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The analyze of relationship between microclimate and microbial carbon-dioxide production in the soils of the Tapolca and Gömör-Tornai karst terrains, Hungary

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Abstract

In the karst areas, the epikarst system is a very sensitive environment, due to its position at the interface between soil and vadose zone. The epikarst is a weathered zone that develops as a re-sult of both abiotic and biotic process-es. In this paper we present the result of the complex investigations of epikarst zone which overlap dolines within two typical karst areas (Gömör-Torna and Tapolca) from Hungary, based on multi-criteria analysis tech-niques (microbiological activity as-sessed as biomass amount and CO2 production, seasonality of air and soil microclimate, slope orientation and exposition), in order to reveal control factors of karst processes, the territori-al and local distinctions of karst disso-lution that occur in the epikarst zone. The data were compared, taking into account the human activities' impact on both sampled study areas. After four years of monitoring, the results show that there are significant season-al and diurnal variations of physical, chemical and biotic parameters of soil that cover and affect the epikarst zone. Spatial variations of these parameters were recorded as well.

Keywords: *epikarst, microclimate, soil, CO_2 pro-duction,, karst corrosion*

Rezumat. Analiza relației dintre microclimat și producția microbială de dioxid de carbon din sol în zonele carstice Ta-polca și Gömör-Tornai, Ungaria

În cadrul zonelor carstice, sistemul epicarstului este un mediu complex și senzitiv care se dezvoltă ca interfață între profilul de sol și zona vadoasă. Epicarstul este o zonă de alterare/meteorizare a rocilor carbonatice formată prin procese abiotice și abiotice. În această lucrare sunt prezentate rezultatele unei investigații complexe care a avut loc în epicarstul ce corespunde dolinelor din cadrul a două regiuni carstice (Gömör-Torna și Tapolca) din Ungaria folosind tehnici de analiză multicriterială în vederea identificării factorilor de control a proceselor carstice precum și pentru a determina diferențieri teritoriale și sezoniere ale proceselor de disoluție specifice epicarstului. Datele obținute au fost comparate luând în considerare gradul de impact antropic din cele două zone carstice eșantionate. După patru ani de măsurători și observații, rezultatele obținute indică existența variațiilor sezoniere, diurne și spațiale semnificative ale parametrilor fizici, chimici și biologici ai învelișului de sol care acoperă și influențează epicarstul din zonele carstice studiate.

Cuvinte-cheie: *epicarst, microclimat, sol, producția de CO_2, coroziunea carstului*

Introduction

The epikarst system is an extremely complex and sensitive environment which acts as a transition zone between the topographic surface or soil cover and the vadose zone of the karst landscapes. Initially, the term epikarst, coined by Mangin (1973), was defined as the upper aquifer of the vadose zone. Ac-cording to Williams (1983), the epikarst is the "sub-cutaneous zone", namely, the upper weathered layer of rock beneath the soil but above the permanently phreatic zone that acquires a secondary permeability, due to significant chemical solution. In fact, the term "subcutaneous zone" is an English adaptation of several French synonym terms (sub-superficial, sub-epidermic, karst cutane) which were consecrat-ed by the French geographers, (Ciry 1959, Birot 1966, Bakalovicz, 2014) in the middle of the twentieth cen-tury.

At the beginning of the 21st century, Bakalovicz (2014) stated that epikarst is the "skin" of karst and the soil should be considered as entirely part of it. Therefore, contrary to opinion of Williams (1983), the "epikarst can be easily defined by its hydrologic functioning, rather than by a set of landforms", the epikarst is where water storage takes place. There are a multitude of factors that act to the epikarst for-mation, abiotic and biotic (Mangin, 1973; Jakucs, 1980; Bárány, 1998; Klimchouk, 2004), but it is stated that the epikarst zone develops the best in pure crys-talline limestone or marble where it can reach a thickness of 10 m (Williams, 2008). However, the most comprehensive definition of the epikarst was proposed during the Karst Water Institute, in 2003 (Jones, et al., 2004; Jones, 2013).

Carbon dioxide is a key chemical that drives dissolution in the carbonate karst areas. The main source of carbon dioxide from karst systems is the soil which formed on the carbonate terrains (Ford & Williams, 2007). The principal amount of carbon dioxide from soil is biogenic (Faimon et al., 2012). It is produced by the respiration of soil biota, both autotrophs and heterotrophs (Kuzyakov & Larionova, 2005; Kuzyakov, 2006; Song et al., 2017), but its production may depend on several factors, such as temperature and soil moisture, soil profile depth, soil structure, organic matter content, availability of soil nutrient, total rainfall, solar radiation and photosynthesis, but also various anthropogenic factors, such as soil tillage, or artificial change in vegetation cover (Dijkstra et al., 2013; Blecha & Faimon, 2014). Also, there is a seasonal variation of CO_2 concentrations, the highest values are in summer and lower values occur in autumn/winter (Faimon et al., 2012).

The production of CO_2, as a quantitative measure of the microbial activity of soil, is used since the mid-nineteenth century, but the measurement of microorganism respiration have to be correlated with other parameters of microbial activity, such as organic matter content, nitrogen and phosphorus transformations, pH, changes in soil weight (Stotzky, 1965). Since then, various methods have been developed in order to quantify accurately the microbial soil activity (Stotzky, 1965; Bauer et al., 1991; Solaim-an, 2007; Creamer et al., 2014; Pal & Marschner, 2016).

In Hungary, studies on karst soils and epikarst, including microbial activity, have been performed by Keveiné & Zámbó (1986), Zámbó (1998), Zámbó & Telbisz (2000), Zámbó & Ford (2003), Szili-Kovács & Török (2005), Szili-Kovács et al. 2009, Keveiné Bárány (2009), Knáb et al. 2010,2012.

Materials and Methods

In each study, karst areas were chosen dolines as characteristic sites for in situ measurements and soil sampling (Fig. 1).

Figure 1: Field measurements at Tapolca karst area. In the back ground there are basalt-capped buttes

Within the Gömör-Torna karst, the sites for surveying were located in three division of it: the Aggtelek Plateau, Alsó-hegy and Szilice Plateau (Fig. 2).

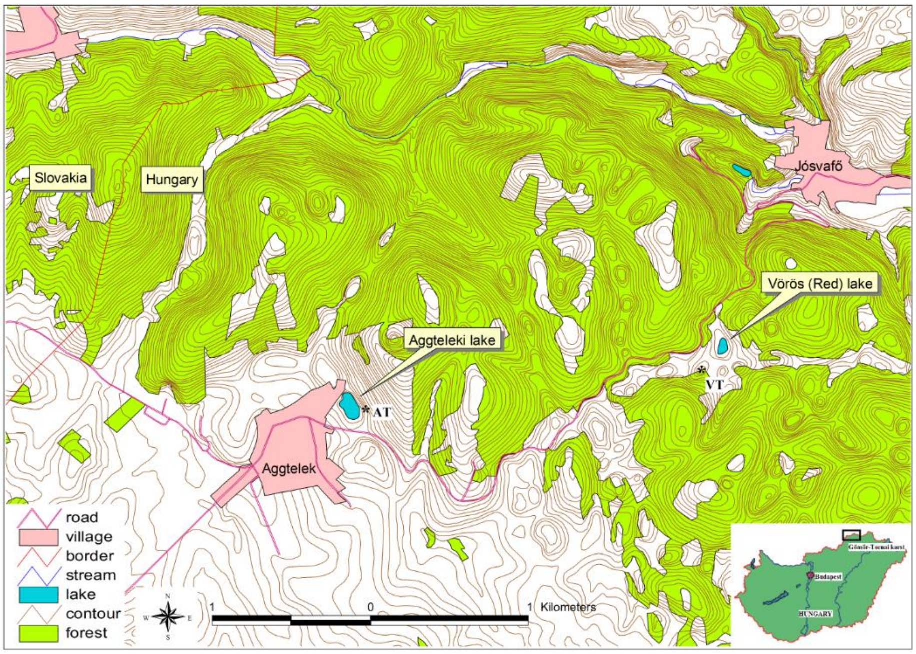

Figure 2: The locations of the measurement points in the area of Aggtelek Plateau: AT- Lake Aggtelek, VT – Lake Red (Vörös)

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The first one (AT) was established close to Lake Ag-gtelek, formed in a former doline and located in the western part of the karst plateau (Fig. 3). For the second one (VT) a doline was chosen, close to Lake Vörös ("lake red").

Figure 3: Lake Aggtelek (AT), one of the se-lected measurement points from Ag-gtelek Plat-eau

Then, the next soil sampling and microbiological surveys were carried out in dolines that are next to the Béke Cave (BT), an environment without the disruptive effects of human activities. The fourth site was established close to Lake Derenki (DT), in Alsó-hegy, a semi natural area, both with barren and covered karst.

The last site was located in the vicinity of Szilice village (Szilice-Plateau, Slovakia), on a downhill, next to Lake Papverme (PvT).

There were also five sampling sites in the Tapolca karst terrain. They were distributed in the middle part of Tapolca karst, along the line that links the small lakes that are supplied by karstic springs and precip-itations (Fig. 4): Lake Pokol (PoT), Alsó-Cser (ACsT), Zalahaláp doline (TA), Felső-Cser (FCsT), the doline at the forest margin (VAD), and illegal waste deposit (IH).

For each study site, soil profiles were made and examined, in order to describe and identify the soil types. Soil samples were taken for chemical and min-eralogical analyses.

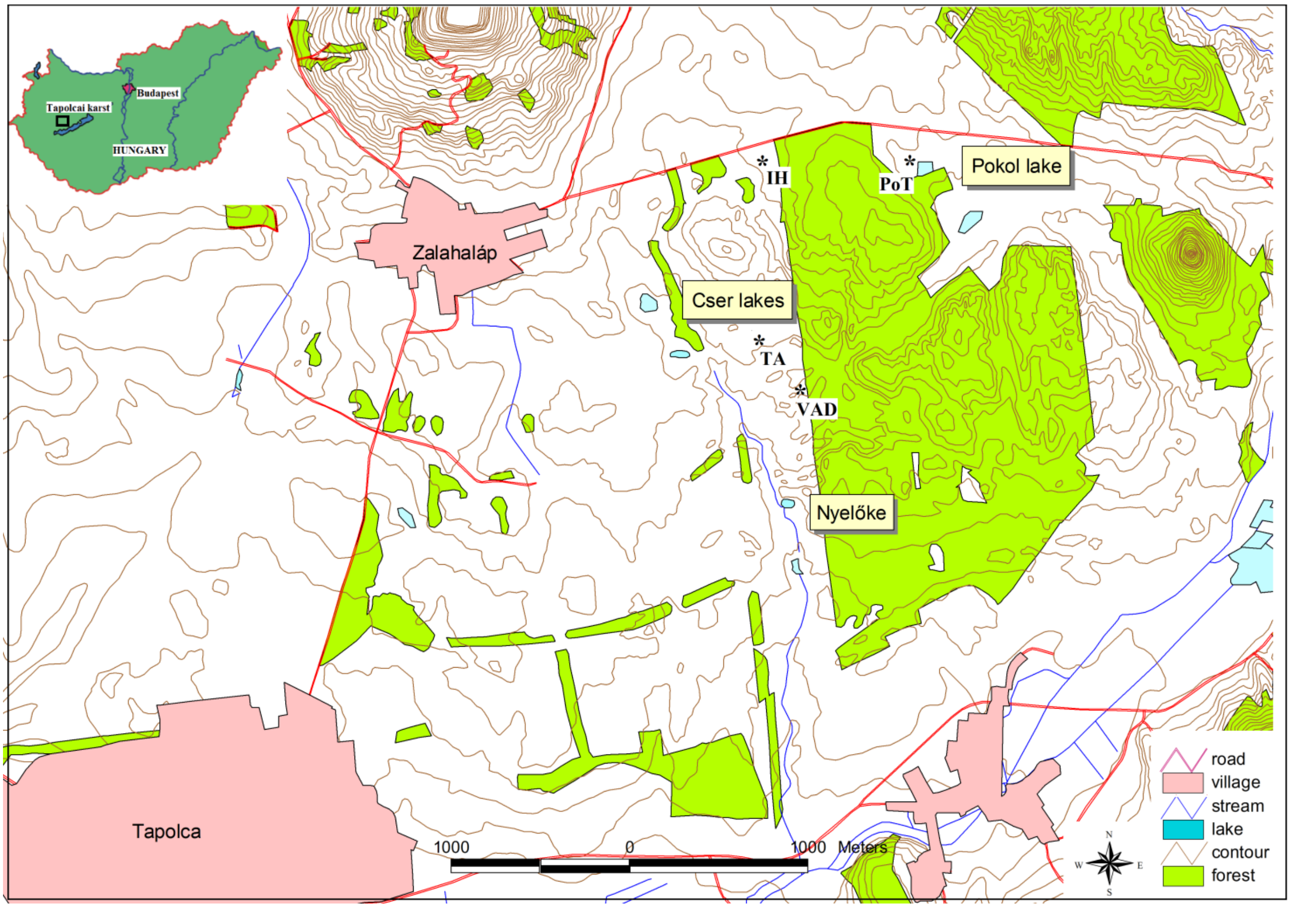

Figure 4: The locations of the measurement points in the Tapolca karst area: IH – Illegal garbage deposite, TA – Tapolca (Zalaháláp) doline, PoT – Hell (Pokol) lake, VAD – Dolines at the forest margin

Then, rain-stimulated experiments were set up on the soil monoliths. The soil solution was collected, in order to measure pH, carbonate and hydro carbonate content. The determination of the water samples' bicarbonate content was accomplished according to the valid Hungarian Standards Institution (MSZT 448-11: 1986). Microbiological parameters of soil solution were analyzed for the characterization of microbial-influenced karst corrosion.

In situ measurement data for the characterization of microclimate were recorded by a mobile weather station every two hours: air temperature (at 0, 20 and 100 cm high above ground), the relative moisture of air, the evaporation at 20 and 100 cm above ground, wind speed and wind direction every two hours. Soil temperature, soil pH and carbon dioxide concentration were also measured.

Soil temperature was recorded by a conventional mercury soil thermometer, 0.1 °C accuracy Pt, at 5 and 20 cm deep. The soil moisture content was determined with the help of an Eijkelkamp 14.22 Soil Moisture Measuring System with Gypsum Blocks meter, while the pH of soil and soil solution was measured by a Hanna pH meter.

The measurement of the carbon-dioxide concentration of the soil air, which reveals microbial respiration, has been achieved with the help of Gastec Model GV-100 car-bon-dioxide pump, which contains 2L and 2LL-type sampling tubes/pipes, side by side/in parallel with the microclimate measurements, in the same locations.

In every doline that was selected as a sampling site, observations and measurements were made and samples were taken from the north side, south side and bottom to find out the effect of exposure. The measurements were accomplished through 2 hour-long intervals for a whole day, in different seasons. The applied method was convenient for the demonstration of the differences between locations, between the diverse depths along the soil profiles, and between the daily dynamics and seasonal distinctions.

In this way, connections were searched between the microclimatic phenomena and the values/rates of soil climate (temperature and moisture of the soil, pH, carbon-dioxide concentration), to identify the spatial distinctions, diurnal and seasonal changes.

Samples for microbiological investigation were cultivated onto three different culture media, and colonies with various morphology were isolated. After isolating community DNA from the soil samples, clone libraries were constructed. The phylogenetic identification of the bacterial strains and molecular clones was based on the 16S rRNA gene sequence analysis.

In karst soils and in cover sediments the sampling was carried out partly by drilling holes, and partly by the extraction of large ground monoliths combined with rainfall simulation tests. The physicochemical (grain composition, pH, humus and carbonate content, etc.) and microbiological parameters of the soil solution which percolates through the ground monoliths were compared. Measurements were carried out and assessed according to the appropriate procedures of the MSZT (Hungarian Standards Institution).

This paper presents the partial result of the complex investigations of epikarst zone which overlap dolines within two typical karst areas (Gömör-Tornai and Tapolca) from Hungary based on multi-criteria analysis techniques.

Results and Discussions

Study Areas

Our studies were performed within two different karst regions, in terms of natural environment characteristics and the degree of anthropogenic impacts: Gömör-Torna karst system and Tapolca karst system. The aim was to compare the developmental karst processes between the two areas, according to the local natural factors and anthropogenic impacts.

The Gömör-Torna karst area is located in north-eastern Hungary, along the Hungarian-Slovakian border, between the Sajȯ and Bȯdva rivers. The sites for measurements and sampling tests were selected in Aggtelek Plateau – a subunit of the Gömör -Torna karst area and part of the Aggtelek National Park (which was designed as UNESCO World Heritage) – and Alsȯ-hegy ("Lower Mountain"). Within the Aggtelek National Park over 250 caves were inventoried, including the 26 km-long Baradla-Domica cave system, a cross-border cave that is famous for its outstanding speleothems.

The Aggtelek Karst consists of mainly Middle Triassic limestones (Veress & Unger, 2015). On the surface of the plateau the perceive karst features are dolines and sinkholes. Several doline lakes, blind valleys and dry valleys with a series of dolines complement the karst landscape.

In the area, the climate is humid continental with a long summer and a strong mountainous influence (Tanács, 2011). The average mean annual air tempera-ture values vary between 8.5°C and 9.1°C, and the air humidity is between 90%. The amount of annual precipitation is around 620 mm (Tanács, 2011). Natu-ral vegetation consists of forests. Dry oak-forests cover the limestone ridges of the karst plateau. Dominant species are the sessile oaks (Quercus petraea (Matt.) Liebl.), followed by the Turkey oak (Quercus cerris L.), field maple (Acer campestre L.), hornbeam (Carpinus betulus L.), and common ash (Fraxinus excelsior L.) (Kotroczó, et al., 2007). Beech stands (Fagus sylvatica L.) occur in the hollows and deeper valleys. The presence of the black pine (Pinus nigra J.F. Arnold) is probably the result of plantation

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works from the beginning of the 20th century (Tanács, Szmorad, & Bárány-Kevei, 2007).

Studies on chemical composition and soil taxonomy from Gömör-Torna karst terrains started in the second half of the 20th century (Zámbó, 1986, 1998; Zámbó-Telbisz, 2000). Following Bridges's (1978) and Stefanovits's (1981) methods, alongside with other particular in situ and laboratory tests, the prevalent soils that were described are rendzina and red-earth soils (Zámbó, 1986, 1998; Zámbó-Telbisz, 2000).

Later, based on the results of studies, regarding the correlation between three species composition of forests and soil proprieties from Haragistya-Lófej forest reserve and Szilice Plateau (Tanács-Barta, 2006; Tanács, et al., 2007), subtype soils were dis-criminated according to the World Reference Base for Soil Resources (Barta, et al., 2009), which was a similar approach to classification from the Slovakian part of Gömör-Torna karst terrain (Rozložnik-Karasová, 1993). Mineral types and content analysis of soils from this region are given by Knauerné (1992) and Fekete et al. (2006, 2008).

Compared to the Gömör-Torna karst, Tapolca karst area is only a small region. It is located in the western part of the Transdanubian Mountains, be-tween Balaton Uplands and Keszthely Mountains. The Tapolca karst system coincides in part with a sedimentary basin, mainly made up of quasi-horizontal Sarmatian limestone strata that are called Tinnyei Formation (Budai, et. al., 1999). It is com-posed of various clayey and calcareous layers, thus water permeable and impermeable layers are altering in it. Pleistocene-Holocene alluvial-diluvial sandy and clayey deposits superimpose Sarmatian limestone discontinuously. Consequently, patches of open karst alternate with covered karst, leading to a mosaic-like pattern of Tapolca karst terrain.

The Sarmatian limestone that generated the nowadays general topographic surface with 120-160 m elevations is underlaid with Main Dolomite For-mation and Sédvölgyi Dolomite Formation (Budai, et al., 1999). In the northern part of the Tapolca basin, dolomite formations outcrop as inselbergs above the surrounding area that has 120-160 m altitude. Therefore, this area, which displays remnants of Cretaceous cone karst peneplain, is the most diversified morphological part of the Tapolca karst area, where both paleokarst and recent landforms occur equally (Büki, et al. 2011).

Small and shallow dolines have been developed mostly on the brink of dolomite and Sarmatian limestone which explains why they are arranged in rows in some places and others through merger evolved into uvalas (Futó, 2003). Many fossilized dolines, formed during a tropical climate, are filled with red clay and bauxite.

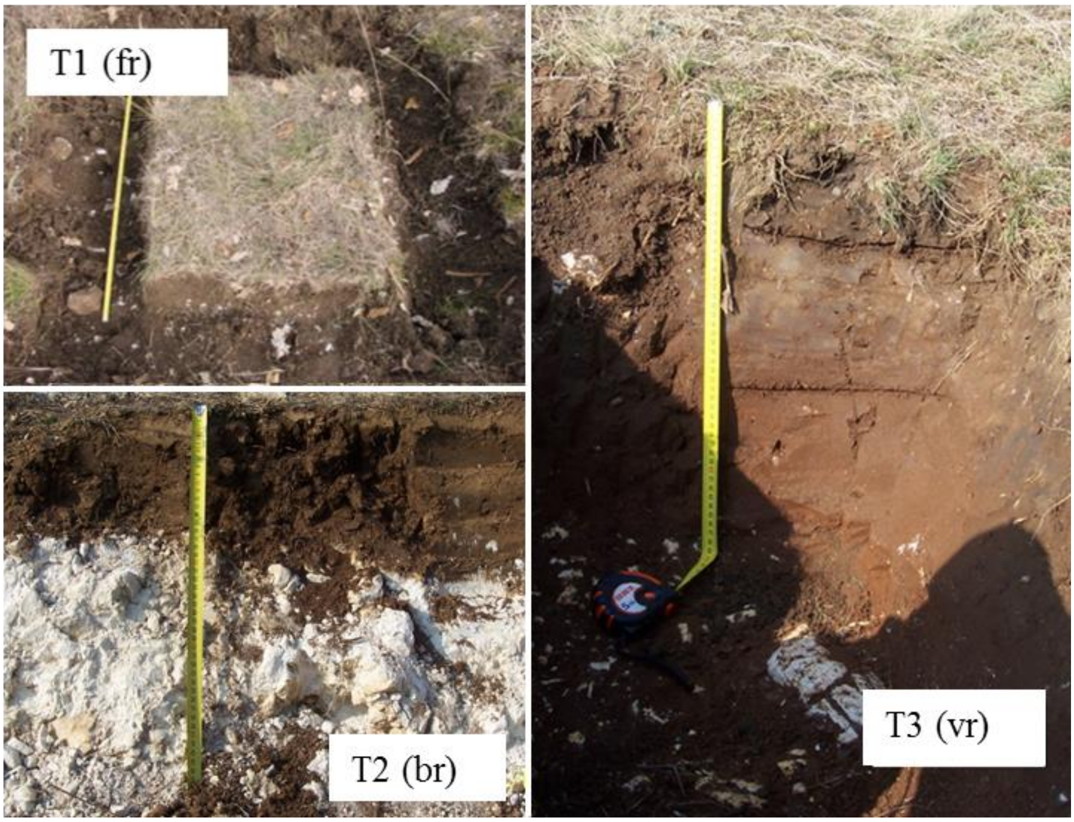

Figure 5: Soil profiles on the Tapolca-karst. T1 (fr) - black rendzina, T2 (br) - brown rendzina, T3 (vr) - red clay rendzina

In the porous-structured limestone field, the level of karst water runs along close to the surface, during the whole year, which emerges to the surface when the water is high, feeding/supplying periodic karst springs.

Three periodic-watered lakes (Alsó, Felső-Cser, Névtelen) had been evolved close to Zalahaláp, in a karst hole, coated with watertight layers. In the northern side of the Tapolca-karst terrain, there is Lake Pokol (Hell). Its depression is incised on a basalt-bordering karst field and fed by a small stream dominantly during the rainy period of the year.

Regarding the soil types, there are no peculiar studies. According to the geological map and 1: 100.000 scaled Agrotopo-maps (www.mta-taki.hu), the soil cover from Tapolca karst terrain consists of rendzina types, leptosols and brown forest soils.

In the vicinity of Lake Cser, protosoils and weakly soiled sediments (Pannonian sand, sandy and pebbly lacustrine sediments) are dominant. Red-clay sediments with bauxite fill paleokarst recesses and dolines, whose bottoms are overlaid with colluvium (Móga, et al., 2011). Highly eroded soils and the rocky surface are significant in the area of flat terrains.

Soil profiles in the karst terrains

The results of mineral content and chemical characteristics of soils from the Tapolca Karst ter-rains were compared to those on the Aggtelek karst terrains (Knauerné, 1992). Three typical soil profiles (T1, T2, and T3) were analyzed from morphological and chemical point of view (Fig. 5). Therefore, the clay and loam fraction of the sample taken from three typical soil profiles (T1, T2, T3, Fig. 6) of dolines from Tapolca are similar to the soil profiles of Ag-gtelek. Also, these soils contain sand fractions in a few percent, due to Pannonian sediments which cover the surface in patches. Each tested soil sample had carbonate content in variable amounts. The hu-mus content was the highest (6.26%) in the black rendzina (T1), but this value is still behind the mini-mum rates of 7-8% that were recorded for rendzina subtypes in the Carpathian basin, according to Kiss records (2012). The pH values of all rendzina types are higher than 6.5 units, and their hydrolytic acidity is minimal. Hargitai's Q value of two rendzina types (T1, T2) is higher with two units than the red-clay soils' in Aggtelek (Knauerné, 1992). This fact shows the formation of humic substances (Buzás, 1998), which are related to the fields characteristics. There-fore, it can be explained with dissimilarity of the natural vegetation and the water type of the soil.

Based on the cluster analysis that included 52 rendzina profiles performed by Kiss (2012), the clas-sification of the soils of the Tapolca-karst terrain into rendzina types is not unambiguous. The mor-phological properties and weak structure of the pro-file (Fig. 6), the depth of soil, and the sand content of the samples gave an intermediary position (in the case of T1, T2) between the leptosol and rendzina soils, because the humus content is lower compared to the rendzina typical soil.

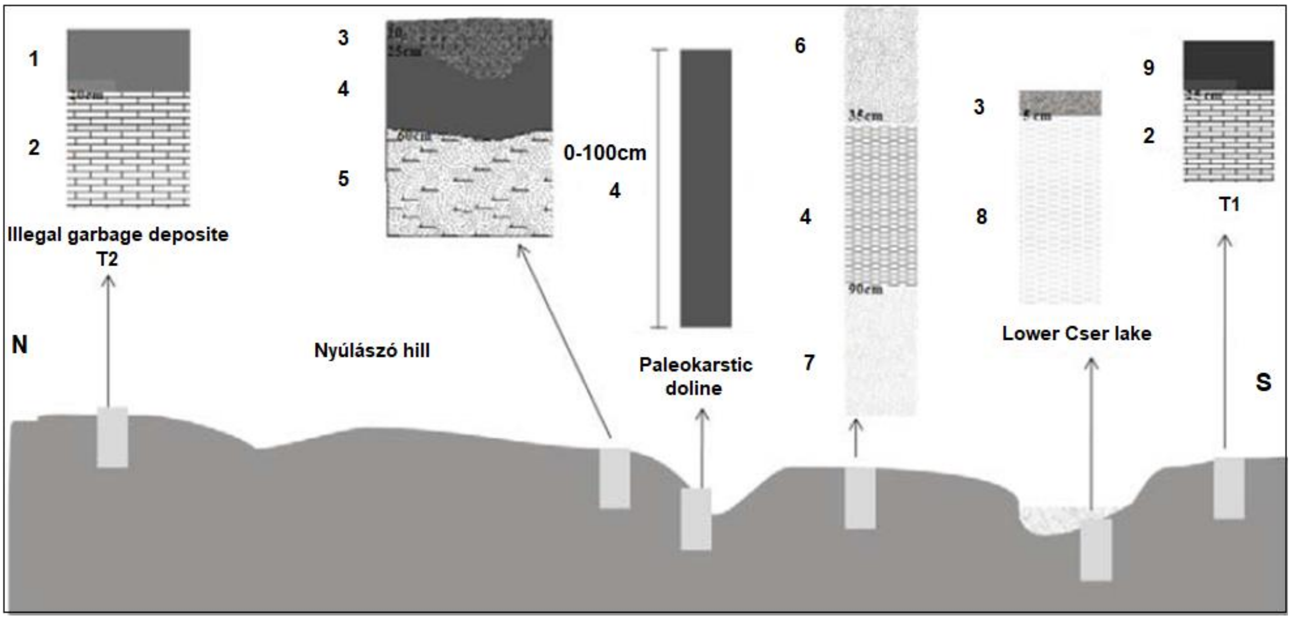

Figure 6: Theoretical N-S soil profile through the Tapolca karst terrain. T3 soil profile (which is not presented in this picture) is nearby T2 (See Fig. 5). 1- brown rendzina, 2 - limestone, 3 - humic level, 4 - red clay, 5 - coarse sand with high $CaCO_3$ content, 6 - doline infill red clay, 7 - weak humic sand, 8 - lake sediment, sandy clay, 9 - black rendzina

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The classification of the T3 soil is even more problematic: the color and clogging of C layer, the appearance of the clay membrane in the profile reflects the red clayey origin. However it has a low acidity (pH > 7 value) and, because of the carbonate content of the upper layer, present cli-mate, fills a part in the recent development of the soil (water balance processes), beside the effect of the ballast-rock (dolomite, layer D).

Microclimate of atmosphere, soil air and soil proprieties

Climatic and microclimatic factors are important drivers in the activity of soil biota and implicitly they are responsible for carbon dioxide production and its amount from soil air (Jakucs, 1971; Zámbó, 2001; Keveiné Bárány, 2009). Also, climate is a mor-phogenetic factor in the control of erosion processes and weathering of rocks, however, in the karst sys-tem it is an ecological factor which provides the dy-namism of karst development (Keveiné Bárány, 1998, 2009). On the dolines surfaces from karst areas and closed recesses microclimate areas evolve, especially where exposure has a significant role in the spatial and temporal changes of the energy that precede distinctions. All of these facts have an influence on the formation of air and soil temperature, the evolu-tion of local distinctions of soil moisture, the plant-cover of dolines, the microbial activity of the soil and finally, the formation of spatial differences in the karst corrosion processes of karst fields (Keveiné Bárány, 2009). Measurements performed within do-lines from both Tapolca and Gömör-Torna karst dur-ing 2009-2012 revealed that there are microclimate differences induced by the morphometry and mor-phology of dolines. It revealed a significant discrep-ancy in terms of diurnal air temperature and evapo-transpiration that is associated with the exposure of dolines.

Our simultaneously-accomplished measure-ments performed in sampled dolines from Tapolca, next to Lake Vörös, revealed the effect of the vegeta-tion coverage – rocky grassland versus forest – on the microclimate of the dolines. In contrast to the previ-ous site, the whole area of the Derenki dolines is covered by forest, which dimmed the distinction of temperature values among the measuring spots. Thus, during the summer, the results show that in the dolines, next to Lake Vörös, the highest air tem-perature (at 20 cm above ground) and the largest diurnal temperature fluctuations (amplitude) have been measured at the northern edge (VTE) of the dolines (i.e. on the side exposed to the south) that are covered by rocky-lawn. During a 24-hour day, air temperature ranged from 23 °C to 31°C. By the reason of the shadow effect, lower and much more moderate temperature values have been recorded at the bottom (VTA) and at the northern exposure stations (VTD) of the dolines. However, the two stations' values hardly differed from each other (21-25°C). Regarding the soil temperature, they were recorded similar var-iations depending on position and exposure of the sides of doline depressions. At 5 cm depth, the soil temperature was lower than the air temperature, as well as the amplitude (VTD: 19-20°C, VTE and VTA: 16-20°C) (Fig. 7).

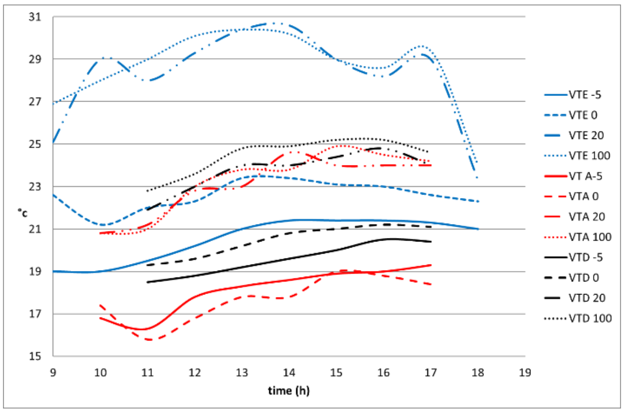

Figure 7: The temperature variation in the dolines above ground surface and with the depth of soil, located in the vicinity of Lake Vörös

In Derenki site (DT) from the Gömör-Torna karst terrain, the recorded air temperature values were lower (17-20, 5°C) at all three measuring stations (DTD, DTA, DTA), than those from Vörös doline site (VT). Soil temperature measured at 5 cm depth (17-19°C) was much closer to air temperature at all three stations (DTD, DTA, DTA) than in Vörös doline site, and showed a similar trend, next to the low air temperature values. It should be noticed that temperature values, air and soil, are slightly higher at the side dolines with southern exposure than those with northern exposure (Fig. 8).

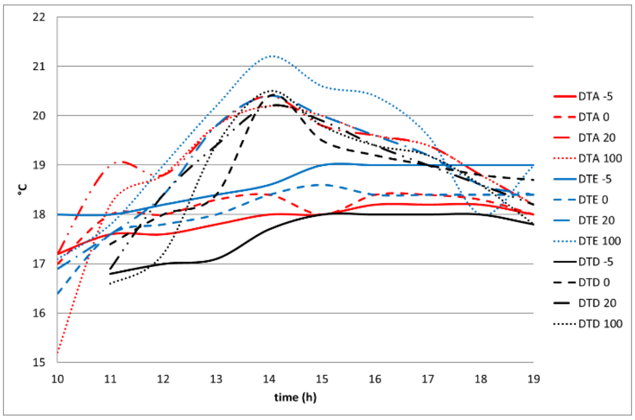

Figure 8: The diurnal temperature variation in Derenki dolines from from the Gömör-Torna karst terrain, NV Hungary

By comparing microclimate data recorded in Vörös doline site (VT), Tapolca karst terrain, with those in

Derenki site (DT), Gömör-Torna karst terrain, it is obvious that the elevation of the study are-as, the certain morphology of dolines, which consists of large-sized, flat bowl-shaped dolines in Derenki and the small, sheer-sided dolines, next to lake Vörös, along with the complexity of vegetation cover, play an important role in the development of dis-tinct microclimates, although it is difficult to identify which of the factors is defining for temperature-shifting.

The seasonal and diurnal changes of the carbon dioxide concentration in the soil air

Measurements of CO_2 content in soil air on study sites show a great variance between them, according to local microenvironment from each station and the depth at which the measurements were made. Overall, the recorded values, measured by a 2L-type pipe method, ranged from 100 ppm up to 30 000 ppm or 3%.

Within dolines from Vörös doline site (VT), the maximum values of the soil air's CO2 content (>3%) has been always measured on the bottom, at 20 cm depth in the soil (VTA) while the lowest values (1-2000 ppm) were recorded at 5 cm depth in the soil (Fig. 9).

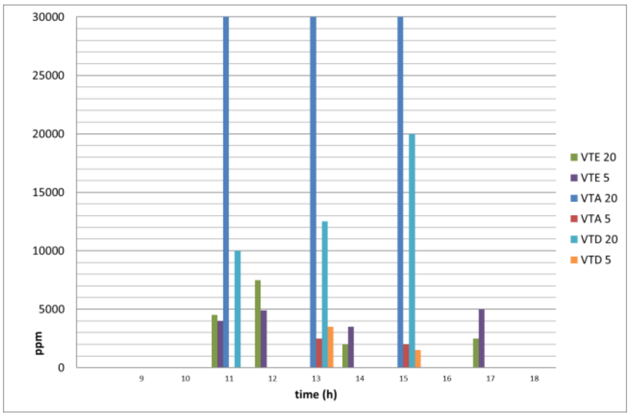

Figure 9: The change of the CO_2 concentration of soil air at the VT (Vörös doline) measuring spot

On the cooler, sloppy southern sides (VTD), similarly to the dolines bottom, the CO2 concentrations were above 10000 ppm (1%). The concentration values of CO2 soil air at Tapolca were similar to the dolines from Derenki site (DT), but were lower than those from Aggteleki karst terrain. The difference is supposedly caused by different physical soil characteristics and microbial activity (Fig. 10).

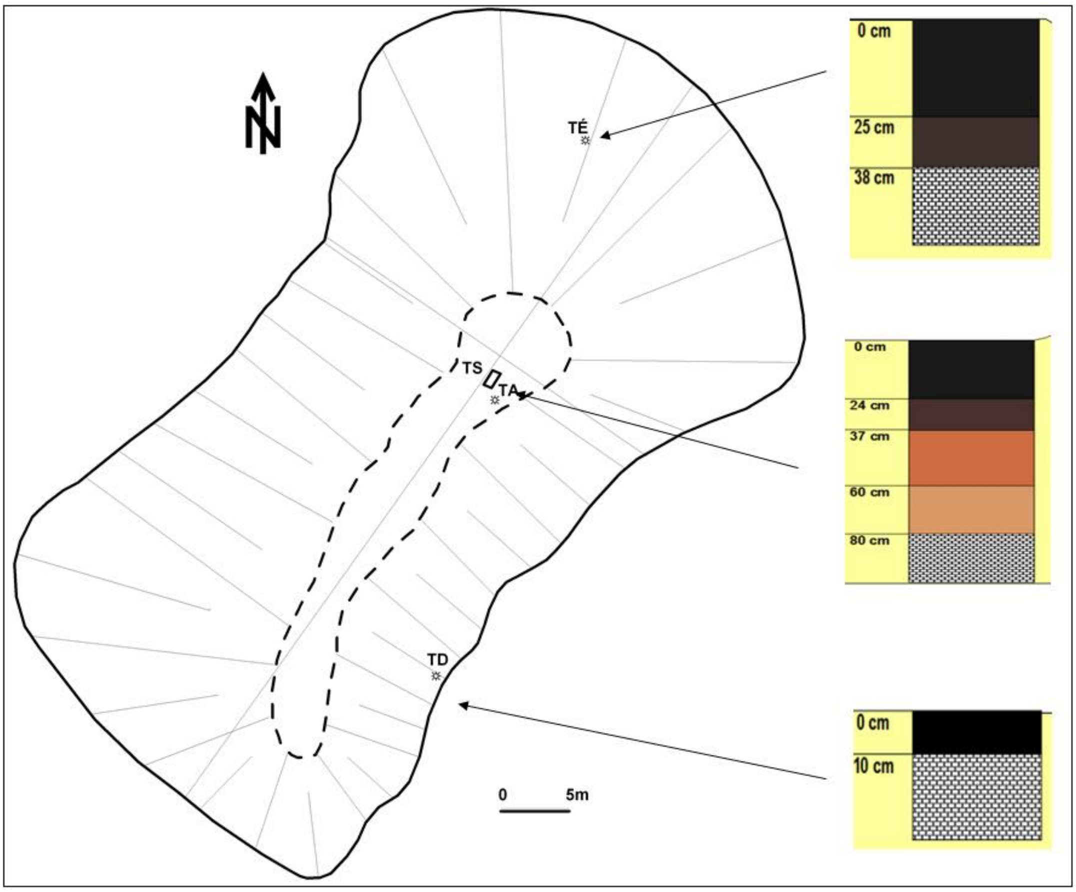

Figure 10: The sketch of a doline (Tapolca doline – TA) and location of measuring points - Tapolca karst area. For each point is illustrated the soil profile: TD – southern side of the doline, TS – soil profile in the bottom of doline, TÉ – northern side of doline

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At 80 cm depth in the soil from bottom dolines, carbon dioxide values ranged between 1-2%, which represent about half or two thirds of the values determined at 20 cm soil depth. Therefore, the gained results of the field measurements in both karst study areas are in good accordance with literature data (Jakucs, 1971; Zhang & Zhang, 1983) and they clearly certify that the carbon-dioxide production rate in the soil does not increase directly in proportion to the depth, but has a maximum value at the depth of 20-40 cm.

Seasonal measurement carried out in all study sites also validate that the CO2 concentration values show increasing tendency in the daytime, if there are no circumstantial disturbing factors, mainly weather extreme events. However, the highest carbon-dioxide concentration was recorded during late afternoon and evening. This tendency occurred more conspicuously in the case of carbon-dioxide measurements that were made at deeper levels of soil.

The analysis of the relationship between microclimate and microbial carbon-dioxide production in soil with field measurements

Due to the changing weather conditions of July 30, 2011 (high air temperature and sunny sky followed by a rain storm during the early afternoon) during the field trip in Tapolca karst area, it has been possible to investigate the relationship between quickly changing microclimate and CO2 concentration in soil air as a result of microbial activity. The hourly evolution of air temperature at three and soil temperature at three different above topographic surface and at 5 cm soil depth shows a direct correlation between increasing temperature and CO2 content in the first 5 cm of the topsoil (Fig. 11).

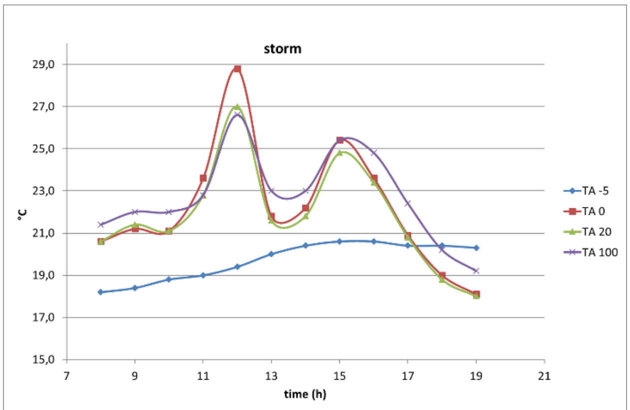

Figure 11: The diurnal variation of air and soil (blue line) temperature within the Tapolca doline (Zalahaláp) (TA)

The upward linear trend of CO_2 concentration lasted until the storm, and then it fell back during the rainstorm. After that, CO_2 concentration raised again due to of the influence of late afternoon warming which followed the rain episode. The values, measured in three different soil depth reveals that a disturbing effect of weather factors was detectable in the first 20 cm soil profile. As it can be seen in Figures 11 and 12, the effect of temperature decrease on microbial activity was experienced in the first 5 cm of the soil profile. Furthermore, the cooling effect of the rain on the soil which slowed down microbial activity was supplemented by the anoxic environment created by the replacement of air from soil pores with water and depletion of available oxy-gen for aerobic bacteria that are responsible for organic decomposition and main CO_2 producers.

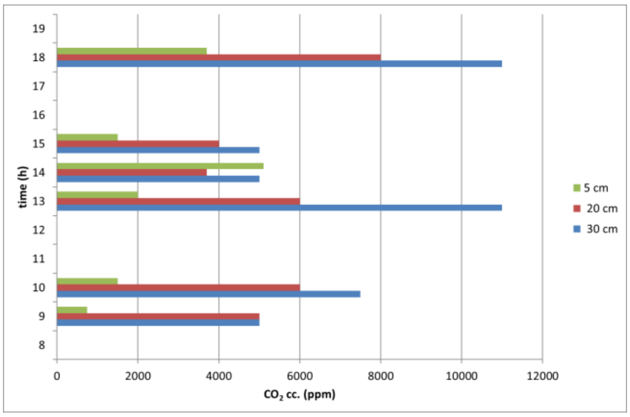

Figure 12: The change of the CO_2 concentration of soil air into TA doline during a summer rain storm

The results of microclimate and CO_2 measurements, performed in parallel, support the previously recognized fact that meteorological factors affect the microbial CO2 production from soil (Jakucs, 1971; Keveiné & Zámbó, 1986; Zámbó, 1998; Zámbó & Ford, 2003; Szili-Kovács & Török, 2005; Szili-Kovács, et al., 2009; Keveiné Bárány, 2009; Knáb, et al., 2010; Knáb, et al., 2012; Knáb, et al., 2018). The alteration of sunny, cloudy and rainy weather may result in significant temperature changes in the layers, close to the surface. Increase in air and soil is accompanied by the intensification of enzymatic activity of soil bacteria and simultaneously, the rate of carbon-dioxide production.

Although there is a great diversity of soil organisms (plant roots, alga, protozoa, invertebrates), whose breathing contributes to CO2 content of the soil atmosphere; their particular contribution is difficult to differentiate and quantify. Consequently, the assessment of the respiration of microorganism decomposing soil organic matter is a suitable method for determination of CO2 supply to soil.

The daily dynamics and depth dependence of the carbon-dioxide concentration from soil air

The measurements carbon dioxide content of soil atmosphere within a brown forest soil about 80 cm thick that has developed on the bottom of a dolines from Tapolca confirms the results of previous examinations. There is an increasing trend of the Carbon dioxide concentration in the topsoil and then, gradually, the organic matter content is diminishing along with all physical and chemical soil proprieties. Thus, in the tested soil profile, from the topographic surface towards the subsoil evolution (Fig. 13), the carbon-dioxide concentration of soil atmosphere shows an increase from 6000 ppm at 5 cm depth to 15 500 ppm at 15 cm depth, and only 1500 ppm at a depth of 30 cm.

Figure 13: A 80 cm deep soil profile (TS) in the Tapolca (Zalaháláp) doline (TA) with values of the measured CO_2 concentration at different deep level (See Fig. 12)

Then, the values show slight oscillations between 1500 and 2000 ppm that were interrupted by a peak (8000 ppm) at 35 cm depth, which may be a consequence of the root level of the plants (Fig. 14).

These results were strongly supported by the biomass determinations that were also made by the microorganism diversity.

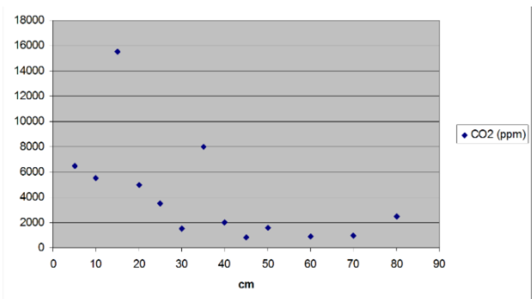

Figure 14: The changes of CO_2 concentration of the soil air in the TA doline with the depth of soil

The biomass decreases from the topsoil to the bottom, and the compound of microorganism communities are strongly different. In addition, the available oxygen gas involved in aerobic respiration decomposition processes at a depth of 70- 80 cm of soil profile is very low.

Conclusions

In order to understand the effect played by the different soil types on karst corrosion processes, we measured the microclimate on the field and the amount of CO2 in the karst soil. We defined the spatial and temporal quantitative changes of CO2 concentration of microbial origin. We investigated the correlation between microclimate, surface coverage, exposure, soil depth and the microbial activity (CO2 production). In every case, we measured the highest values of the CO2 concentration in the bottom of the sink hole –15-20 cm. We wanted to verify the de-pendency on depth, as well. Starting from the sur-face to downwards, we found out that the carbon-dioxide production rate in the soil does not increase directly in proportion to the depth, but has a maxi-mum value at the depth of 20-40 cm. These results were strongly supported by the biomass determinations that were also made by the microorganism diversity. The biomass decreases from the topsoil to the bottom, and the compound of microorganism com-munities are strongly different. Our measurement states that the meteorological factors also affect the microbial CO2 production from soil. According to our measurements, the amount of CO2 concentration showed a growing tendency during the day. We measured the highest CO2 concentration late in the afternoon. During the evening, as the temperature dropped, the concentration of CO2 dropped, as well. The alteration of sunny, cloudy and rainy weather may result in significant temperature changes in the layers, close to the surface. Increase in air and soil is accompanied by the intensification of enzymatic activity of soil bacteria and simultaneously, the rate of carbon-dioxide production.

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Authors contribution

The research of the epikarst has been carried out in teams, where the researchers participated according to their profession and skills. J. Móga fulfilled the geomorphological studies and field measurements, the soil field and laboratory works were led by K. Kiss and M. Szabó. D. Strat participated in the hydrological and ecological field investigations. The microbio-

logical and laboratory investigations were coordinated by A. Borsodi. K. Kiss, D. Strat and B. Barbara have contributed in the editing of illustrations and main text.

References

Bakalowicz, M. (2014). The epikarst, the skin of the karst. Karst Waters Institute Special Publication 9.https://www.researchgate.net/publication/267426221

Barta, K., Tanács, E., Samu, A., & Keveiné, B. I. (2009). Hazai rendzinák megfeleltetése a WRB nemzetközi talajosztályozási rendszerben. Agrokémia és Talajtan, 58(1), 7-18.

Bauer, E., Pennerstorfer, C., Holubar, P., Plas, C., & Braun, R. (1991). Microbial activity measurement in soil — a comparison of methods. Journal of Microbiological Methods, 14(2), 109-117. doi:10.1016/0167-7012(91)90040-W.

Bárány Kevei, I. (1998) Geoeocological system of karst. Acta Carstologica, 27(1), 13-25, Ljubljana.

Birot P., 1966, Etude de l'usure d'un versant calcaire sous un climat tropical humide: in Macar, P., (ed.), L'evolution des versants, Coll. Internat., Univ. Liege, 69-74.

Blecha, M., & Faimon, J. (2014). Karst soils: Dependence of CO2 concentrations on pore dimension. Acta Carstologica, 43(1), 55-64.

Bridges, E. M. (1978) World Soils, 2nd edition. Cambridge: Cambridge University Press, 128 pp.

Budai, T., Császár, G., Csillag, G., Dudko, A., Koloszár, L., Majoros, Gy. (1999) Geology of the Balaton Highland: Explanation to the Geological Map of the Balaton Highland, 1:50.000. Geological Institut of Hungary, Budapest (Hungarian, English).

Büki, G., Knab, M., Karoly, M., Móga, J., & Borsodi, A. (2011). Osszehasonlito diverzitas vizsgalatok a Tapolcai karst talajainak bakteriumkozossegein. Karsztfejodes, XVI, 143-155.

Buzás, I. (1988). Talaj- és agrokémiai vizsgálati mód-szerkönyv 2. A talajok fizikai–kémiai és kémiai vizsgálati módszerei. Budapest: Mezőgazdasági Kiadó.

Ciry R., 1959, Le role du sous-sol gele quaternaire dans le modele des plateaux bourguignons: Compte Rendus Academic Sciences Paris, v. 248, 2608-2610.

Creamer, R. E., Schulte, R. P., Stone, D., Gal, A., Krogh, P. H., Lo Papa, Murray, G., Winding, A. (2014). Measuring basal soil respiration across Europe: Do incubation temperature and incubation period matter? Ecological Indicators, 36, 409-418. doi:10.1016/j.ecolind.2013.08.015

Dijkstra, F. A., Carrillo, Y., Pendall, E., & Morgan, J. A. (2013). Rhizosphere priming: A nutrient perspective. Frontiers in Microbiology, 39, 600-606.

Faimon, J., Ličbinská, M., Zajíček, P., & Sracek, O. (2012). Partial pressures of CO2 in epikarstic zone deduced from hydrogeochemistry of permanent drips, the Moravian karst, Czech Republic. Acta Carstologica, 41(1), 47-57. Retrieved May 2008, 2018, from https://ojs.zrc-sazu.si/carsologica/article/viewFile/47/62

Fekete, J., Szendrei, G., & Csibi, M. (2006). Character-ization of Hungarian Red Soils. Agrokémia és Talajtan, 55, 29–38.

Fekete, J., Csib, I. M., & Stefanovits, P. (2008). Magyarországi vörösagyagok jelentősége, fontosabb talajtani jellemzőik. Talajvédelem (különszám), 585-594.

Ford, D., & Williams, P. (2007). Karst Hydrogeology and Geomorphology (Revised Edition ed.). Chichester, England: John Wiley & Sons Ltd. Retrieved May 15, 2018, from https://sudartomas.files.wordpress.com/2012/11/karsthydrogeologyandgeomorphology1.pdf.

Futó, J. (2003). Bakonyvidék. In: Székely, K. (edit) Magyarország fokozottan védett barlangjai. - Mezőgazda, Budapest, 339-344.

Jakucs, L. (1971). A karsztok morfogenetikája. A karsztfejlődés varienciái. Budapest: Akadémiai Kiadó, 310 pp.

Jakucs, L. (1980) A karszt biológiai produktum. Földrajzi közlemények, 28(4): 331-339.

Jones, W. K. (2013). Physical structure of the epikarst. Acta carstologica, 42(2-3), 311-314.

Jones, W. K., Culver, D. C., & Herman, J. S. (2004). Epikarst (Vol. Special Publication 9). Leesburg, Virginia: Karst Waters Institute.

Keveiné Bárány, I. (1998). Talajföldrajt. Nemzeti Tan-könyvkiadó, Kiadás helye: Budapest Nyomda.

Keveiné Bárány, I. (2009) A karsztok ökológiai rendszere. JATE Press Szeged, 121 pp.

Keveiné, I. & Zámbó, L. (1986). Study of relationship between bacteria activity in karstic soils and cor-rosion. Annales Universitatis Scientiarium Buda-pestinensis de Rolando Eötvös Nominatae, 20-21, 325-333.

Kiss, K. (2012). Vörösagyag-talajok vizsgálata az aggtelekikarszton (a béke-barlang vízgyűjtőjén). Karsztfejlődés, XVII, 89-103, Szombathely.

Klimchouk, A. B. (2004). Towards defining, delimiting and classifying epikarst: Its origin, processes and variants of geomorphic evolution. Speleogenesis and Evolution of Karst Aquifers, 2(1), 1-13. Retrieved May 13, 2018, from http://speleogenesis.info/pdf/SG5/SG5_artId3263.pdf

Knáb, M., Buki, G., Szili-Kovacs, T., Marialigeti, K., Moga, J., & Borsodi, A. (2012). Tenyesztesen alapulo es tenyesztestol fuggetlen molekularis biologiai diversitas vizsgalatok a Gomor-Tornai karszt talajainak bakteriumkozos-segein. Karsztfejlodes, XVII, 105-116.

Knáb, M., Kiss, K., Adam, L., Szili-Kovacs, T., Palatinszky, M., Márialigeti, K., Borsodi, A. (2010). Hazai epikarszt rendszerek talajaiban elofordulo mikrobakozossegek szerketenek es aktivitasanak osszehasonlito elemzese. Karsztfejlodes, XV, 35-48.

Knáb, M., Szili-Kovacs, T., Kiss, K., Palatinszky, M., Marialigeti, K., Móga, J., & Borsodi, A. K. (2012). Comparison of soil microbial communities from two distinct karst areas in Hungary. Acta Microbiologica et Immunologica Hungarica, 59(1), 91-105. doi:10.1556/AMicr.59.2012.1.10

Knáb, M., Szili-Kovacs, T., Marialigeti, K., Móga, J., & Borsodi, A. K. (2018). Bacterial diversity in soils of different Hungarian karst areas. Acta Microbiologica et Immunologica Hungarica, 23, 1-20. doi:10.1556/030.65.2018.002

Knauerné Gellai, M. (1992) Az Aggteleki Nemzeti Park térségéből származó vörösagyag-minták földtani-geokémiai vizsgálata. Kézirat, ANP.

Kotroczó, Z., Krakomperger, Z., Koncz, G., Papp, M., Bowden, R. D., & Toth, J. A. (2007). A síkfőkúti cseres-tölgyes fafajösszetételének és struktúrájának hosszú távú változása. [Long-term changes in the species compositionand structure of the Turkey oak-sessile oak stands at Síkfőkút (in Hungarian)]. Természetvédelmi Közlemények, 13, 93-107.

Kuzyakov, Y. (2006). Sources of CO2 efflux from soil and review of partitioning methods. Soil Biology & Biochemistry, 38, 425-448.

Kuzyakov, Y., & Larionova, A. A. (2005). Root and rhizomicrobial respiration: A review of approaches to estimate respiration by autotrophic and heterotrophic organisms in soil. Journal of Plant Nutrion and Soil Science, 168, 503-520.

Mangin A., 1973, Sur la dynamique des transferts en aquifere karstique. Proc. 6th Internat. Cong. Speleology, Olomouc, v. 3, 157- 162.

Móga, J., Kiss, K., Szabó, M.K., Borsodi, A., Kéri, A., Mari, L., Knáb, M., & Iván, V. (2011). Természeti és antropogén hatások vizsgálata a Tapolcai-karszt epikarsztos rendszerében. Karsztfejlődés, XVI, 185-201, Szombathely.

Rozložnik, M. & Karasová, E. (1993). Slovensky Kras. Banská Bystrica. 476 pp.

Solaiman, Z. (2007). Measurement of Microbial Biomass and Activity in Soil. In A. Varma, & R. Oelmuller (Eds.), Advanced Tecniques in Soil Microbiology (Vols. Soil Biology, 11, pp. 201-211). Berlin Heidelberg: Springer.

Song, W., Tong, X., Zhang, J., Meng, P., & Li, J. (2017). Autotrophic and heterotrophic components of soil respiration caused by rhizosphere priming effects in a plantation. Plant Soil Environment, 295-299. doi:10.17221/233/2017-PSE

Stefanovits, P. (1981). Talajtan. Budapest: Mezőgazdasági Kiadó.

Stotzky, G. (1965). Microbial respiration. In Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties (Vol. Agronomy Monograph 9.2, pp. 1550-1572). American Society of Agronomy, Soil Science of America. doi: 10.2134/agronmonogr9.2.c62.

Szili-Kovács, T. & Török, K. (2005). Szénforráskezelés hatása a talaj mikrobiális aktivitására és bio-masszájára felhagyott homoki szántókon. Agrokémia és Talajtan, 54: 149–162.

Szili-Kovács, T., Zsuposné Oláh, Á., Kátai, J., Villányi, I., & Takács, T. (2009). Talajbiológiai és talajkémiai változók közötti összefüggések néhány tar-tamkísérlet talajában. Agrokémia és Talajtan, 58: 309-324.

Tanács, E. (2011). Temperature and precipitation trends in Aggtelek karst (Hungary) between 1958 and 2008. Acta climatologica et chorologica, 44-45, 51-63.

Tanács, E. & Barta, K. (2006). Talajvizsgálatok a Hara-gistya-Lófej erdőrezervátum területén. Karszt-fejlődés, 11, 235-251.

Tanács, E., Szmorad, F., & Bárány-Kevei, I. (2007). A review of the forest management history and Present state of the Haragistya karst plateau (Aggtelek karst, Hungary). Acta Carstologica, 36(3), 441-451.

Veress, M., & Unger, Z. (2015). Baradla-Domnica: Large Cave System on the Hungarian-Slovak Border. In D. Loczy (Ed.), Landscapes and Landforms of Hungary (pp. 167-176). Springer International Publishing Switzerland. doi:10.1007/978-3-319-08997-3_20.

Zámbó, L. (1986). A talaj-hatás jelentősége a karszt korróziós fejlődésében (Aggteleki-karszt). Kandidátusi disszertáció, Kézirat. Budapest.

Zámbó, L. (1998). Talajtakaró. In: Baross, G. (ed.) Az Aggteleki Nemzeti Park (95–117). Budapest: Mezőgazda Kiadó.

Zámbó, L. (1998). The experimental examination of microbial origin corrosion aggressivity of karst soils. Acta Carsologica, 27(1), 16 -25.

Zámbó, L. (2001) A mikrobiális talajhatás morfológiai jelentősége a karsztosodásban. Földrajzi konfer-encia, Szeged.

Zámbó, L. & Telbisz, T. (2000). A mikrobiális befolyásoltságú karsztkorró- zió vizsgálata magyarországi karsztok talajaiból származó kismintákon. Karsztfejlődés, V, 21-39. BDF, Természetföldrajzi Tanszék, Szombathely.

Zámbó,L., & Ford, D. (2003). Corrosional factors of the epikarst. In:Horváth,G.(ed.), Soil Effecton Karst Processes (pp. 7–18). Budapest.

Zhang, M. & Zhang, F. (1987). Soils under karst forest in Maolan. Collection of Maolan karst science ex-plore. Guizhou Science Express, 111-124.

Williams, P. W. (1983). The role of the subcutaneous zone in karst hydrology. Journal of Hydrology, 61(1-3), 45-67. doi:10.1016/0022-1694(83)90234-2

Williams, P. W. (2008). The role of the epikarst in karst and cave hydrogeology: a review. International Journal of Speleology, 37, 1-10. Retrieved May 13, 2018, from http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1173&context=ijs.