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BIOGEOMORPHOLOGICAL FEEDBACK IN KARST AREAS

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Abstract
In the last decades, the research on ecosystem services have emerged in the field of geography. The negative impacts of human activities on the vulnerable karst areas are getting enforced quickly, which have an unfavourable influence on ecosystem service provision. On karstic areas, there are significant geographical processes, connected to biological activities. This issue is not adequately discussed in the current literature of karst ecology. In our study, we give an overview on the biogeomorphological feedbacks that change the functions and overall value of karst ecosystems.

Keywords: biogeomorphology, karst ecosystems, ecosystem services

1. Introduction

Scholars of natural science have always been preoccupied with the relationship between the environment and the ecosystem characterizing it. However, the more specialized science has become, the less attention academics have paid to the effects different ecosystems have on landscape and society. Recent decades have seen changes in this process though, as research on biophysical interactions have gained more interest (Jones et al. 1994; Reinhardt et al. 2010). 80% of all geomorphological changes can be attributed to ecosystems in karst areas (Phillips 2016). Ecologists have long been aware of the interdependence of populations and the natural environment in an ecosystem (Corenblit et al. 2011). Of course, ecologists focus on the characteristics of ecosystems and environmental stress, first of all. A significant step in the further understanding of biogeomorphological feedback was depicting keystone species as ecosystem engineers (Matthews et al. 2014) and applying this notion to phenotypes and niche constructions. According to ecologists, organisms and communities do not only adapt to their physical environments, but they also modify them, and develop an adequate niche (competition) condition to other species. Jones et al. (1994) called these organisms as “ecosystem engineering” species. The abundance (cover ratio) of the keystone species’ community has a significant impact on its physical environment due to its structure and function. Ecosystem engineering organisms control the available resources for other species both directly and indirectly by modifying the biotic or abiotic components of the natural environment, maintaining the already existing habitats, or creating new ones. Autogenic engineers modify their environment by modifying themselves, thus providing direct energy source for other species. Allogenic engineers modify their environment by mechanically changing different materials from one physical form to another (Jones et al. 1994).

Preliminary studies made the development of a macroevolutionary concept possible according to which geomorphological feedbacks (such as sediment erosion and sediment deposition) are the results of ecological (biodiversity, social structure) and evolutionary (adaptation, speciation) processes. The characteristics and the size of the habitats' geomorphological niche dynamics are modified by physical state changes, so the landscape creating skills of ecosystem engineers are made use of, thus making it possible for other species to appear in the ecosystem (Corenblit et al. 2010). These studies proved that living organism do not only respond to the changes of their physical environment, but they can also modify and control them directly, and by doing so they change the characteristics of natural landscapes (Viles 1988; Phillips 2016). It is now proven that ecosystems mutually interact with their natural (physical) environment through biogeochemical cycles, which serve as the basis of energy flows and nutrient cycles. According to previous studies, karst processes also strongly interact with the ecosystem (Jakucs 1980; Kevei Bárány – Zámbó 1986). Our present study adds further data to the understanding of karst ecosystem services and the positive and negative geomorphological feedback of the ecosystem.

2. Biogeomorphological feedbacks and ecosystem services

Biodiversity usually enhances the survival possibilities of the species in any landscape. However, the more and more intense human activities have to be taken into account when studying the function and the biogeomorphological feedback of a landscape. Humans have changed agriculture through land use, but they have also changed the atmospheric composition through biogeochemical cycles indirectly. Most scientists agree that the increasing concentration of greenhouse gases together with the resulting climate change influence ecosystem patterns and types, which, at the same time, affects the physical processes of the landscape in return. Forecasts show that climate-induced changes significantly disturb landscape function by modifying biotic-abiotic interactions. However, it is still a question whether the magnitude of this climate-induced modification exceeds the high natural variability of a given landscape.

Our previous studies (Bárány Kevei 1998) were already complex researches of the karstecosystem. Investigating the relationship of microclimate, soil, vegetation and microbial activity became more and more significant. Karstic soils (rendzina and brown woodland soil) as well as xerophilic and thermophilic vegetation (karstic scrub woodlands and oak forests) influence the quantitative and qualitative characteristics of the karstic dissolution mechanism. Morphological characteristics are affected by soil microorganisms which, by decomposing soil organic matter, produce CO_2 and increase the carbonic acid content of the solvent water, hence these microorganisms are ecosystem engineers. Both indirect (microclimate, soil, etc.) and direct effects are important in biological weathering (root acids) (Jakucs 1980; Bárány Kevei 1998; Phillips 2016). Corals directly influence morphological development as they build coral reefs and barriers (by colonies of tiny corals and a photosynthetic alga species). Reverse interaction and adaptation can also occur, when the internal bio-energies of an ecosystem influence geomorphological processes, and biotic components are affected by them. An example of this mechanism is the destruction of the calcium carbonate structures secreted by corals when any of their essential life conditions (clean water, a minimum temperature of 20°C, high salinity and solar radiation) changes, and, as a result, the building of the carbonate structure stops. There are examples of such interactions (co-evolution) when changes are caused by biogeomorphological interactions existing between living organisms and morphological structures. In karstic regions, this feedback is mainly present as an interaction (calcite deposition is an abiotic process, but carbonate rocks mainly result from biotic processes). Although the dissolution of calcite minerals is not of biotic origin, biogenic CO_2 in the soil atmosphere speeds up the dissolution of minerals indirectly and significantly. We are also aware of negative feedback on karsts, for example, when ecosystem engineers, through their own internal processes (i.e. genetic engineering) and niche construction, have a negative effect on those organisms which take part in an anyway positive feedback (Estrada Medina et al. 2013). Karst dissolution dynamics are mostly characterized by a local positive feedback that was created by ecological filtration, but, at the same time, an increase in the catchment basin decreases the effect of the positive feedback (Watts et al. 2014). Biogeomorphological feedback also has a significant role in the spatial pattern of the depressions in karst regions (dolines), due to which effect the depression pattern is usually not random in the catchment area (Bárány Kevei et al. 2015).

The study of ecosystem services gained more publicity in the past one and a half decades due to the fact that various environmental activities significantly changed landscape values. It is becoming more and more obvious that the research of a system can only be realized with a holistic attitude (Goldscheider 2012), because the components and the processes of a system function closely interrelated in a karst region.

Previous research already signified those effects which are likely to alter the development and function of karst regions having high aesthetic, land use and recreational values in the long run. Such alterations include the temporal and spatial changes of atmospheric and soil CO_2 amount, which, in turn, may accelerate climate change. Global warming may cause qualitative changes in the valuable as well as vulnerable ecosystem. These processes are also connected to strong biogeomorphological feedbacks in karst regions at the same time, which have been rarely mentioned in research literature so far. In addition, the water storage and potable water supply functions of karsts may also become endangered with increasing temperature in the future, which also makes it important to carry out research into this direction (Pfeffer 2009).

As indicated above, the study of landscape functions and feedbacks is not possible without knowing about human activities. The dynamics of the karst ecosystem and landscape are characterized by interaction. The magnitude and the type of ecosystems are controlled by the abiotic environment in this interaction (Reinhardt et al. 2010). There is a greater and greater consent that the ecosystem pattern (Trájer et al. 2016) and the type of karst regions are also affected by the growing concentration of greenhouse gases together with climate change.

3. Ecosystem services in karst regions

Assessment of ecosystem or environmental services is one of the most dynamically developing field of system-approach landscape research. It refers to the assessment of natural and landscape conditions which are used by people either directly or indirectly. This definition and its methodology became one of the central challenges of international environmental politics in the past few years. In 2001, an intergovernmental body was created to protect biodiversity and ecosystem services (IPBES – Intergovernmental Platform on Biodiversity and Ecosystem Services). It is also an important issue in international scientific circles. According to the simplest definition, ecosystem services include the recording of environmental functions that can be made use of by people, and completing the structure → function relationships with assessments. The assessment methods used in the decision-making process of employing ecosystem services in the landscape planning process are the same as those used in functional landscape analysis, geoecological mapping, and landscape potential estimation as well as the financial value of landscape potential. The assessment of ecosystem services is needed in order to improve human life quality. The aims of research are the same as the aims of landscape ecological research, its method is model construction.

The relationship of biodiversity and ecosystem services is complex – the anthropocentric view of ecosystem services concept is connected to biodiversity protection and natural conservation goals on the specialized policy level too. From the theoretical point of view, the ecosystems services are also strongly connected to the indicators characterizing the different levels of biodiversity. These connections may vary from ecosystem service to ecosystem service, and one must also take it into account that biodiversity has lots of other attributes besides species diversity (for example, functional diversity, succession phases, etc.), all of which have different relationship with the various services. For example, karst geodiversity including the aesthetic of its unique morphological features is connected to community level attributes, according to previous experience (Harrison et al. 2014).

Geodiversity is a must to maintain biodiversity. It has an exceptionally great significance in karstecological systems. At the same time, certain ecosystem types may show opposite tendencies concerning certain services. As for carbon sequestration, the bigger biomass production of the homogeneous stands of certain fast-growing plant species have, the better they capture and store CO_2 than the potential vegetation of an area with more diverse plant species. What kind of patterns, tendencies may appear in the amount of provided ecosystem services due to the vegetation of a karst region having diversified morphology, great geodiversity, all of which due to biogeomorphological feedbacks? Maintaining landscape potentials and ecosystem services is based on geodiversity that originates in the special surface and subsurface geomorphology of this landscape type.

The holistic approach, i.e. taking into account the role of biotic and abiotic landscape-forming components, is the basic condition of the assessment of ecosystem services, of the proper application of methodology. An important step in this research direction was that both the Millenium Ecosystem Assessment and the UK NEA state that geodiversity contributes to providing ecosystem services. However, the details of this statement were not included systematically in the assessment structure (Gray 2012; Gray et al. 2013). At the same time, the more special policy support of ecosystem services may also help protecting the interests of geological and biodiversity conservation. It is an important professional task in the near future both on theoretical and practical level, as the local and global elements of landscape change (land use change, climate change, hydrological processes, etc.) are significant degrading sources of typical geomorphological features, soils and other abiotic landscape forming components (Gordon – Barron 2013).

An interesting theoretical component of ecosystem services is that ecosystems are service providing units on the biotic services level when we speak about maintaining ecosystem services. However, ecosystems are service providing units on the abiotic level due to biogeomorphological feedbacks, which has gained less interest so far in the interrelationships of ecosystems, their functions and services. Previous studies already mentioned the service of maintaining habitats and breeding places when classifying ecosystem services (for example, CICES 2.3.1.2: Habitats for plant and animal nursery and reproduction e.g. seagrasses, microstructures of rivers etc. – Haines-Young – Potschin 2013). Biogenic processes have a central role in landforming and its dynamics as well as providing other services in karst regions.

Our previous research analyzed the qualitative changes of karstic lakes with a special focus on habitat function (fish population) on the Gömör-Torna Karst

Region between 2008 and 2010 (Samu et al. 2013). The water quality degradation of karst regions is a great environmental risk due to the sensitivity of these areas. Lakes have a central role in providing lots of services, for example, they maintain the equilibrium of lake ecosystems (which is a regulating service). The infill of karstic lakes decreases the diversity and the aesthetic value of the landscape. Therefore, we sought to determine to what extent sensitivity is affected by different variables in a multi-variable system (Kevei Bárány et al. 2012). Our analyses showed that the living organisms of karstic lakes are the most vulnerable to acidity and water temperature. Among all starting independent variables, climate parameters (air temperature, first of all) are determinant in maintaining the equilibrium of the ecosystem (Tanács 2011).

The infill of karstic lakes resulting from water degradation and organic matter enrichment is a negative biogeomorphological feedback. The results of previous studies indicated that this anthropogenic ecological process has negative effects both on maintaining services (for example, ecosystem status indicator) and cultural services (recreation potential, aesthetic value originating from landscape heterogeneity).

Another significant biogeomorphological function of karst regions is influencing the level of atmospheric CO_2. CO_2 already plays an important role in rock formation as a significant amount of CO_2 was bound when limestone was formed. When limestone dissolves, karst water contains additional, equilibrium and aggressive CO_2, of which amount adds to the amount of CO_2 already present in the atmosphere when CO_2 leaves karstic water during dripstone formation or surface travertine formation. It is a negative feedback concerning the composition of the atmosphere. If the process happens with the help of the vegetation (during the CO_2 absorption of photosynthesizing plants), then it is a positive biogeomorphological feedback from the karstmorphological point of view, because the resulting formations increase the aesthetic value of karsts. Goldscheider (2012) connected the vulnerability of karsts to inadequate land use; where soil erosion enhances, soil will be transported away from karstic rocks, and the rocks undergo desertification. Soil erosion results in decreasing agricultural production, which also means the degradation of the vegetation causing further soil erosion. This process results in decreasing biological activity, photosynthesis also declines together with carbon fixation (Fig. 1). Though, it should be mentioned that soil erosion is interconnected with land use changes and recent land use changes are absolutely different in developing, overpopulated, tropical karsts (e.g. China) than in “developed”, depopulating, temperate karsts (e.g. most of European karsts) (Zhang et al. 2003; Telbisz et al. 2015).

If the positive biological feedback, which is positive from the aspect of global atmospheric processes, ceases to exist due to land use, then a negative feedback will prevail. The carbon fixation ability of different types of karstic forests in the Aggtelek study area was analyzed in stands which could be characterized with a great variety of species based on the morphological and pedological characteristics of the area. According to the vegetation mapping, the study area (Tanács et al. 2010) is characterized by thermophilous oak forests, turkey oak-sessile oak forests, oak-hornbeam forests (sessile oak-hornbeam forests, oak-hornbeam forests, mixed sessile oak forests), beech forests (hornbeam-beech forests, beech-hornbeam forests, mixed beech forests, beech forests without hornbeams), beech-sessile oak forests, linden scree forests, ash scree forests, aspen forests, and birch forests. We calculated the carbon fixation ability of the different types of forests with the help of a model based on tree stands structural data. The tendencies found in the study area reflect the habitat differences of the karstic region having varying relief (Tanács – Barta 2014). Birch forests had the greatest amount of biomass and carbon, oak forests were characterized by a mean amount,

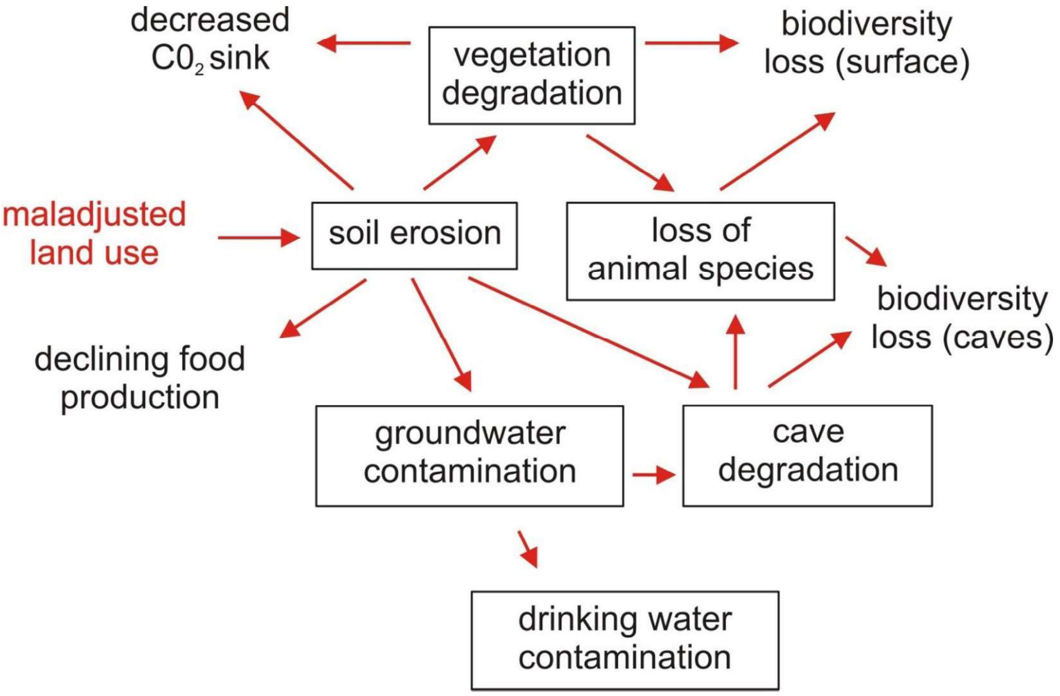

Fig. 1. Exemplified illustration of interconnected vulnerabilities and impact pathways damaging a karst ecosystem and reducing its natural values and ecosystem services (Goldscheider 2012)

while dry oak forests had the smallest carbon fixation potential. Carbon fixation during photosynthesis is indicated by biomass increase, which results in intensifying karst corrosion, a long-term effect that is a positive biogeomorphological feedback. High-density climax forests with great biomass production have the most favourable carbon fixation ability. Due to their morphological and pedological variety, forests in karst areas can often be characterized with smaller biomass production. For this reason, the geodiversity and the biogeomorphological processes of karst regions may also result in the decrease of this service (carbon fixation).

4. Conclusion and further plans

Based on the relationships between the diversity of ecological systems and ecosystem services, it can be stated that those natural systems which have greater biodiversity are more stable, so they also provide a greater amount of services. However, biodiversity in many cases implies geodiversity. Based on the results obtained in karstecological systems, we may ask what kind of patterns, tendencies are the results of the biodiversity of karstic vegetation, where the karst area shows morphological variety due to biogeomorphological feedbacks, in the magnitude of ecosystem services. Changes in the status of a karstecological system occur integrated, and they are closely interrelated to the components. Degradation or an alteration in any element of the water system beneath the vegetation-soil-surface influences the other components of the system. Therefore, sustaining the biodiversity of karst regions is closely related to adequate land use and the protection of karst water. The relationship between biodiversity and ecosystem services is complex in this landscape type too. Karst surfaces with varying relief have a greater extent of such forest associations which characterize karstic slopes, and of which carbon fixation ability may be smaller, than of such climax forest communities that may theoretically appear as characteristic of that climate zone. A further interesting research direction may be how the forestation of dolines influences different ecosystem services. Forestation is a natural succession process in this case, but environment preservational land use practice stops forestation by grazing and mowing (in order to maintain grass associations). Also, future research may aim at studying how different surface covering patterns influence the water flow rate of karst springs and streams, and what kind of quantitative relationship exists between heavy metal contamination and potable water quality as well as potable water providing service.

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