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An Assessment of Changes in Ecological Stability and Landscape Management Practices over the Last Centuries: A Case Study from Vrbovce, Slovakia

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Abstract. The landscape is an open system influenced by natural and anthropogenic factors that in a long-run fundamentally affect its state and development. A comprehensive understanding and assessment of the anthropogenic impacts on the environment is a key prerequisite to maintain its good ecological state. However, as the impacts of anthropogenic activities on the environment are omnipresent, necessary measures for their mitigation should be addressed to improve the landscape ecological stability. In Slovakia, agricultural activities on large blocks of land are considered as one of the main anthropogenic factors negatively influencing the landscape ecological stability, which however could be eliminated by effective landscape management activities. This study assesses the ecological stability of the cadastral area of the village of Vrbovce in both historical and current contexts and suggests several “green” measures aiming at improving its ecological stability. The information about the land types and structures were obtained by manual vectorization of historical and current topographical maps. Based on this information analysis of land utilization and its development was carried out for a period of more than 250 years. For each historical period, a coefficient of ecological stability was evaluated to assign a degree of ecological stability for each period. Moreover, an analysis of positive and negative landscape-ecological impacts was also performed to identify the problematic areas within the cadastral area that need to be addressed by mitigation measures. Based on these analyses several mitigation measures were suggested to improve the ecological stability of the area. Most of them were related to the agricultural land, which makes up a significant part of the area and represents its less ecologically stable part. The proposed measures respect the original rural character of the area and its specific scenery which is a result of centuries of man-land interaction. The measures are mostly focused on transforming some of the less ecologically stable areas into natural grasslands which would be used for ecological cattle and sheep breeding as these activities were historically the primary source of living in this area.

1. Introduction

Landscape is our everyday part of life we are closely connected with it and as it influences us and gives us various natural resources, we transform it and use it for our needs. Each type of landscape is specific and unique. In addition to the natural processes that transform the character of the landscape it is constantly changing, especially by its activity, either positively (e.g., protection and revitalization) or negatively (e.g., deforestation). It is very important to know the change of landscape structure, as it



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reflects specific outputs of human activity in space and time, including economic, social, cultural potential and represents the intersection between the natural properties of the territory, the technical possibilities and knowledge of mankind. The knowledge of landscape change and its development over the last decades to centuries is therefore indispensable in the area of landscape management and enables to implement a complex of measures aimed primarily at maintaining or increasing ecological stability [1], [2]. We strive for appropriate measures to optimize the deployment of landscape features and rational use of individual components of the natural environment. Most often, the assessment of the country goes in the direction of determining ecological stability, which is usually expressed by the ecological stability coefficient (KES), which is characterized by a numerical value and the corresponding interpretation. In the context of landscape-ecological research, KES is determined most often on the basis of two approaches: 1) a ratio of relatively stable and relatively unstable areas; 2) established on the basis of landscaping, taking into account their ecological significance. At present it is possible to determine the coefficient of ecological stability according to several domestic [3], [4], [5] and foreign authors [6], [7], [8]. However, one must note that the usage of the individual approaches differs from one to another.

The aim of this work is to determine the ecological stability of both historical and contemporary landscape structure of the cadastral area of the village of Vrbovce. Within the study, the approaches of Míchal, Reháčková and Pauditšová were used as well as the analysis of clashes of positive and negative landscape-ecological factors identifying problematic areas in the current state of the landscape structure. In addition, the work also aims to propose a way of managing the country in terms of spatial and functional division of the territory by applying technical, biological and ecological measures while maintaining the rural landscape infrastructure to improve ecological stability and biodiversity, especially in agriculturally intensively used areas.

2. Material and Methods

2.1. Study area

The investigated locality lies in the district of Myjava near the village of Vrbovce in the western part of Slovakia (Figure 1). The total area of the locality investigated is 5147 ha and it lies in a hilly country of the White Carpathians mountain range, with an altitude ranging between 350 m a.s.l and 650 m a.s.l. In the past, the area underwent significant and rapid transformation from a naturally forested to an agricultural landscape [9].

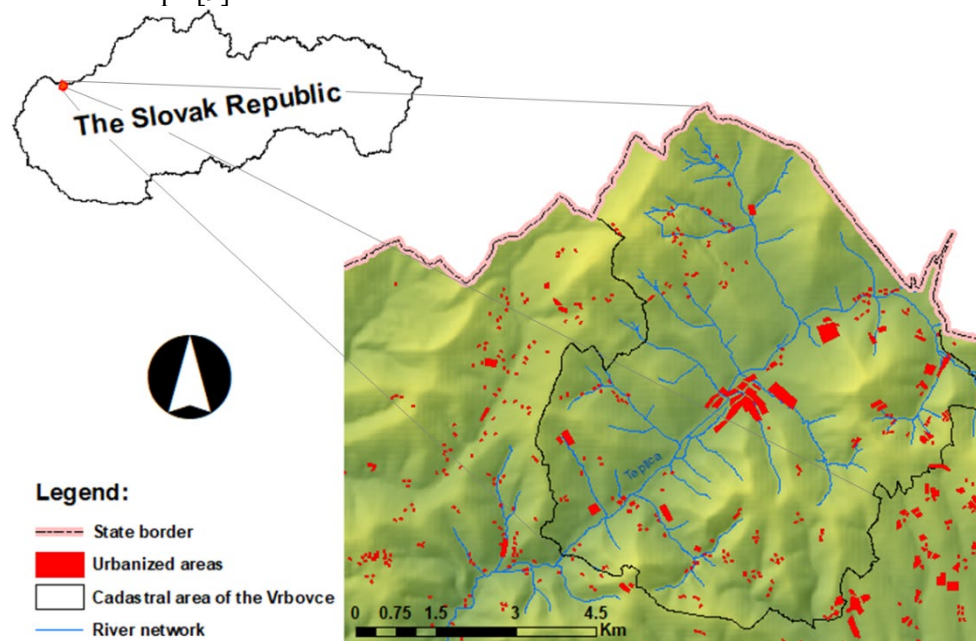


Figure 1. Location of the area of interest in Slovakia.

The typical character of the landscape in the first half of the 20th century was characterized by a mosaic of small and narrow plots that were often divided by vegetation strips, drainage furrows, terraces, or unpaved communications, which acted like significant surface runoff and erosion alleviation elements [10]. The communist collectivization of the agricultural land, which took place after the end of World War II, resulted in the loss of this stable landscape, which was replaced by a number of large cooperative fields. This transformation led to an increased occurrence of flash floods and significantly intensified erosion processes, which also resulted in deteriorating biodiversity and ecological stability of the selected area as well as to the losses of natural ecosystems and overall worsening of the environment. There is the protected landscape area of the White Carpathians, which belongs to the second level of protection. The area belongs to a moderately warm climate region, with a mean annual air temperature of 7.5°C and mean annual precipitation totals ranging between 700-800 mm. In the area of interest there are loamy and clay-loam soils. The cadastral area of the village of Vrbovce belongs to the basin of the Teplica river, which springs in the White Carpathians and flows through the southern part of the cadastre. Within the area several important tributaries flow into it: Haluzníkov, Liešťanský, Lulovský and Zápasečník creeks, on which the Vrbovce reservoir is built.

2.2. Input data and its analysis

Land use mapping is considered to be one of the most important source of information on land development in the past. It is also an important tool that the society can use to look at land use. The basis for the calculation of KES and its development from historical mapping to the present is the analysis of the mapping of the site and the determination of the structure change and its development over the last decades. Data in digital form were processed in ArcGIS, where vectorization of maps from different time periods was performed: I.MM (1764-1787), II.MM (1810-1869), III.MM (1875-1884), MTM25 (1952- 1957). The way the land was used in each of these periods is shown in both Table 1 and Figure 2 where it is also compared to the current state of land use (LU2018).

Table 1. Percentage of the area of the land use types identified on the individual historical and concurrent maps. The percentage is expressed as a percentage from the total catchment area. Due to the different amount of land use types identified, they were further classified into four categories: 1) arable land, 2) natural grassland, 3) forests, 4) permanent cultures 5) urbanized areas and 6) water bodies.

Land use type	I.MM	II.MM	III.MM	MTM25	LU2018
Arable land	75.05%	53.90%	51.80%	44.22%	16.22%
Natural grassland	8.67%	9.17%	31.49%	37.61%	43.99%
Forests	13.64%	32.83%	12.01%	13.13%	28.42%
Permanent cultures	-	1.65%	1.34%	1.19%	8.51%
Urbanized areas	2.64%	2.45%	3.36%	3.85%	2.74%
Water bodies	-	-	-	-	0.1%

With regard to the quality of digital materials from various historical periods, four categories of landscape elements were identified for the period of I.MM, 5 elements on the maps II.MM, III.MM and MTM 25 and for the current use of the landscape from the year 2018 as much as 6 landscape types identified. The above-mentioned events, such as the colonization of the remote locations and the collectivization of agriculture caused significant changes in the way the land was used.

Table 1 and Figure 2 show a decrease in arable land from the period of I.MM when it covered more than 75% of the total area of while now only slightly more than 16%. In addition, an upward trend in grassland, dating back to the III.MM period, can be seen and can be associated with the creation of a new breeding area for cattle and sheep in this area. It currently stands at around 44%. This activity, together with agriculture, was a basic source of livelihood in the 20th century. The use of land by the

forest in this area has a periodic shape, the maximum coverage was in the period II.MM and LU2018 (33-28%) and the lowest land use by the forest was about 12-14% (I., III.MM and MTM25). This pattern can be explained by deforestation and its subsequent restoration. Permanent crops (orchards, gardens and vineyards) were defined in historical military maps at up to 2% of the total land area, and their share has now increased to 9%. Urbanized areas are maintained at the same level, although they are slightly increasing during the period under review, which may be due to people moving into the community and the permanently populated areas of solitude. It can be assumed that the houses in these areas are rather bought by people coming from larger cities, which use them only for recreational purposes.

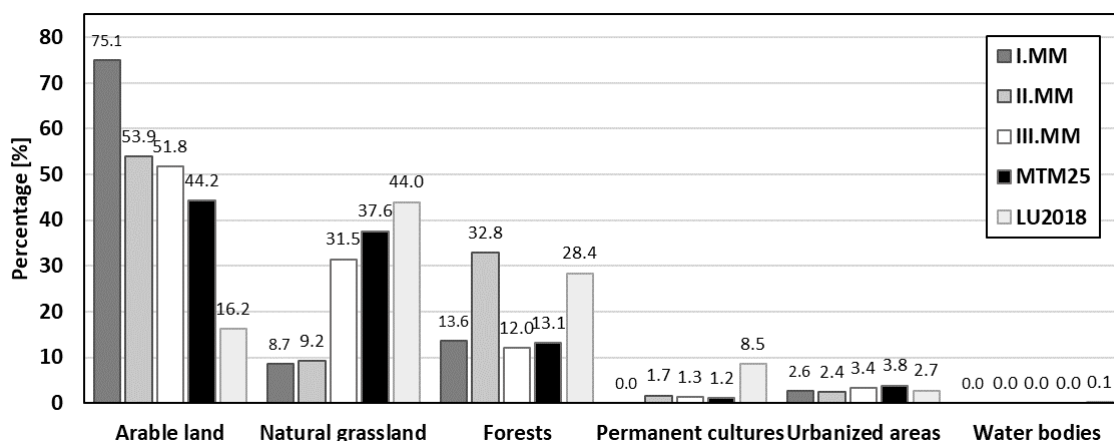


Figure 2. Comparison of the percentage of land use categories from the total catchment area in the particular time intervals represented by various historical mappings (I. MM, II. MM, III.MM and MTM25) and the concurrent map of land use (LU2018).

2.3. Methodology of calculating the coefficient of ecological stability (KES)

To express the ecological stability of the landscape method according to Míchal, a simple mathematical relationship is used, expressed by the sum of relatively stable and unstable surfaces [6]:

$$KES = \frac{S}{L} \quad (1)$$

where: S is the area with stable ecosystems (forest, non-forest woody vegetation, meadows, pastures, vineyards, wetlands and orchards) and L is area with relatively unstable ecosystems (arable land, urbanised land, hop gardens). The values of this coefficient are then classified according to Table 2.

Table 2. The classification of the landscape according to the coefficient of ecological stability [6].

KES	Class description
< 0,10	Territory with maximum disruption of natural structures, basic ecological functions must be intensively and permanently replaced by technical interventions
0,10 – 0,30	Territory with a clear disturbance of natural structures.
0,30 – 1,00	Territory that is intensively used mainly by agricultural large-scale production, weakening of self-regulation processes cause them considerable ecological lability
>1,00	Territory with almost perfectly balanced landscape in which technical objects are relatively in line with conserved natural structures

The methodical procedure according to Reháčková and Pauditšová is based on the results of the mapping of the current landscape structure and the current vegetation. To determine the degree of ecological stability of the forest vegetation, the authors used the results of Smejkal [8]. Partial values of ecological stability levels of individual landscape elements were suggested by the authors, based on

their professional and practical experience. The authors worked on the calculation of the coefficient of the ecological stability with the following mathematical relationship [4]:

$$KES = \sum_{i=1}^n \frac{p_i S_i}{p} \quad (2)$$

where: KES is the coefficient of ecological stability calculated for the area of interest (-), p_i is a total area of the individual types of landscape features (ha), S_i is a degree of ecological stability of each of the features, p is a total area of the area of interest (ha), n is the number of different types of landscape features identified in the area.

The degrees of ecological stability for individual types of the landscape features are carried out according to Table 3.

Table 3. Interpretation of the coefficient and the degree of ecological stability [4].

Landscape assessment	KES	Degree of ecological stability	Possible measures
landscape with very low ecological stability	1.00 – 1.49	1	high need for implementation of ecostabilization elements and management measures
landscape with low ecological stability	1.50 – 2.49	2	the need to implement ecostabilizing elements and management measures
landscape with medium ecological stability	2.50 – 3.49	3	conditional need to implement ecostabilizing elements and management measures
landscape with high ecological stability	3.50 – 4.49	4	implementation of appropriate management measures
landscape with very high ecological stability	4.50 – 5.00	5	implementation of maintenance management

3. Results and discussions

Problem areas were identified by the analysis of clashes of positive (socio-economic phenomena) and negative (stress) landscape-ecological factors. The problematic areas were represented by, e.g., areas defining natural resources, legislatively both protected and unprotected territories that are currently qualitatively or quantitatively devalued (see Figure 3). The data needed for this analysis were taken from the Landscape Atlas of the Slovak Republic [11].

One of the most serious problems in the area is the threat of surface runoff during rainfall and sudden snow melting. In these situations, there is a possibility of soil erosion, but also shallow landslides on agriculturally used slopes near watercourses. The risk of groundwater contamination is localized in the supra-regional and regional biocorridor, the gene pool significant site, the protected landscape area (PLA) White Carpathians (2nd degree of protection) and in the forests of specific destination. Middle radon risk is a problem especially in the southern part of the territory and its presence is in settlements, forests, underground sources, in the regional biocorridor as well as in wetlands and gene-funded localities, while in part it extends to the PLA. The occurrence of landfills is not only an aesthetic problem, but landfills are also a source of environmental pollution and a potential source of health risks. That is why it is more striking that their occurrence was in residential areas and, surprisingly, in PLAs. Medium pollution of rivers is in the regional biocorridor, PLA (2nd degree of protection), forests, underground water sources and nearby settlements.

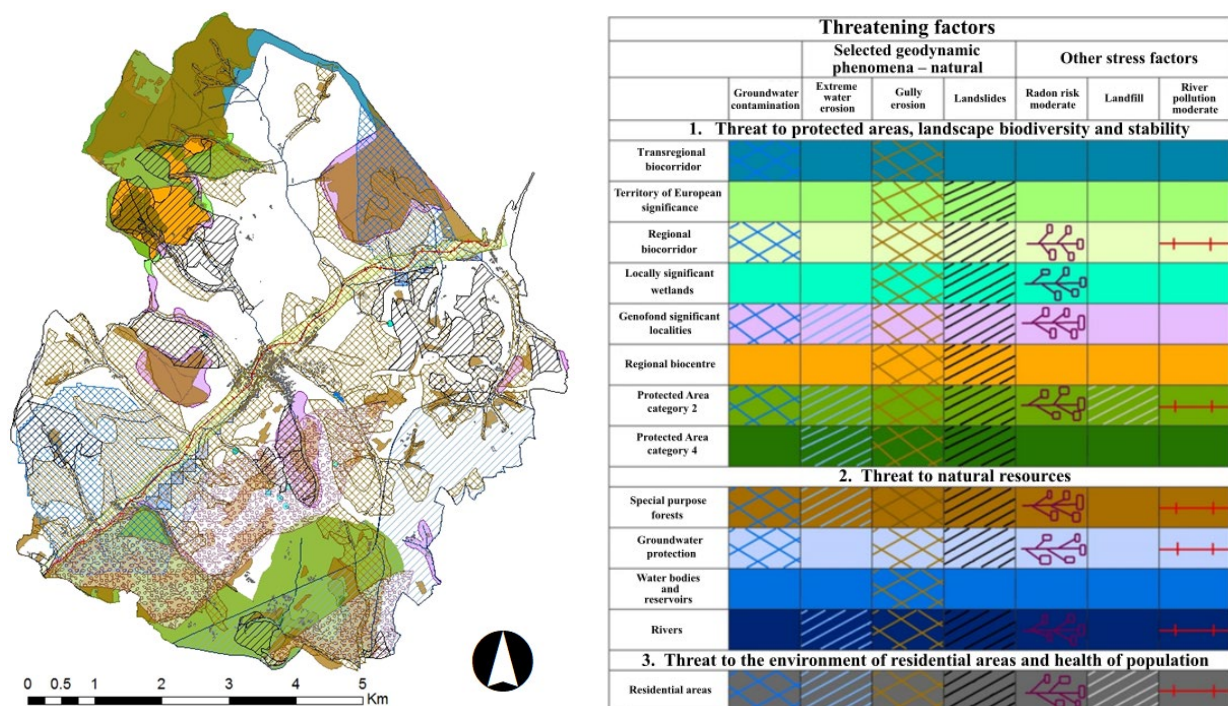


Figure 3. Analysis of the clashes between positive and negative landscape-ecological factors.

In terms of applied methodical procedure of calculation of KES according to the methodology of Reháčková and Pauditsšová, at the end of the 18th century (I.MM) it is a country with low ecological stability, when it was necessary to implement new ecostabilization elements and management measures (Table 4). Over time, at the beginning of the 19th century (II.MM), the country became more stable, but as pointed out in the analysis of land use at the end of the 19th century (III.MM), deforestation appeared, thereby slightly disturbing and deteriorating the territory's stability. Subsequently, through land management in the next period (MTM25), arable land is lost, grassland and forest are increasing and currently (LU2018) is a country with moderate ecological stability, with a conditional need to implement new ecostabilizing elements or the application of appropriate management measures.

Table 4. Calculated values of the KES for the individual time periods.

Period	Degree of KES	Landscape assessment	Summary
I.MM	1.56	Low ecological stability	Improvement
II.MM	2.16	Low ecological stability	
III.MM	1.97	Low ecological stability	
MTM25	2.12	Low ecological stability	
LU2018	2.80	Middle ecological stability	

In addition to the processed numerical results, a graphical output for the current period was created, showing relatively stable (green) and unstable (red) areas in the cadastral area of the Vrbovce village (Figure 4a). Figure 4a shows that the least stable areas are located in the south-eastern part of the area covered by arable land, in the central and northern parts of the territory, respectively. in the upper part of the Teplica basin, which is covered by arable land and urbanised areas. The remainder of the territory seems relatively stable. Regarding the ratio between these areas (stable vs. unstable), which, according to the method for calculating the coefficient of ecological stability based on Míchal, represents a value of 3.4. This value represents an almost balanced country in which technical objects are relatively in line with conserved natural structures.

Based on the results of the individual analysis, specific negative phenomena have been defined that affect the overall ecological quality of the landscape. A wide-spread problem in the area is erosion, landslide, slope deformations, and are caused by intense rainfall activity and the formation of surface runoff on steep slopes (e.g., meadows) and arable land. One of the basic measures to eliminate their impacts is the layout of the land, based on the reduction of erosion-effective slope length, landscaping and orientation. This is one of the most effective and oldest ways of protecting farmland and therefore, erosion-infiltrating ditches and protection stripes in the area of the right-hand tributaries of the Teplica: Haluzník creek and the Lulovsky creek (Figure 4b) are proposed. At slopes above 12° and in places where there is a risk of high to extreme erosion, we recommend delimitation to permanent grassland, which in part was also implemented in previous period during the first stages of the landscape management. The basic element of grassland management is their mowing, which we also calculate and eliminate the concentrated surface runoff and allow for the creation of more favourable conditions for the infiltration of rainwater into the soil profile. At the same time, as a further erosion mitigation measure, it is proposed to change the direction of the tillage on slopes by $15\text{--}20^\circ$ across the contour. Flood events often recurring on a given territory, although not only within the agricultural areas and large meadows, threaten the urbanised area of the village. Small water reservoirs - polders - are proposed to contain intense rainfall in critical areas (critical points – Figure 4b), which will improve the ecological stability of the area, but mainly the flood protection of Vrbovce. Landscape management and ecostabilization measures are listed in Figure 4b.

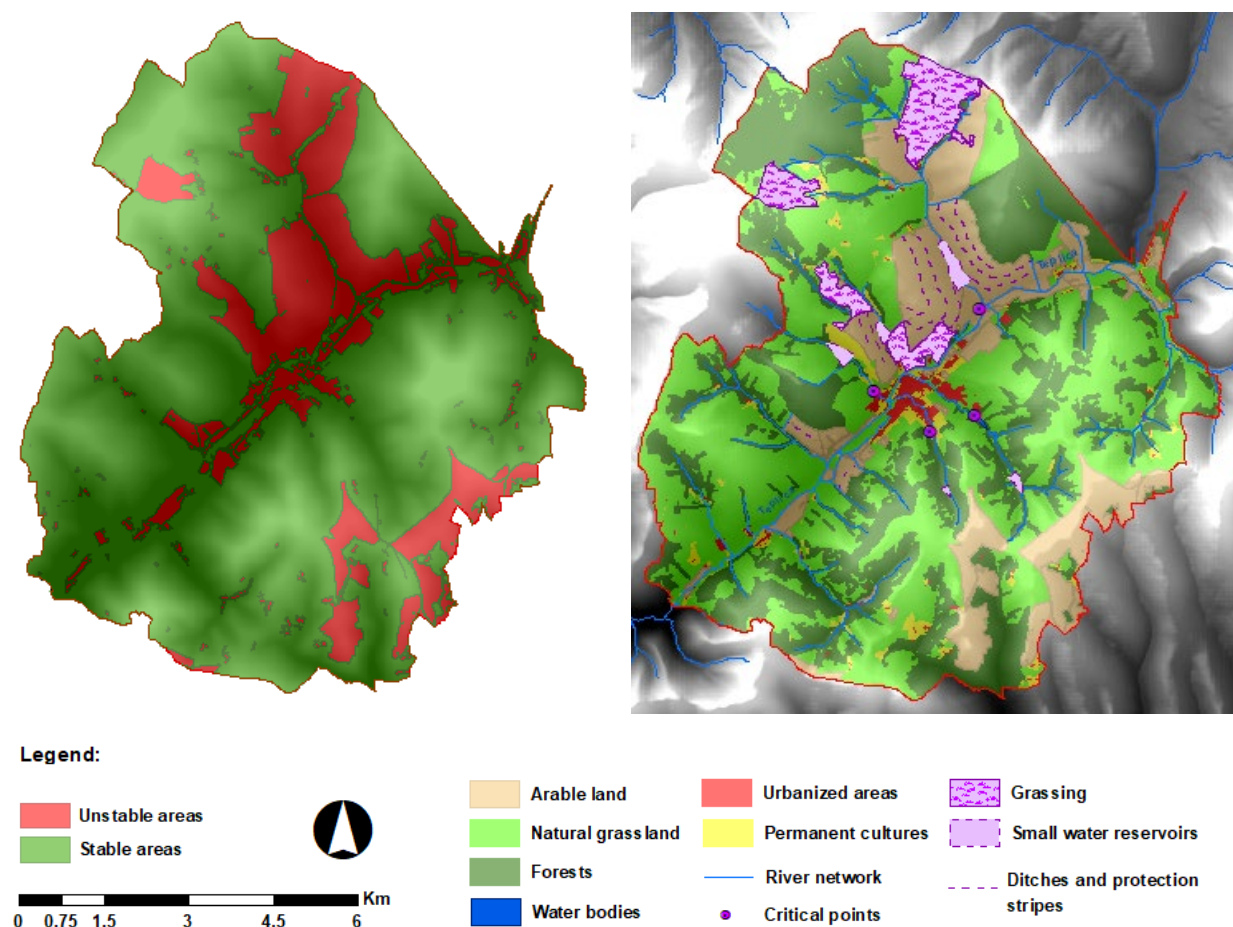


Figure 4. a) Relatively stable and unstable areas, b) Proposed managerial and ecostabilization measures in the cadastral area of the Vrbovce village.

Implementation of the managerial, ecostabilization and flood control measures in the country can increase the ecological stability of the area, which is also confirmed by the recent work on land use change, which significantly changes character and affects hydrological processes affecting flood drainage and soil erosion (see e.g., [12], [13], [14] and [15]).

4. Conclusions

This work was devoted to evaluation of the landscape-ecological stability and landscape management in a cadastral area of the village of Vrbovce. Since the country is constantly changing and evolving in space and time, whether by natural or anthropogenic activity, it is necessary to take care of its protection, revitalization and its deterioration. It would be a pity if the area with a very specific type of settlement deteriorated and we would not be able to protect it for future generations.

In general, there are positive and negative socio-economic elements in the country, which positively define human activities aimed at protecting nature, stability, biodiversity and protecting individual natural resources in order to ensure their rational use. From the analysis of land use from the history to the present, there is a tendency for the arable land to decline in the area of interest and to increase the vegetation and grassland areas. Landscape-ecological stability calculations in different mapping periods suggest that the current landscape is much closer to its natural state than it was during the historical periods. Different types of functional utilization of the area have been recorded in the area, mainly arable land, meadows and forest areas are dominant. The level of ecological stability is relatively favourable, it reaches a moderate level, however, several negative phenomena have been recorded in the territory, which have a negative impact on biodiversity and ecological stability of the country. Therefore, a proposal for their improvement was suggested, especially in agriculturally intensively used territories by means of management and ecostabilization measures based on optimal spatial and functional use of the area. In order to improve the resistance of the area to soil erosion the method of land management in the river basin was taken into account (interrupted large-scale land line management damping - ditches and vegetation protection strips), which will reduce soil erosion, which poses a serious threat to the most fertile top layer of the soil. With a significant slope of the terrain on arable land, we recommend delimitation to permanent grassland, associated with regular mowing, creating more favourable conditions for the infiltration of rainwater into the soil profile and maintaining the water in the country. In the areas where the tributaries joint the Teplica River, small water reservoirs are designed for the protection of the village to store flash flood waters created during intensive rainfall activities. The proposed management measures and ecostabilization elements in the country take into account the preservation and improvement of the structure of the natural areas, respect for the original specific character of the rural area, the original character of the development and the historically formed surrounding landscape, the improvement of the conditions for the target species and communities and the creation of a new grasslands for growing cattle and sheep.

In conclusion, the degree of ecological stability of a cultural landscape cannot be understood only as a weighted average of the ecological stability levels of individual parts, but this degree also depends on their arrangement and on the purposeful spatial distribution. Therefore, in order to maintain high and lasting productivity and ecological stability of the landscape, it is necessary to isolate the individual ecologically labile parts of the country from a system of stable and stabilizing ecosystems. In the future, it is necessary to give preference in this area to management methods that respect the natural conditions and requirements of the inhabitants and at the same time maintain the typical landscape character, which will also be reflected in the overall ecological stability of the country.

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