Complex (physical- and human geographical) comparative analysis of karst and non karst landscapes from the viewpoint of modern environmental possibilism

Karsztos és nem karsztos tájak komplex (természet- és társadalomföldrajzi) összehasonlító vizsgálata a modern környezeti posszibilizmus nézőpontjából

OTKA 3. éves, záró jelentés (2012. szept.1.-2015.aug.31.)

Final scientific report

1. Achievement of tasks undertook for the 3rd year

In the work plan we undertook the following tasks for the 3rd year of research:
- GIS and statistical analysis of the study area #2.
- Completion of possibly missing field data, with shorter field trips to both study areas.
- Presentation of the results referring to study area #2 in conferences and publications.
- General evaluation and summarizing conclusions referring to the main hypothesis of this proposal (namely, how the karst influences social factors), conference presentations and publication of the results

This year, we performed all of the above tasks. We continued the geoinformatical and statistical analysis of both study areas. One of the main issues was that we extended our analysis back in history to the first part of the 19th century, because it is the period, from which reliable census data are available. Furthermore, we carried out several field trips and in-site semi-structured interviews with local people at both study areas.

This year also, we made great efforts to publish and disseminate our results. We participated at several international (Abu-Dhabi – Symposium of Karstology in UAE and Hungary; Vienna – EGU 2015; Budapest – EUGEO 2015; Aggtelek-Rožňava – 10th Scientific Conference „Research, Use and Protection of Caves of Slovak and Aggtelek Karst") and national conferences (Bük – Karsztfejlődés 2015; Budapest – Tájökológia 2015) to present the results of this project. Further on, we published the results in international and Hungarian scientific journals and outlined the general conclusions of our study (cf. the publication list connected to this project; the latest publications are now in print or under review).

2. Final scientific report about the results achieved during the project

2.1. Review of the theoretical background

In order to get a strong theoretical background to our research, we reviewed the Hungarian and international literature in connection with the nature-society relationships (determinism, possibilism, reductionism, landscape ecology, GIS approach). Then we carefully discussed how our quantitative methods can be positioned amongst these approaches and how our investigations can contribute to the confirmation of „integrated geography".

In addition, we reviewed the publications dealing with the impact of karst on society. In fact, most of these publications do not directly target the nature-society relationships, instead, these connections are rather indirectly expressed and former results about karst-society relations are scattered in scientific literature. Thus, we think that the collection of these papers was an important

step to highlight the significance of karst-society relationships and that this field is worth to be more thoroughly studied. In general, one can observe that the special morphological, hydrological, pedological and ecological settings of karstlands do influence the socio-economic development, mostly to a disadvantageous direction, namely, karst terrains are relatively difficult to access, population densities are lower, moreover, natural decrease and migration away are typical processes. The almost only positive effect of karst is related to tourism.

2.2. Montenegro

In order to demonstrate the usefulness of GIS approach in the study of human-environment relations, we selected firstly the country of Montenegro. The country as a whole is a natural research unit, its situation does not need special explanation for the international reader, therefore its study could provide important quantitative results to the topics of human-environment relations. The area of Montenegro is 14,026 km^2, there are 1256 settlements in the country and the mean population density is 45 p/km^2. By using digital terrain analysis, variegated GIS and statistical tools, we managed to justify the following statements.

The spatial distributions of both the population and the settlements are in close relationship with topographic factors, but not in the same way. Namely, the settlement density linearly decreases with elevation a.s.l, while the characteristic settlement area exponentially increases when going upwards. The population density is not related to absolute (i.e. a.s.l.) elevation, but it is in close correlation with height, which was calculated as the elevation relative to the lowermost point of the 5 km neighbourhood. Some other social statistics, such as population change and illiteracy are also in indirect connection with topography, though not as closely as the previous factors.

Lithology also impacts the spatial pattern of population. The limited availability of water as well as the difficulties of road construction on karst terrains are reflected in the spatial distribution of population. About 2/3 of the area of Montenegro is categorized as karst, but only 1/3 of the population lives there. On the other hand, the settlement distribution is only slightly influenced by the presence of karst.

As for the spatial pattern of ethnics, we found that mainly social (historical, political, economic) factors determine it, and even the boundaries between different ethnic territories can not be directly linked to natural features.

2.3. Gömör-Torna (Gemer-Turňa) Karst (GTK)

According to our research plan, we outlined this study area so that it incorporates not only the karst but the neighbouring non-karstic landscapes as well. Thus, certain differences (not all) with respect to neighbouring landscapes, can be attributed to karst-related effects. The whole study area, including GTK, is 3781 km^2 with 249 settlements and 65 p/km^2 mean population density. The study area encompasses 8 different landscapes (Rudohorie Mts, Rudohorie Foothills, Northern valleys and basins, GTK, Cserehát Hills, Szendrő Hills, Putnok Hills and Southern valleys and basins). Here we note that in some cases we aggregated similar landscapes into one unit, namely the valleys and basins.

First, it is observed that the GTK is clearly distinguishable from its surroundings using only the topographic characteristics (elevation and slope histograms). Second, we found that the spatial distribution of settlements and that of the population result two quite different maps. Whereas the settlement density does not show significant correlation with natural factors, the population density and median settlement population correlate with distance to the closest significant river. Looking at the regression curve of the above correlations, it is obvious that GTK settlements have even less people than it could be estimated based on these relationships, thus it is a demonstration of the impact of karst on population.

As for the comparison of Cserehát Hills and GTK, it is concluded that these terrains are relatively similar to each other from the viewpoint of population distribution. Both landscapes are

rarely inhabited, but their settlement networks are dense. On the other hand, the spatial pattern of settlements is not the same, there is a more uniform distribution in Cserehát but an uneven distribution in GTK where plateaus are practically uninhabited while foothills are relatively densely populated.

The most densely populated parts of the surroundings are the valleys and basins and the Rudohorie Foothills due to the diversity of environmental factors. The environmentally based tourism has only a limited effect on population changes, and it is detectable only in case of Aggtelek village. The spatial distribution of ethnicity and religion is in many cases in good agreement with natural landscapes, but this agreement does not mean direct cause and effect relationship between environment and human factors, instead, the compound processes of peopling of peripheral areas, wars, migration and cultural identification resulted the present situation.

In case of GTK we looked for relationships between natural and social factors not only in the landscape scale but also in the settlement scale. We found that nature-society relationships are usually weak but statistically significant in the settlement scale (e.g. relationships between inhabited area vs elevation; inhabited area vs slope; inhabited area vs distance from karst; population vs river distance; population change since 1870 vs river distance; road network density vs distance from karst; etc.). However, we concluded that relationships are more unambiguous if category means or landscape means are taken into consideration. The above results can help to assign a kind of statistical interpretation to the topics of nature-society interactions and the geographic possibilism approach. In the landscape scale, which is a larger scale, we can observe a relatively strong environmental determination of settlements, population and road density. However, in the settlement scale, several local factors (either of natural or of social origin) may lead to significantly differing development scenarios. Another result, that population changes had different trends in the recent past (since the change of regime, 1990) and in a longer study period since 1870. The recent population changes have no observable relationship with basic natural factors, whereas the longer period population changes were significantly influenced by elevation a.s.l. and by distance from larger rivers. It is also stated that settlement planforms (orientation and elongation) are also significantly influenced by the abovementioned physical factors. As for the land cover, it is in an intermediate position between nature and society, because it reflects both natural and social constrains and effects. This transitional position is demonstrated by the results of statistical and GIS analysis, too, because the proportion of forests and the proportion of agricultural lands are in close connection with relief factors (especially slope) on one hand, and social parameters (e.g. population; road density; settlement size) on the other hand.

We examined demographic changes since the first part of the 19th century. Even at the beginning of the studied period, the more or less plain and the hilly-mountainuous landscapes had different population densities but the differences have been highly increased since then. Already in the 19th century the hilly landscapes could be characterized by stagnation or occasionally by decrease. The only exception was the Putnok Hills, where coal mining and the industrialization of nearby areas stimulated a locally significant population growth. After a weak increase in the first half of the 20th century, there was a serious decline of population in all hilly and mountainuous areas especially after 1970. However, after the change of regime in 1990, the decrease was stopped in some landscapes due to the inflow and higher reproduction rate of Roma people. The GTK was the least densely populated area from the beginnings, but Cserehát Hills had similarly low values. However, the population decrease after 1970 was more intensive in the GTK. In order to explore inner mosaicity of natural landscapes, we analysed landscape scenarios by clustering settlements according to their demographic scenarios. We got 5 settlement groups from the worst demographic situation to the relatively better situated types. In order to characterize ageing, we calculated the proportion of population aged 60 or over, and we found that it is the highest in the Hungarian part of GTK (29%), and it is relatively high in the Slovakian part of the karst, too.

In order to characterize the present economic situation, one can consider the unemployment rate; it is rather high in the Slovakian part of GTK, while it is the lowest in the Hungarian karst area. Thus, these parameters suggest a relatively favorable position of karst in Hungary but a poor

situation in Slovakia. Among other factors, it is clearly in connection with tourism. As Slovakia has many natural attractions and high mountains (as nature-based tourism competitors), it seems reasonable that the Slovak Karst receives relatively little attention in spite of its karst peculiarities.

Meanwhile, the Hungarian part of GTK has an outstanding tourist importance within the study area. While only 5% of population live in the settlements of Aggtelek Karst, the overnight stays show that about three quarter (72%) of visitors arrive to the karst within the study area. However, the present development of karst-related tourism is very localized, observable only around Aggtelek. Thus, it is proposed that tourism should be spatially more distributed. In fact, there are some initiatives for this, but these are not too effective yet. Beside the natural settings of karst, another paradoxical advantage can be mentioned from the viewpoint of tourism: the low development of the area. Due to poverty, the villages escaped the uniformization and modernization of the second half of 20th century, and folk architecture has been preserved that has become by now a tourism potential together with the semi-natural landscape.

The attitude of local people towards natural settings and especially towards karst was examined by semi-structured interviews and field observations. A remarkable change of landuse is the almost total disappereance of pastures as a result of the cease of grazing. Even some decades ago, thousands of sheep and cows were kept mainly on the large, uninhabited and waterless northern karst plateaus (Plešivska, Silicka, Jasovska) during the summer period, where the animals got water from cisterns. Today, there are only 1-2 shephards, because people do not undertake this harsh way of life even if salaries are acceptable now. Thus, the spreading of forests is typical in the whole karst terrain. The unfavourable arable lands on karst were abandoned even earlier, at the end of the 19th century. In the second half of the 20th century most inhabitants of these villages believed that peasants' work (the cultivation of both animals and crops) is only a misery and they intentionally sent their children to towns and cities so that they (the children) have a better life. Further signs of the ageing and depopulating villages are the orchards becoming wild around the settlements. The extending forests' cultivation provide work for few people only.

Living on a karst area is usually not important in the thought of local people except at Aggtelek and its surroundings. Few people stroll through the karstic hills and mountains and even school children are rarely taken for a visit to karst natural monuments. Based on interviews with mayors we can say that environmental thinking is usually not typical in local management, the goal is most often the survival. However, there are some villages where they try to preserve or revive the positive elements of traditional agriculture. Rural tourism and forest schools provide some possibilities for certain villages on the verge of extinction to preserve at least the architectural heritage. Since the human resources are limited in the small, ageing villages, and the present socio-economic conditions are unfamiliar for local people, we observed in many cases that the points of revival are often linked to persons arrived from „outside" (e.g. teacher, priest, national park employee, tourism entrepreneur).

Beside the above results, we studied the morphometrical properties of dolines as well as the relationship of microtopography and the anthropogenically influenced vegetation cover by using up-to-date airborne LiDAR data. Our results demonstrate that the difference of the LiDAR-based Digital Surface Model and Digital Terrain Model is in close correlation with canopy height mapped in the field. Further on, we quantitatively demonstrated that dolines influence some elements of vegetation, and that there are vegetation variations within the dolines according to slope and aspect. Finally, it is observed that canopy height is larger in the central parts of dolines that results that the forest top surface is significanty smoothed with respect to the topographic surface. All of the aforementioned observations provide important information to forestry as well.

2.4. Apuseni Mts

This study area is 16,730 km^2 with 1381 settlements in 181 communes, its mean population density is 47 p/km^2. We had several field trips in Apuseni Mts, where natural settings of karst terrains (Királyerdő / Pădurea Craiului; Bihar / Bihor; Torockó / Trascău Mts, Béli-hegység / Codru

Moma; Poieni karst plateau) were studied. Questionnaire survey was also carried out in these areas and statistical data were also used to investigate nature-society relationships in these terrains.

We selected four parameters in connection with relief, which are not fully independent from each other, but they characterize the surface in different ways. The most often used parameter is elevation, which implies differences mainly in climate. The slope expresses the terrain ruggedness, which has a strong impact on building or cultivation potentials. The height is also in connection with ruggedness and denotes transport difficulties with a vertical dimension. Finally, river distance reflects the remoteness of a given settlement, the distance to the main arteries of transport.

We examined the relationship strength between the above factors and settlement and population density. The results demonstrate relatively strong correlations with all 4 parameters ($r^2 \sim 0.9$). The type of best-fit function is nonlinear for all cases, but it is varied according to the studied relationship. Settlement density can be best modelled by height. On the other hand, the correlation of settlement density and elevation is rather weak due to the fact that there is a special landscape in the heart of Apuseni Mts, the Land of Moţi, which is an area with lots of tiny, scattered settlements found at high elevation. Population density has good correlations with all relief parameters, Up to 1966, slope and height result slightly better correlations, but since 1977, river distance has the strongest correlation with population density.

The land cover is influenced by nature to a varying degree, but when a cultural landscape is considered (as in the case of Apuseni Mts), it is expected that the human impact is very high, and land cover reflects how the humans utilize the landscape. We determined determination coefficients (r^2) between land cover categories and relief parameters using several function types. The relationships proved to be very strong in most cases ($r^2 > 0.9$, except with river distance), which testifies that landuse in the Apuseni Mts is well adapted to relief conditions.

Geological settings are also important in the interpretation of the spatial pattern of population. Although only 15% of the total area is covered by Quaternary sediments, 68% of the population live on these terrains, consequently the population density is relatively high there (180 p/km^2). Naturally it is partly due to the fact that these sediments are found at lower levels. The other end of the spectrum are the magmatic (plutonic and volcanic) terrains where population density is lower than 7 p/km^2. However, this low density may be also the result of the fact that magmatic rocks are mostly found at higher elevations. Population density of karst terrains is similarly low (8.4 p/km^2). Further on, if population densities are compared for each 50 m interval elevation class it is found that population densities of karst terrains are the lowest in almost all classes (except 3 zones), and their population density is only 41% of the population density of nonkarst terrains on the average.

Mixed karsts are typical in the Apuseni Mts (e.g. Királyerdő / Pădurea Craiului; Aranyosfői-fennsík / Scarişoara plateau; Vaskohi-karszt / Vaşcău Karst), where water is more available than on autogenous karsts, thus settlements with traditional agriculture could form on these plateaus centuries ago.

We extended our research back in history to the first part of the 19th century and examined population changes in each 100 m interval elevation class. This approach pointed out that long-standing, significant population increase took place only in the nearly lowermost 200-300 m zone. In this zone, the most remarkable growth occurred during the last two decades of the communist regime, but later on, it was followed by a drastic decline. In all other elevation zones up to 800 m, growth is observed only till 1910, and after the decline of the 1st world war this population level was hardly restored by 1941. Thereafter, a slightly fluctuating, but more or less uniform rate population decrease can be observed. As for the zones upper than 800 m, the situation is somewhat special, because an abrupt increase occurred between 1941 and 1956. However, this change is only virtual, it is connected to an administrative reform. Till 1941, the population living at higher elevations were attributed to their lower elevation communal centers, but since 1956 they are counted where they really live. During the last two decades of the communist regime, there was an intense (and real) decline, but a slower rate decrease continued in the post-communist era. It clearly demonstrates how the population flowed from upper to lower parts of Apuseni Mts in the two decades before the change of regime, and how people moved outside the Apuseni Mts to larger

cities and even abroad after the change of regime. The aforementioned changes are properly reflected in the movement of population centroids as well. From 1966, the population centroids moved at faster, while after 1990 at slower rate towards terrains, which are lower, less rugged, smaller in height and closer to significant rivers.

We also studied the geomorphological properties of superficial (dolines, sinks, gorges) and underground (caves) karst landforms. Moreover, we tried to quantitatively evaluate the tourist potential of karst terrains. The lookup of potential natural attractions in tourist maps resulted 599 objects, and 81% (487 objects) of them was of karstic origin. This high proportion is especially large if one takes into account that karstifiable rocks present only 6% of Apuseni Mts. The most significant, internationally reputed attractions (Tordai-hasadék/Cheile Turzii, Pádis-fennsík/Padiş Plateau, Székelykő/Piatra Secuiului) are all karstic objects. Based on the above results, it is stated that karsts are of outstanding importance from the viewpoint of nature-based tourism. At least, if the potential is considered. Thereafter, we examined the spatial distribution of real tourism using the number of overnight stays. The spatial distribution of real tourism only partly overlaps the karst terrains, and there is no correlation between the number of overnight stays and the number of karstic objects at the commune level. The most attractive locations are the spas (Menyháza/Moneasa, Feredőgyógy/Geoagiu), which can be considered as special karst-related locations as the thermal waters are due to karstic hydrogeological settings.

Quantitative relationships between environmental and social factors were also studied in the commune scale. In general, we found that the relationships are weak but statistically significant in some cases (r~0.3-0.4), because given the 181 communes, relationships with >0.15 linear correlation coefficient are significant at the 95% confidence level. Just to mention some significant relationships: the proportion of Romanians (and of Orthodox people) increases, whereas the proportion of Hungarians (and of Calvinist people) decreases with slope. It goes back to historical differences in the spreading of these two peoples. Hungarians preferred plain, lowland terrains (or at least basins), whereas Romanians adapted better to mountain lifestyle. The education level is in a weak relationship with river distance. It is logical because central functions (schools, universities) are found mainly in settlements located in larger valleys where transport possibilities are better.

Finally, it is concluded that three important natural settings can be highlighted that provided (or still provide) the economic bases of people living in the Apuseni Mts, though their proportions were variable during different periods of history. First, the traditional landuse management, which is the most typical in the Apuseni Mts for centuries. It is characterized by a harmonic balance between grazing, complex agriculture around the houses and forest management. The second important natural basis of economy in the Apuseni Mts is mining. However, after 1990, the mining industry collapsed at one blow, and a number of settlements became severely disadvantaged locations left in an economic and environmental crisis. The third natural basis for living is (or could be) tourism in modern times. Spas are the most valuable resources in the context of tourism today, but an important and still partly untapped possibility is connected to karst areas. Further on, the traditional way of life, and the historical heritage sites (of Romanian national heroes) are also important attractions. Nonetheless, it still remains a question whether tourism will be capable to provide a solid basis for the maintain of population and for a sustainable development. Moreover, tourism may cause environmental problems as well, which should be managed, too.

2.5. Final conclusions

The GIS-based, quantitative analysis proved to be a useful tool in the exploration of the strength and dynamics of human-environment relationships. The advantage of regional studies with respect to global analysis is that the impact of certain environmental factors can be more obvious in smaller, more homogeneous units. Further on, even today, better resolution data of certain factors (e.g. lithology, land cover, social statistics) are available only in a regional scale, whereas worldwide geological, land cover or population databases are still of lower resolution or accuracy.

Environmental settings (namely elevation, relative height, slope, river distance, lithology, hydrography) have a relatively strong impact on the spatial distribution of human population and on land cover as well. This impact can be best described by nonlinear relationships. The best explaining factor for population density and for most land cover categories is the slope angle, i.e. terrain ruggedness, but in some cases, the best correlations are observed with river distance. One of the novel features of our study is that we used a quantitative approach for temporal changes as well. This way, we pointed out that the even if the human-environment relationships of a given historical moment are strong, there are changes in time, and for instance, the relationship of population change and elevation had a switching sign during the studied period in the Apuseni Mts. As the natural settings were more or less stable during this period, the changes can be explained from the side of society, which conforms the theory of cultural possibilism.

The karst terrains, which we studied in the framework of this OTKA project, are also prone to processes observed in other karst areas, notably, that their population densities are lower than that of their neighbouring landscapes (but there are differences between karst and karst, too – the population density is influenced by the type of karst as well) and ageing and depopulation are characteristic processes of the studied karstlands, too. Karst-related tourism has a high potential and it may act against the above negative processes, however, its preserving effect is rather limited in space. Nonetheless, this type of tourism is significant and it merits further support and development.

2.6. Dissemination of results

Beside scientific publications, we also payed attention to present the results of our project in more popular forms as well. We gave some lectures organized by the Hungarian Geographical Society and published popular papers in the „A Földgömb" magazine. Moreover, we provided a possibility for university students to join our research. Several of them participated at the field trips linked to the project, and some of them even wrote her thesis about topics in connection with the project (Váczi A.: „A természet és a társadalom összefüggéseinek vizsgálata térinformatikai módszerekkel a Sajó és Hernád folyók közti tájak példáján keresztül" – environmental science MSc; Nagy Zs.: „Barlangokról alkotott kép a magyarországi médiában és a közgondolkodásban" – geography BSc; Unferdorben E.: „Természeti és társadalmi tényezők egymásra hatása a Gömör–Tornai-karszt területén" – geography BSc).