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MICROCLIMATE OF KARSTIC DOLINES

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Összefoglalás - A karsztos területek formaképzésében és fejlődésében meghatározó tényező a klíma. A mikroklíma a karsztok geoökológiai folyamataiban játszik fontos szerepet. A tanulmány a karsztos dolináknak - a karsztok fagyzugainak - speciális mikroklímáját mutatja be, különös tekintettel a különböző tengerszintfeletti magasságokban elhelyezkedő dolinák mikroklímájának különbözőségeire és hasonlóságára.

Summary - Climate is determinant factor of the formation and development of karst surfaces. Microclimate plays an important role in the karstic geoecological processes. This work highlights the specific microclimate condition of karstic dolines as the frost pockets of karstland with special attention to the differences and similarities in the microclimates of dolines in different elevation.

Key words: microclimate, microclimate of karstdolines, air- and soil temperatures

INTRODUCTION

Climate is a determinant factor of the formation and development of karst surfaces. Amount of precipitation is the most important one of all climatic factors, as the magnitude of solution is essentially defined by it. Today, however, a new trend, namely the study of karstic geoecological systems, has got into focus besides classical karst-research.

For these investigations, the knowledge of the microclimate of karstic environment is not sufficient as the changes of the karstic geoecological system take place near, and right below the surface in the soils, and through these changes the dynamics of the system is modified. It is microclimate that plays an important role in this process. My studies of microclimate today already constitute apart of the exploration process of the climate-soil-vegetation system.

My work highlights the specific microclimatic condition of karstic dolines as the frost pockets of karstland, paying a special attention to the differences and similarities in the microclimates of dolines in different elevations above sea level (*Bárány-Kevei*, 1985).

METHODS

The field microclimate investigations were performed in a doline in the Aggtelek Karst and Bükk Mountains. Between 7 and 9 July in 1998, we examined microclimate in one of the grassy dolines of the Lusta Valley on the Bükk Plateau, and between 13th and 16th July 1988, we performed observations of microclimate in the juniper grove of the Aggtelek Karst. The air temperature was measured by Assmann-type aspiration psychrometer, while soil temperature was measured by mercurial-soil-thermometer in depths of 2, 5, 10, 20 and 30 cms. Observations were performed in every hour by day and night. The instrumental measurement was supplemented by visual perceptions. The microclimatic measurements were made under two different weather conditions. The measurings in the Bükk Mountains began on a clear day; it was followed by a wet day and then by clear night. A more favourable weather situation prevailed at the time of the microclimatic measurements in Aggtelek; therefore, the warm up processes of the daylight can be studied better here.

RESULTS

Temperature as the most important climate element depend on radiation. Radiation provides energy operating in the geoecosystem. The quantity of energy transmitted or reflected back to the atmosphere depends on the quality of the surface which intercepts the radiation. Nevertheless, as the majority of the Hungarian karstlands is covered by soil and vegetation, a significant portion of the energy radiated on the surface is generally absorbed. Convection of heat penetrates into deeper layers and gets onto the rock surface by the favourable conductivity of the rock-bed which influences the intensity of the solution processes especially at the division lines of rocks. The energy yield of solar radiation depends on the duration of insolation, cloudness and the limitation of the horizon. The angle of slope is significantly modified by the impact of exposition in the insolation period.

In addition to the culmination height of the sun, the solar spaciousness also plays a role in the warming and cooling of the negative surface forms (depressions), which changes during the year.

Dolines create an independent tertiary microclimatic space (*Wagner*, 1964) in the karst plateaus or in dry valleys because of their specific morphological features. The microclimatic space better can be appointed by their closeness and slope surfaces of different exposition. Characteristic microclimatic processes occur on the slopes, the brim and bottom of dolines which are under the influence of the whole doline but which affect the ecological processes independently in space and time.

During the day, the space of doline is filled by air of a rather higher temperature exchanged only by local turbulent air-movements. In the rise of temperature and cool down processes of slopes differences in their magnitude and time are indicated in accordance with

the radiation conditions. The energy yield of solar radiation depends on the geographical latitude, the duration of insolation, the horizon limitation as well as on cloud cover at any region. The amount of radiation per surface unit is significantly modified by the exposition and angle of the slope in dolines. The steeper and more northerly exposed the slope, the higher is its radiation deficit. Moreover, insolation is most intensive on the slopes of southern exposition during daylight. However, typical characteristics of the daily pattern of radiation that the slopes with eastern exposure receive more intensive radiation from sunrise to 9 a.m. than the one with southern exposure. During the summer months, the slopes of northern exposure are also in more favourable insolation situation in the early morning and evening hours than the slope of southern exposure. The afternoon hours insolation is more intense on the slopes of western exposures. With negative forms in the depressions of dolines, self-shading exerts an important modifying effect on insolation. The early shadow-impact also contributes to the heat deficit of the southern slopes. The heat excess of the morning hours is determinated by the early onset of horizon limitation. From the early morning hours the slope of southern exposition is already in self shade.

It is well-known that daily air temperature pattern derives from the northerly and southerly exposition of slopes (*Fig. 1*). The air temperature is warmer by 4-5°C in the warming-up period on the northern slopes (southern exposition) than on the southern slopes (northern exposition). Concerning to the absolute values of air temperature, no significant difference can be shown in the east-west cross-section (*Fig. 2*). On the other hand, difference is shown at the occurence times of maximum and minimum temperatures. Maximum temperature occurs between 9 and 11 a.m. on the east-facing slopes but it occurs between 1 and 3 p.m. on the west-facing slopes. This characteristic temperature pattern has an important effect on the soil and plant-ecological processes. In accordance with this, the different species establish themselves on different slopes, and the ecological indices of plants are formed as a function of this.

At night a "cold air lake" fills the lower layers of the doline (*Fig. 3*). The radiation minimum was minus 3°C during the night of 9th July in the plateau doline of the Bükk Mountains. Two types of phenomenons developed during the examinations:

One type is the phenomenon when cold air lake accumulates at the bottom of the doline and dew or hoar - frost is formed. The other type is when thick fog develops and the temperature will be higher at the bottom of the doline than on the slopes. The formation of the cold air lake hinders the undisturbed growth of the doline vegetation. This phenomenon can be measured well in the case of dolines covered by trees, where the several meter-high pine trees of the doline brims are of the same age as the slowly-growing pine seedlings not taller than one meter at the doline bottoms.

The daily pattern of soil temperature follows the changes of the daily air temperature with a phase delay in compliance with the exposition conditions and the shadow impact. During the day, the south east-faced slope in the upper layers of soil whereas in the lower layers the south-faced slope is warmer. Warming up begins first on the north-faced, then on the east-faced slopes. Following this, the surfaced slope warms up more than the west-faced slope does

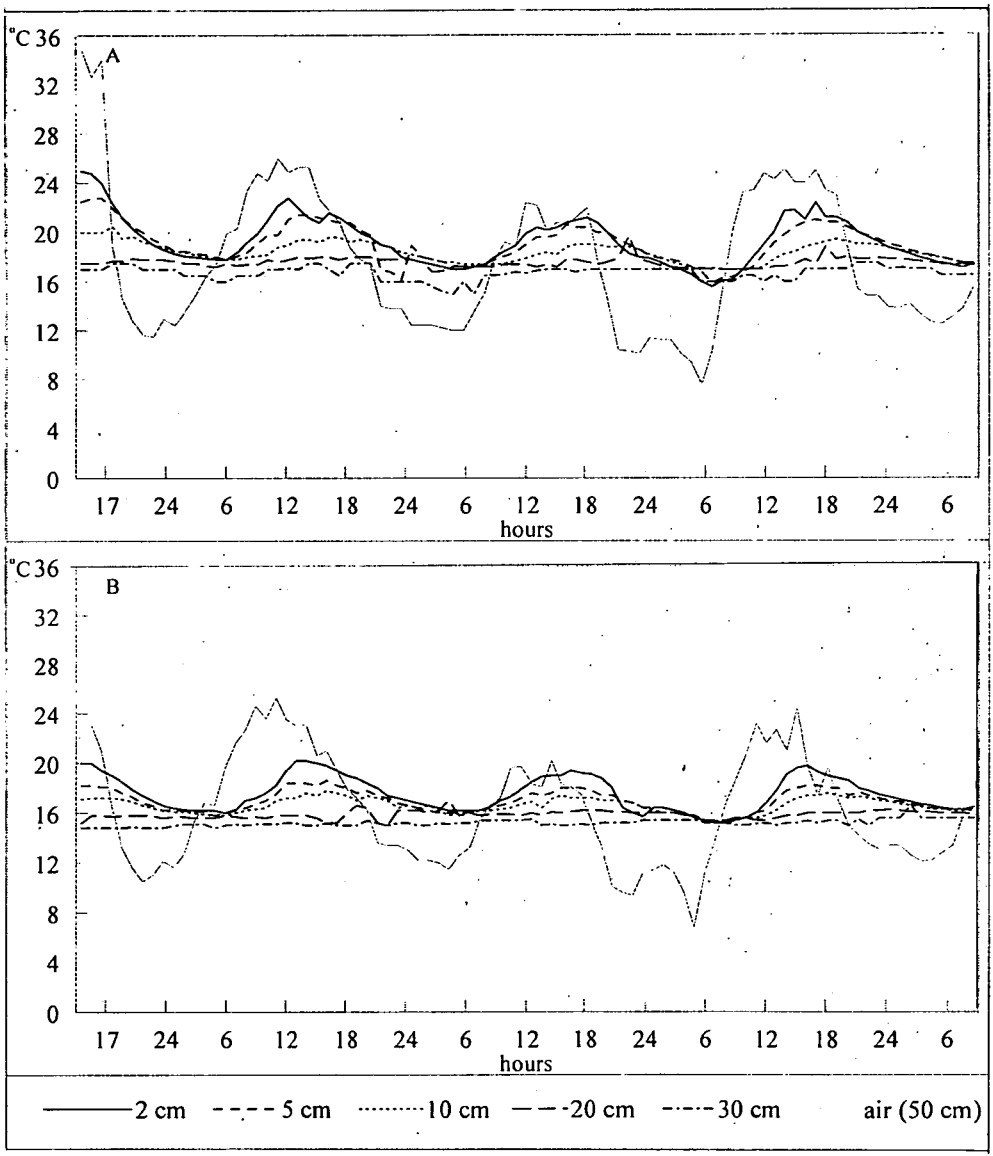

Fig. 1 The course of the soil and air temperature on the northern (A) and southern (B) slope

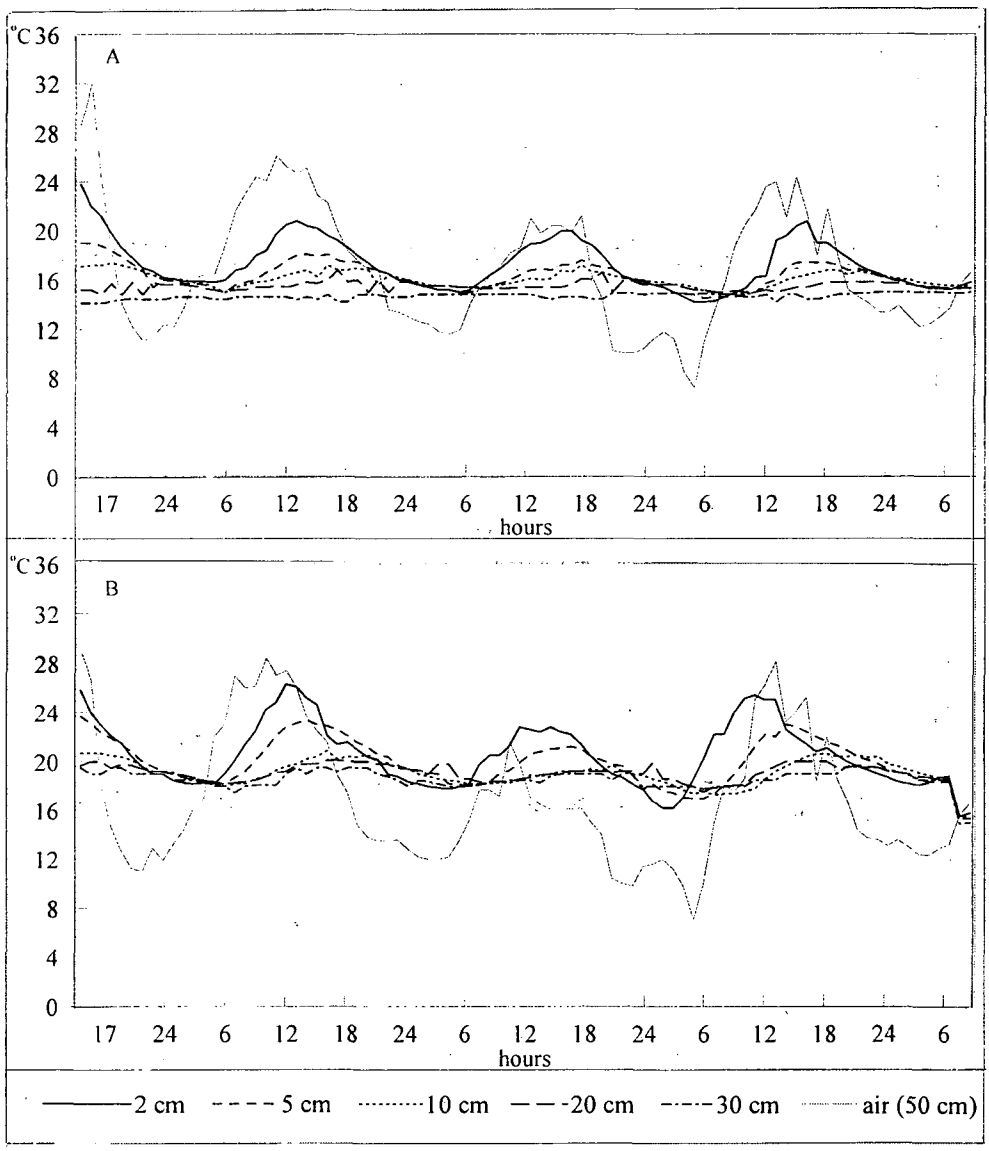

Fig. 2 The course of the soil and air temperature on the eastern (A) and western (B) slope

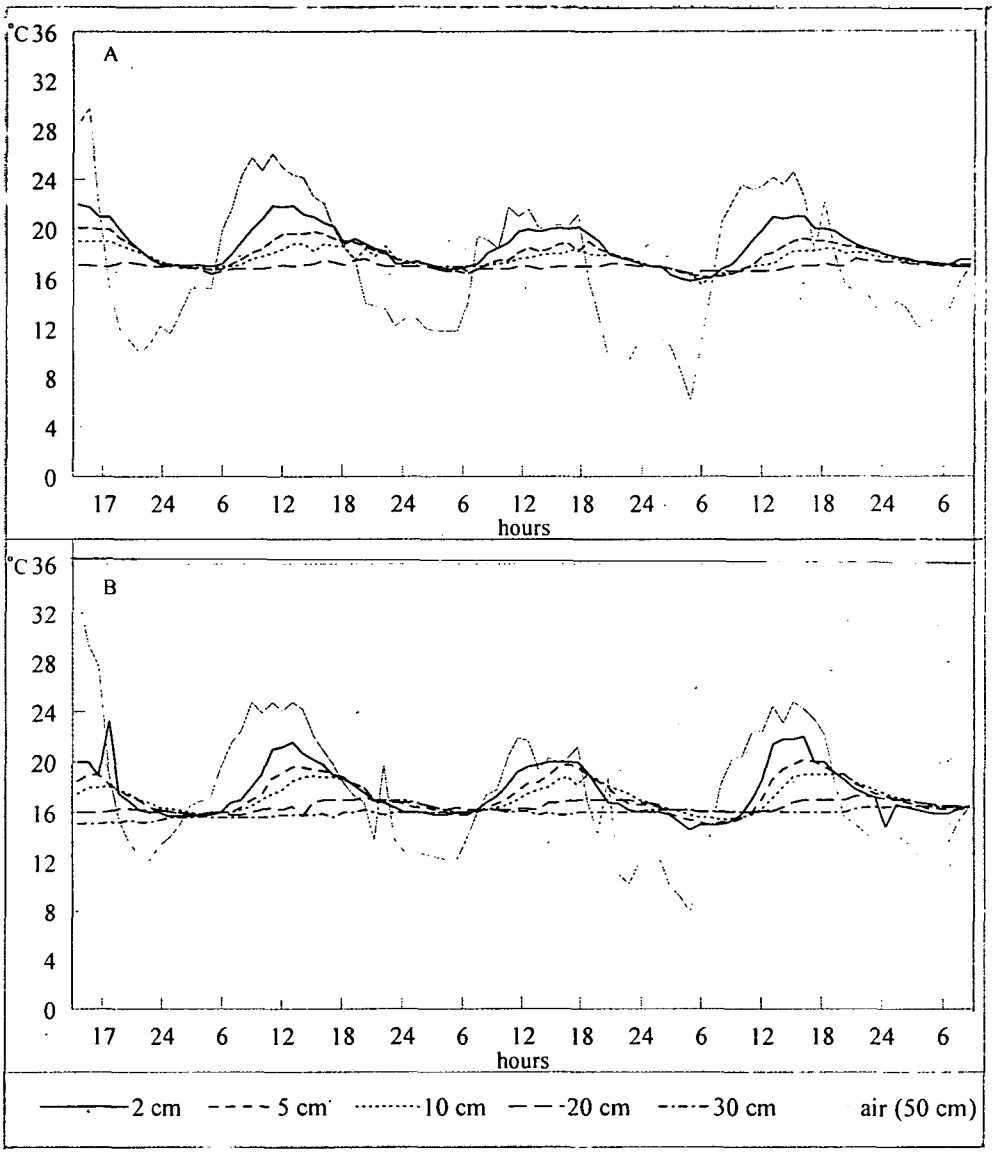

Fig. 3 The course of the soil and air temperature on the bottom (A) and brim (B) of doline

with a somewhat lower temperature maximum.

The coldest one is the southern slope. Phase delay is the greatest towards the deeper layer of the soil (*Fig. 4*). Phase delay in the different soil horizons is well indicated by the diagram which defines the active surface movements in the soil. In both areas in a depth of 30 cms, the day and night temperature waves are levelled off and only some tenth °C of differences are indicated between the warming up during the day and at night. In this layer, there are no significant changes in the different parts of the day. The temperature diagram already reflects the isotherm-state on the different slopes from microclimatic aspect.

It was also shown by the investigations that daily amplitudes of soil temperature decrease more according to the increase of the elevation above sea level than air temperature amplitudes. This is doubly true for soils covered by forest. This raises attention to the fact that consideration should be given to the identical composition of stocks when examining air and soil temperatures.

Our investigations were carried out on different karst surfaces, and reflected on characteristic temperature conditions. On rock-lawns and in the woods the difference between the maximum values of air temperature increase along with the elevation above sea level, but

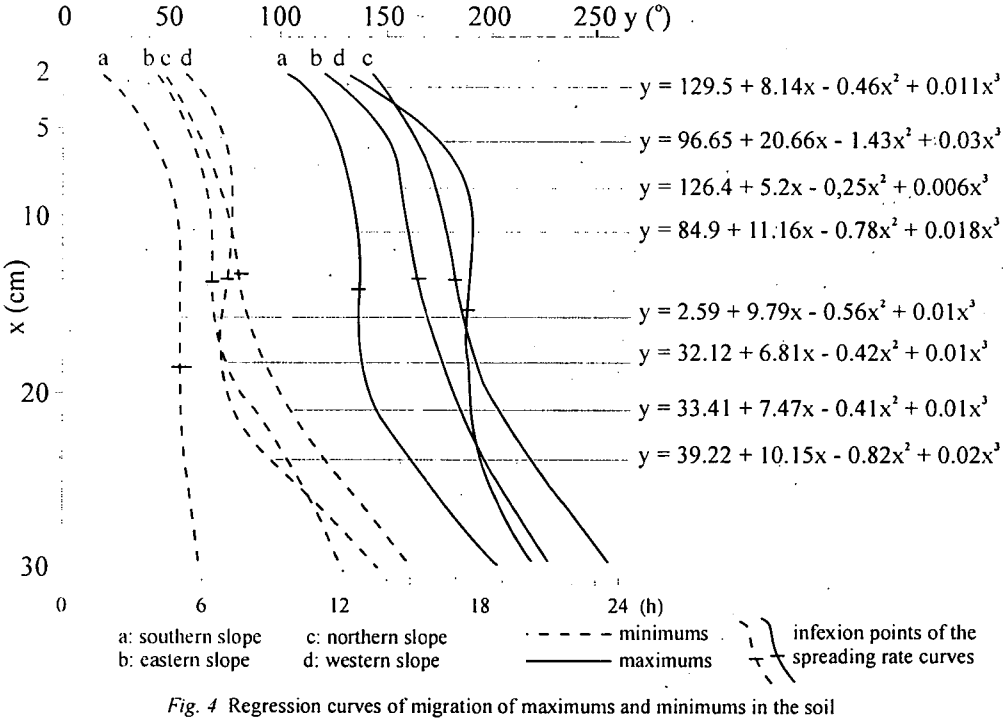

Fig. 4 Regression curves of migration of maximums and minimums in the soil

the diversion of the minimum temperatures decrease. Air temperature in the open meadow and the forest was higher at lower elevation during the day and lower at night. This means that in this case the extreme temperature values result in a greater amplitude that at higher elevations.

The basic difference between the climate of grassland and forest is the fact that the air temperature in grassland is higher during the day and lower at night than in the forest. The soil of meadows, however, is of a higher temperature both during daylight and at night than that of forests. This peculiarity is definitely in correlation with the phenomenon that the shadowing in this part prevails all day and the conduction of heat is slow. However, at night, a double cold air level is formed, one at the tree stratum as at the primarily active level and one at soil level, as the colder and denser air sinks down to the soil. With the increase in elevation above the sea level, the microclimate of dolines becomes more independent. Extremes in temperature are greater in the Bükk dolines than in the ones in the Aggtelek Karst.

SUMMARY

The climate of dolines significantly differs from the climate of the adjacent areas both in the course of daylight warm up and night cooling down.

1. The warm during the day is divergent on the different slopes. In addition to the great difference in temperature between the north- and south-faced slopes, the time difference between the occurences of maximum temperatures on the east and west-faced slopes in rather important from the vegetation aspect. On the east-faced slope, maximum occures at 10 a.m. and at 3 p.m. on the west -faced slope, which results a significant difference in the composition of the vegetation.

2. Cold air lake is a result of the night cooling down, which causes temperatures below 0°C, and induces a rather extreme microclimate along with the strong day warming up. This is also of great significance from the aspect of vegetation growth. This is manifested by a slower growth of vegetation.

3. The difference between minimum temperatures decreases, and it increases between the maximum temperatures with the increase of elevation above sea level. The type of vegetation importantly influences the microclimate. A more extreme microclimate develops in open dolines than in the wooded ones.

4. The temperature differences affect not only the vegetation but also the microbial activity of the soils. According to my observations, the condition of dampness and the temperature comply best with the bacterial activity on the west and northwest-faced slopes. For the strong insolation of the south-faced slopes are high temperatures and low dampness. The desiccation of soil causes the significant enrichment of bacteria population. This also means, from the point of an ecological system, that the decomposition of organic material and material transportation will become slower than on other slopes. The daylight differences of insolation on the various slopes are not compensated by the night emission, because the cold air lake, formed by the sinking cold air, appears in the temperature inversion. This microclimate

pecularity results an inversion of the vegetation pattern as well. Plants of smaller stature develop at the bottom of dolines than at the higher brims.

REFERENCES

Bárány-Kevei, I., 1985: Ökologische Untersuchung der Karstdolinen unter besonderer Berücksichtigung des Mikroklimas. *Acta Geographica Szegediensis 35*, 109-130.

Wagner, R., 1964: Lufttemperaturmessungen in einer Doline des Bükk-Gebirges. *Zeitschr. für Angewandte Meteorologie 5, Heft 3-4.*, 192-199.