogenic impact on the landscape significantly reached high values. This fact was not due to calculation error, but existence of very small acreage areas which entered the denominator of formula for calculating the rate of coefficient of anthropogenic impact on the landscape. The spatial distribution of the coefficient indicated that the largest

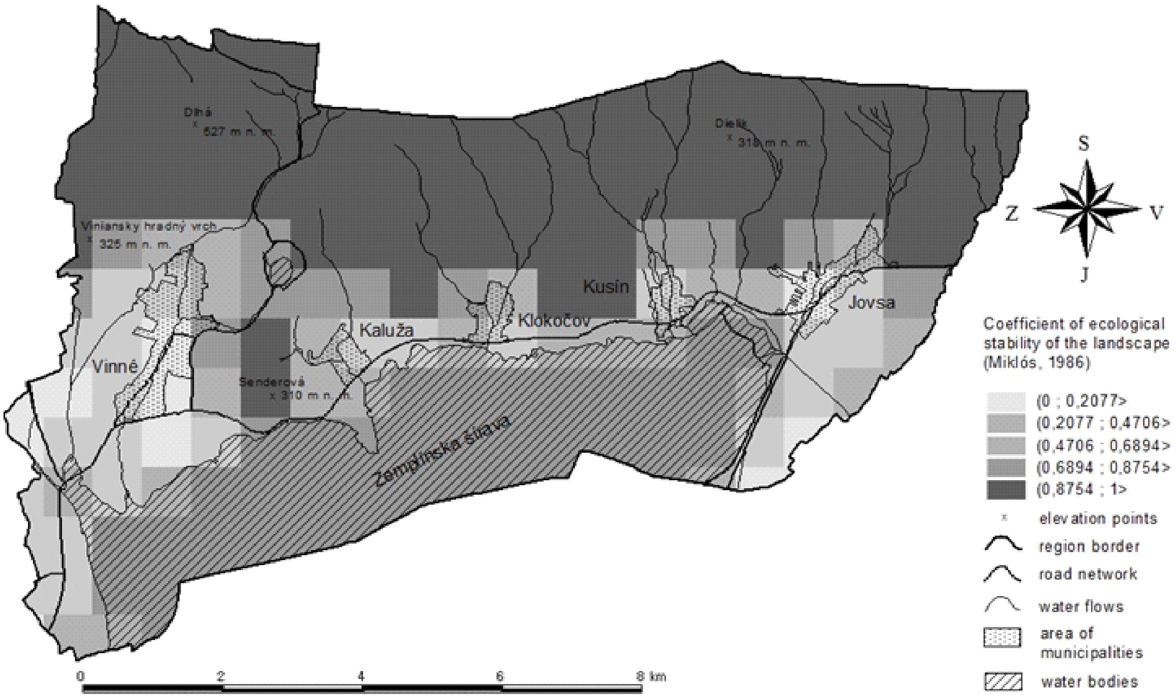

Fig. 3 : Ecological stability of the landscape (year 2009)

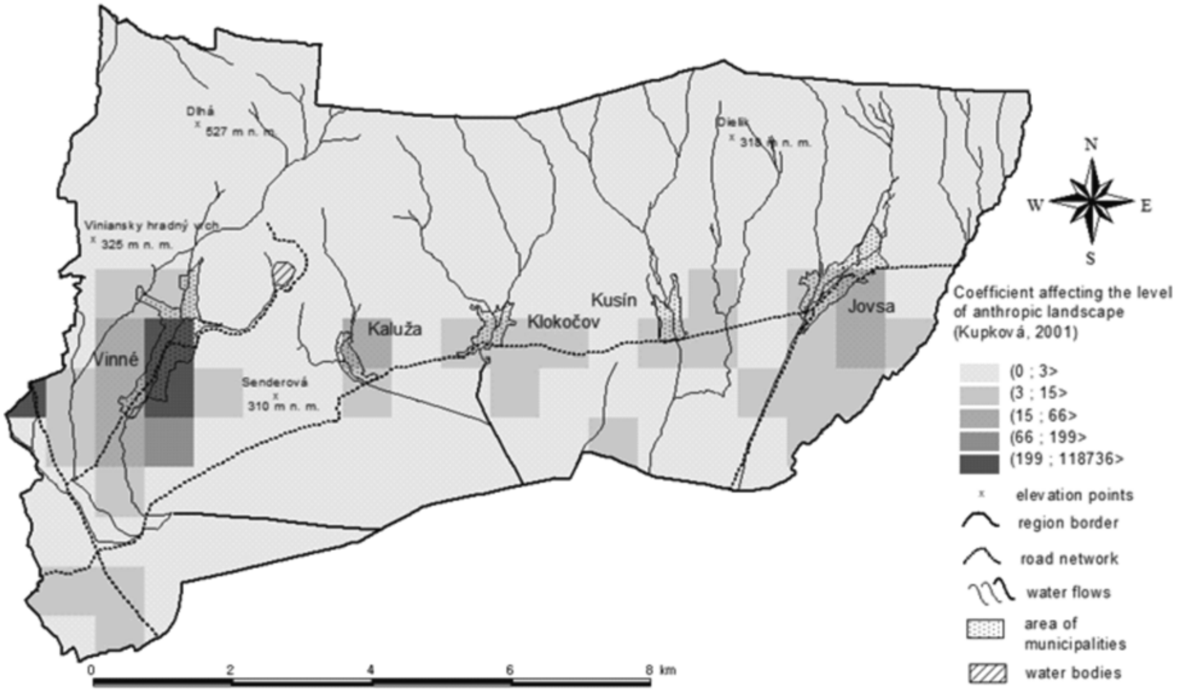

Fig. 4 : The level of anthropogenic impact of the landscape (year 1956)

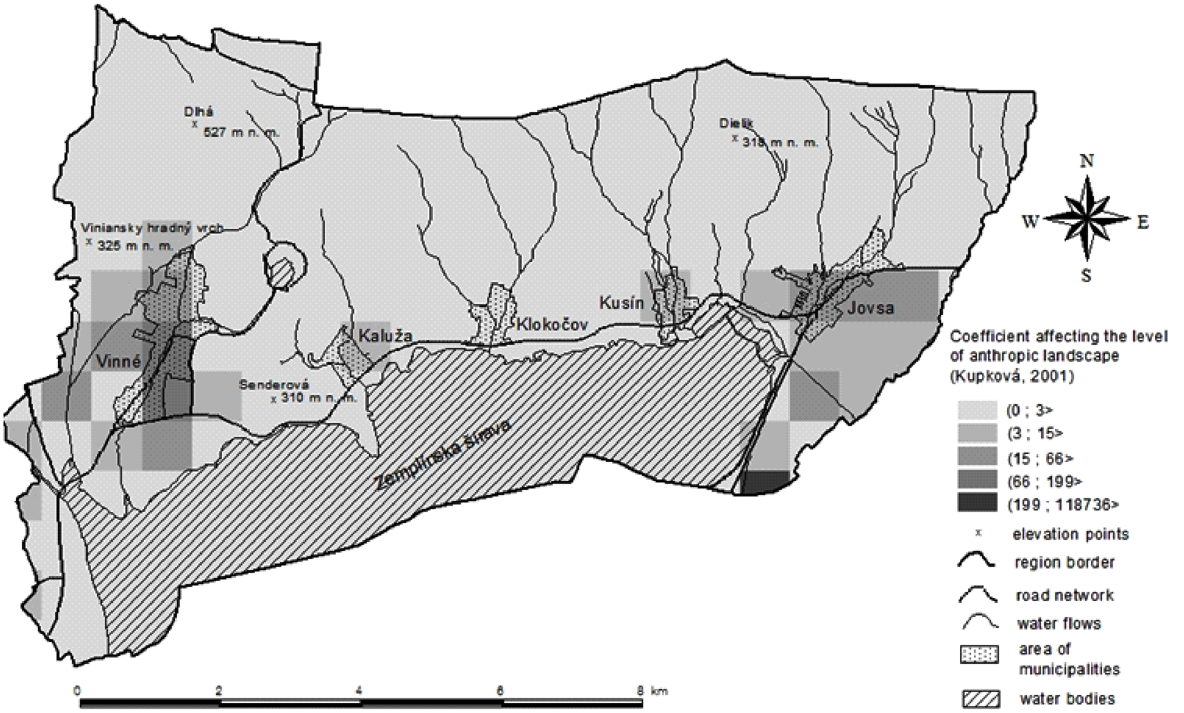

Fig. 5 : The level of anthropogenic impact of the landscape (year 2009)

anthropogenic interference in the landscape have been in the cadastral territories of Vinné and Jovsa. In 1956, the highest values of coefficient defining the anthropogenic impacts on landscape were on the artificial surfaces (areas of discontinuous urban area which is here represented by housing estates and gardens) and on the arable land. In 2009, the largest values of anthropogenic effects were identified at the discontinuous urban areas (housing estates and gardens) in road network and adjacent areas in industrial and commercial units, on the arable land and permanent grassland.

The most striking change in the mosaic of landscape, in the investigated territory, was the construction of water reservoir Zemplínska šírava which succumbed more than 700 ha of arable land and over 1 000 ha of permanent grassland. It was not proved by the number of squares attributable to each interval of the coefficient, expressing the anthropogenic impact on the landscape (Table3). The difference between the sum of the squares of first and second interval between 1956 and 2009 differed by only 1 square due to merging of water areas and the areas of permanent grassland into the areas with a lower impact of anthropogenic activities.

Comparing the maps of anthropogenic impact on the landscape and the maps of landscape ecological stability (Fig. 2 - 5) calculated by Miklós formula (1986) it was confirmed, that the highest values of anthropogenic impact corresponded largely to the lowest values of coefficient of ecological stability of the landscape.

An exception was the square lying to the east of the built-up area of village Jovsa (the data for 2009), which was, according to calculations based on Miklós formula (1986) included in the interval with higher ecological stability of the landscape. In this type of square, predominateda class of permanent grasslands with scattered trees and shrubs, which according to the formula of Kupková (2001) was included to the group of elements with high impact of anthropogenic activities on the landscape. Kupková (2001), in the formula, did not consider the division of grassland to grassland with scattered vegetation and grassland vegetation without distraction. When defining factors of significance, land cover classes and subsequent calculation of ecological stability of the landscape, according to Miklós formula (1986), the breakdown was taken into account. Kupková (2001) did not use the division of permanent grassland into permanent grassland with scattered vegetation and permanent grassland without scattered vegetation. When defining the factors of significance of land cover classes and the subsequent calculation of ecological stability of the landscape, according to Miklós formula (1986), this division was taken into account.

The present study focused on the assessment of the landscape ecological stability in net of squares by means of two methods. In both cases it was confirmed that the highest values of anthropogenic impact on the landscape corresponded to the lowest values of the coefficient of the landscape ecological stability. Regular grid of squares for calculation of the ecological stability of landscape and anthropogenic impact on the landscape allowed to record differences in the stability of the landscape, however, the squares represented artificial, not homogenous units. The optimal solution would be launched research on the smallest complex physical geographical units - geotops.

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