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ECOSYSTEM SERVICES IN HUNGARIAN KARST AREAS

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Summary: Ecosystem service assessments provide a new and effective methodology in environmental management with several good experiences worldwide. In our study, we surveyed the services of a special landscape type, the karst areas in Hungary. Special characteristics of the karstecosystem are the high vulnerability and the three-dimensional and very fast processes. The importance of karsts is indicated primarily by drinking water provision, but they provide several other services with high economic value like soil formation, habitat function, timber production, climate regulation, recreation and aesthetic value. Hungarian karst areas are mainly in bad condition from a socio-geographical point of view, thus we propose that ecosystem services should be better incorporated in regional development processes.

Key words: ecosystem services, karsts, environmental management, vulnerability

1. INTRODUCTION, METHODS

Valuing ecosystem services could prove a comprehensive environmental evaluation method, dealing with both the animate and inanimate goods of nature. Its innovation is, among others, that the different factors and their value can be connected to social demands and present or future anthropogenic use (Costanza et al. 1997, MEA 2003). It can express such functions of natural factors that have not been taken into account or only without regard for their true importance. The analysis of landscapes' functions emerged years before in landscape ecological research (Leser 1986, Mezősi and Rakonczai 1997). With the help of valuing ecosystem services the structure→function→value approach can be completed and therefore could be used in practice easier. The complex systems approach enables overviewing the environmental factors' connections, recognizing contradictory or exclusive functions and optimizing land use. The study is based, besides other literature sources, on the previous results of karst ecological studies at University of Szeged. These studies focused on describing the landscape system of karsts as precisely as possible, with methods of different fields. By proposing the evaluation of ecosystem services, we would like to unify these results and make them more suitable for use in environmental decision making.

2. RESULTS AND DISCUSSION

2.1. The karstecological system

Karst areas are among the most valuable landscapes of Hungary, and they are also very vulnerable. Karstic rocks (limestone, dolomite) have good transmissibility and water holding capacity, therefore specific surface and sub-surface geomorphologic forms can be found on them; the higher geodiversity results in the diversity of living organisms. But the rocks' good solubility, the three-dimensional processes are a source of hazards as well, because harmful effects quickly induce significant changes in the whole system. Only 10% of the Earth's surface is covered with karstic rocks, but 25% of mankind's drinking water is supplied by karstic aquifers. This fact emphasizes the need for the protection of these vulnerable systems. In Hungary, parts of the Transdanubian and Northern Mountain Range and Western-Mecsek have karstic morphogenetics and special karstic landforms (Fig. 1).

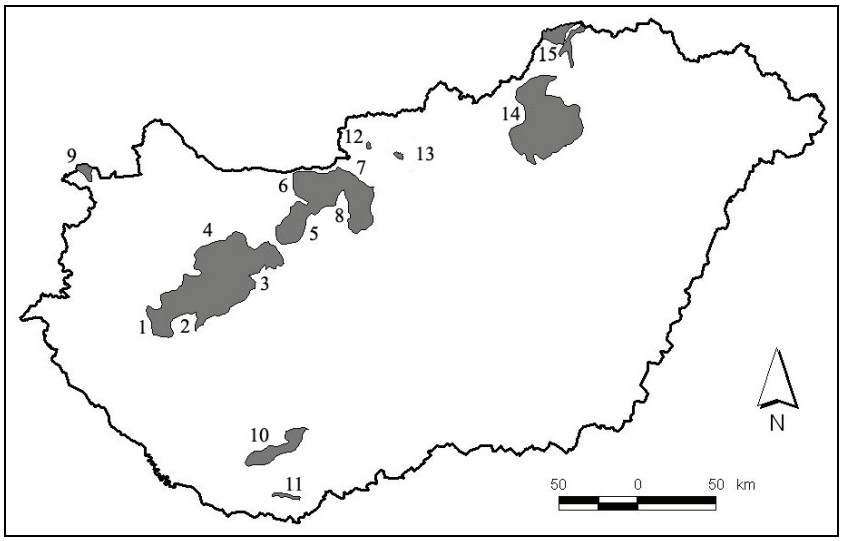

Fig. 1 Landscapes with surface karsts in Hungary
1 = Keszthely Mountains; 2 = Balaton Uplands; 3 = Southern Bakony; 4 = Northern Bakony; 5 = Vértes; 6 = Gerecse; 7 = Pilis; 8 = Buda Mountains; 9 = Surroundings of Sopron; 10 = Mecsek; 11 = Villány Mountains; 12 = Szokolya Basin; 13 = Karst of Cserhát; 14 = Bükk; 15 = Aggtelek Karst (modified after Kordos 1984)

Besides water (with transmitter function), every landscape ecological factor has an important role in the system, and they affect the special morphology and processes of the karsts. Climate is an important element in karst development through its influence on the solvent water's quantity and temperature, but it has crucial role in the formation of the soil and vegetation types as well as a zonal factor. Low temperature, despite its higher gas absorption capacity, decreases the speed of solution processes, and water migration stops entirely in the case of frost. High temperature can also moderate the intensity of corrosion, because the gas dissolving capacity of water is smaller at higher temperatures, and the aggressive carbon dioxide absorption capacity is lower in water with high temperature. The

water originating from precipitation moves differently in the soil and in the parent rock, depending on the infiltration capacity of the rock and on the vegetation cover. The dilution of leaking water reduces dripstone formation. The situation is different in the case of vegetation cover, when evapotranspiration should also be taken into consideration, thus part of the precipitation is getting again in the atmosphere.

Soil is a determining element of the karstecological system. It functions as filter and buffer layer, which strains the external material of the infiltrating water. Different authors do not always formulate clearly that karstic processes depend mainly on the covering rocks, sediments or soils. According to this, we differentiate between covered, hidden-open (Bárány-Kevei and Jakucs 1984), open and bare karsts. Covered karsts are covered with non-karstic rock or sediment, thus corrosion can start where the leaking water finds way towards the soluble rock. Shallow suffusion dolines can be found on these surfaces. On bare karsts, corrosion processes are slow because of the low carbonic acid content. In soil-covered karsts, the carbon dioxide surplus, originating from organic matter decomposition and root respiration, increases the corrosion capacity of leaking water, which strengthens morphogenetical processes. Soils react and respond to external effects according to their physical and chemical properties; therefore soil is an indicator sphere of the karstecosystem. The modifying effect of non-native material coming as a result of human activities or from atmospherical deposition can cause the deterioration of near-surface soil layers. A significant sign of this is the changing acidity and, in parallel, the carbonate content. These are important factors in areas with different vegetation cover because they form the basis of investigating interactions between vegetation and soil.

The hydrogeological-hydrogeographical properties of karst areas are determined by the fact that water from precipitation and from non-carbonate areas quickly disappear in pipes and pores. Water from precipitation moves further as infiltrating water and has a crucial role in the material transport of karsts. Karsts are quite heterogenous, they are covered with soil, with vegetation, or they can be bare, thus it is not possible to give a general scheme to determine the amount of infiltrating water. Böcker (1974) differentiated infiltrating types: infiltration of open karstic surface, of surface covered with soil and vegetation, of permeable clastic deposit, and of covered karst. These types show that there are differences in the water-mediated material transport as a function of karst ecological conditions. Physical properties of the soil affect the infiltration rate. If the soil's transmissibility is greater than the parent rock's, groundwater flows in accordance with the general slope direction of the area. If the soil's transmissibility is smaller or equal to the parent rock's, then water leaks into the rock, holding all of the dissolved material from the soil.

Bio-ecological properties are important factors in the karstecosystem; karst can in fact be treated as a biological product (Jakucs 1980). Karst development strongly correlates with microbial activity; the intensity of corrosion is lower where living beings are less present in the soil. After the decomposition of organic matter, organic colloids can bind several harmful compounds e.g. heavy metals.

The strong interrelations of landscape ecological factors prevail not only in the structure and operation of the system, but in environmental effects as well, a change in one element of the system causes significant changes in the balance of other elements and subsystems (Fig. 2). Methodologically complex approaches are important in the environmental assessments of karst areas. One such approach is the evaluation of ecosystem services in karst areas, which has the advantage of managing different functions

of biotic and abiotic factors of nature in a unified assessment system and presenting their value to the society. In the next chapters, we give a review of the main ecosystem services of karst areas, and, as a justification of the methodology, we assess their degradation and the value of their protection for the society.

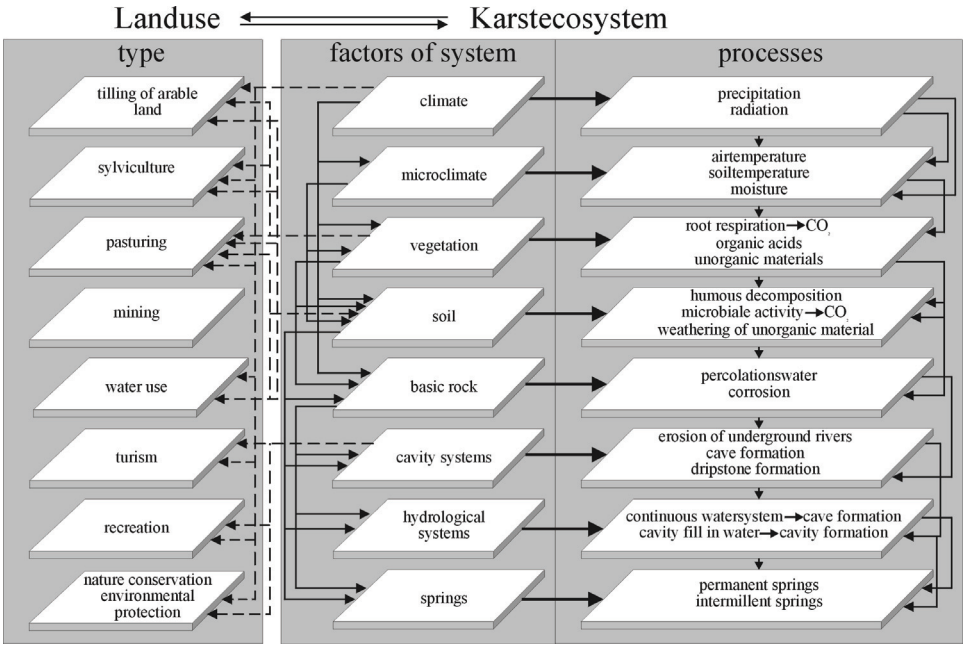

Fig. 2 The karstecological system

2.2. Drinking water provision

In Hungary, 14-16% of the drinking water is supplied by karstic aquifers. The quantity and quality should both be taken into account when speaking about karst waters. Karst water depletion shows a decreasing tendency and now it is approximately in balance with the supply from precipitation. But in the 1970s and 80s, in the case of Bükk mountains, the extraction was higher than the supply, which could be detected in decreasing karst water levels. The fall of karst water levels in the Transdanubian Mountain Range due to bauxite and coal mining is widely known. The pressure decrease extending to the whole aquifer resulted in the drying up of some nearby karst springs (e.g. Tata, Bodajk), while a discharge decrease was observable in the case of some thermal springs. Water level regenerated and pressure rising started owing to the closing of the mines after the political transition in 1989-90 (Csepregi 2003). Karst water levels can be expected to be influenced heavily by global climate change; former studies (e.g. Younger et al. 2002) found that significant decrease would occur in the karst water resources of low- and mid-latitudes by the middle of the century. Besides climate, karst water quantity also depends on land use, the area of built-up surfaces, through the modification of evapotranspiration, which is an important factor of the hydrological balance (Sikazwe 2008).

Karst water quality is an ecosystem service also through the drinking water supply. In Hungary, several studies dealt with the vulnerability and pollution of karst waters, mainly heavy metal pollution in different periods (Mádl-Szőnyi and Füle 1998, Mádl-Szőnyi et al. 2003, Kürti 2005, Szőke 2005, Keveiné Bárány et al. 1999, Kaszala and Bárány-Kevei 2005). The water inflow from agricultural areas can cause the redissolution of dripstones (Jakucs 1987). It is a frequent phenomenon in Central European caves (Photo 1), but this degradation process can also be observed in the Atlantic region (e.g. in Marble Arch Cave, Ireland). Meanwhile, polluted waters entering the cave cause degradation in the quality of curative aerosols.

Photo 1 Redissolution of a dripstone in the Baradla Cave (Aggtelek Karst)

Evaluating ecosystem services may help improve water quality, because the investments needed may be financially comparable with 'the price' of maintaining the present state. E.g. in 2006, thousands of people were taken ill because of the polluted water during a karst flood, and some karst springs were excluded from the drinking water supply in the surroundings of Miskolc, because of coli infection (Lénárt 2006). If we take into consideration the damages in other services, the total costs of interventions needed, these are financially comparable with the consequences of worse environmental status. Water Quality Trading (Boyd et al. 2004) could be a usable method in environmental management of surface and subsurface waters: it works similarly to the carbon trading system: polluters above the limit can buy emission surplus quotas from companies with less pollution.

2.3. Soil formation

In karst areas, all types of ecosystem services of the soils (provisioning, supporting, regulating and cultural) are being degraded. In karstic dolines the acidification of soils can be detected in a considerable part of the country (Keveiné Bárány 2002), in definite connection with acidic atmospheric deposition. The decrease in pH can result in the loss of many nutrients and a considerable amount of calcium. The soil structure may get worse, which also has an effect on the availability of nutrients. And, in extreme situations, toxic elements (aluminium, manganese, iron, heavy metals) may be mobilized. These may have an unfavourable effect on stand increment and soil biota. Soil erosion after forest clearcuts and cultivating is a problem mainly in the Mediterranean region. This is an evident example of the wide-spread process of overusing slowly or conditionally renewable resources, which may cause the degradation of services much more valuable than the exploited one. Karstic erosion badlands are not frequent in Hungary, the biggest occurrences are Ördögszántás above Aggtelek and a slope of Villány Mountains (Photo 2).

Photo 2 Erosion slope in the Villányi Mountains

2.4. Habitat function

There are several methods in the literature for evaluating biodiversity as an ecosystem service, supported by natural and semi-natural habitats. Karstic landscapes are refuges of several unique species of the flora and fauna of Hungary; the spatial distribution of the vegetation-based Natural Capital Index (Czúcz et al. 2008) shows that the quantity and quality of natural and semi-natural habitats are good in our karstlands. The InVEST modelling tool (Integrated Valuation of Ecosystem Services and Tradeoffs – Tallis et al. 2008), which was developed in the Natural Capital Project in the USA, calculates the ecosystem service of biodiversity based on habitat quantity, fragmentation, rarity and on endangering factors, which are similar criteria to those on which the Natural Capital Index is based. The number of endangering factors is limited, because almost every karst area of Hungary got territorial protection in the former decades. The management of protected areas is a typical field of land use conflicts, in most of Hungary's protected forests there is some kind of conflict between national parks and forestry companies. As most karst areas are under nature protection, and they are mostly forested, this is the main or one of the main land use conlicts in karstic national parks. A similar problem is the change in the vegetation of dolines. After forest clearcuts microclimate had turned into extreme (Bárány-Kevei 1985), and *Juniperus*-associations appeared in the place of former forests. Reforestation is very difficult in these patches; there are dead-end directions in the secondary succession of these associations (Bárány-Kevei and Horváth 2005). But it is obvious that treeless, *Juniperus*-dominated dolines have become a characteristic element of karstic landscapes, and the herbaceous associations of dolines enrich the species composition of these landscapes. Altogether, deforested dolines increase landscape diversity to some extent, which can be measured e.g. through tourism. Valuing ecosystem services manage the different natural factors in a uniform system, and thus might help to make similar land use optimizing decisions. Another example of degradation of natural and seminatural karstic habitats is the eutrophication of karstic lakes. In a number of lakes in Aggtelek Karst filling up can be detected to different, but undoubtedly faster extent than the natural process. This is one of the most obvious environmental changes in karstic areas, e.g. Aggtelek Lake has shrunk to a puddle overgrown with bulrush, from an oligotrophic lake with an open water surface of 1.3 ha (Photos 3 and 4).

Photo 3 Aggtelek lake in 1984

Photo 4 Aggtelek lake in 1999

This process can be influenced by climate change too, but the connection with agricultural and residential wastewater influx is proven (Samu and Keveiné Bárány 2008).

2.5. Other services of forests

Raw material production is the most exploited ecosystem service of forests nowadays in Hungary. Its quantitative estimation is relatively simple, because timber has real market. But in karst areas, other functions of forests should be taken into consideration compared with some other landscapes, e.g. in the Aggtelek National Park, proportion of protection-oriented forests is 62.9%, opposed to the average of 33.1% of the country (Tanács 2005). Although in the 21st century forestry is not the main employer, but in some areas its proportion in the structure of employment is above the average level in Hungary (KSH 2001). As karst areas are more densely forested than other landscape types of the country, climate regulation, which is among the most important services of forests nowadays, should be taken into account seriously in the case of these areas.

2.6. Recreation and aesthetic value

Owing to the special morphology and scenery of the surface and caves, tourism appeared relatively early in karsts; Baradla Cave was frequently visited already in the 19th century. Two of the first four national parks of the country were established in karstic landscapes (Bükk National Park 1977, Aggtelek National Park 1984), and nowadays there are practically no karstlands out of territorial protection. The ecosystem service of recreation potential has been principally exploited by the economy of these microregions: Aggtelek National Park is the main employer of the area, and, through the income from cave visitors, it has the best economic potential among Hungarian national parks. Even so, many of these areas can be considered as periphery, from a social geographical point of view. Many problems of Hungarian rural areas appear in these regions: unemployment, communal services breaking off, the ageing of native inhabitants owing to the migration of those of working age. A parallel process is the immigration of gypsies. The reasons of these are mainly the same as in many other rural areas: the migration to urban areas was at first induced by agriculture losing dominance in the country's economy, and later this was strengthened by forced industrialization in the socialist era. The repression of public services is a consequence partly of the settlement structure of these regions, which are characterized by small villages (up to 500 inhabitants). A special factor in the case of Gömör-Torna Karst is that this region was cut off from the original settlement system, most of the villages got far away from towns remaining in Hungary. In developing countries, poverty and bad living conditions are strongly connected to the degradation of ecosystem

services (Duraiappah 2004, WRI 2007). In fact, our karst areas are provisioning a huge amount of ecosystem services, but they are mostly neglected by the current economic, regional development policy. This contradiction appears in other landscapes of Hungary too, drawing attention to an urgent need of changes.

3. CONCLUSIONS, FURTHER STEPS

In this paper, we would like to draw scientists' and decision makers' attention to this new methodology in the environmental management of karst areas. For the single elements of the Total Economic Value, methods of different disciplines should be used, but complex landscape ecological approaches can be justified with regard to the factors' relationships. Our examples, the Hungarian karst areas are specific because of their vulnerability and the fast and three-dimensional processes. Changes in each factor cause changes in the whole system. The extent of fluctuations is influenced by the climate-soil-vegetation system. As further steps, we feel it necessary to define these connections numerically, probably in model-based assessments. Significant differences in the spatial patterns of ecosystem services and socio-economical characteristics (economical indicators of well-being) account for further research on investigating the phenomenon, and in practice, to incorporate the sustainable use of ecosystem services more efficiently in regulations and regional development policy.

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