ACTA Geographica Szegediensis Tomus XXXV. 1994-95. pp. 89-99.

ECOLOGICAL CONDITION OF HUNGARIAN KARSTS

Ilona Bárány-Kevei

Introduction

The investigation of the karst has been focusing on environmental issues, rather than on the classical karst genetic and karstmorphological ones during the past decades. The environmental impacts of the karst regions have to be analysed, since these processes are very rapid. The non-karstic materials can integrate quickly into the karstwater system, modifying or damaging the natural forms that have been developing for millions of years. Karsts are therefore especially sensitive geoecological systems and their research from this aspect has been encouraged since the 80s (Jakucs, L. 1980, Kevei-Bárány, I. 1982, Pfeffer, K.H. 1990).

Karst areas of Hungary occupy 1.5% of the country's surfaces. Larger part of Hungarian karst lies in the Hungarian Mountain Range.

Hungarian karst systems have been used for a long time. The karst regions of Transdanubia are strongly affected by settlements and industry. Bauxite mining resulted in a considerable decrease of karstwater table (Rétvári, L. - Tózsa, I. 1996). Similarly, most of the Mecsek and the Villányi karst areas have changed due to human activity. The karst region of the Bükk Mts has preserved most of its original character, owing to the protective impact of the Bükk National Park, becoming a conservation area much sooner than the other karst regions. The Aggtelek Region has been a National Park for 10 years, thus human impacts are also relatively little, however, due to the grazing agricultural activity and forestry prior to the conservation act of the national park, some traces of human impact still can be perceived.

Now that Baradla Cave with its Domica Branch on the Slovakian side became World Heritage Area (1996), the geoecological investigation of the larst cannot be neglected in landscape protection.

Methods

The research of the karstecological system has methods applicable to all kinds of karst regions. When investigating the factors of the system (soil, microclimate, vegetation and microbial activity) the methods of the scientific fields can be applied respectively. The parametres of the soil samples from the outcrops were analyzed in laboratory: grain composition (aerometrical analysis), carbonate content (Scheibler's calcium-meter), pH value (digital pH meter), hydrolic acidity (titration), heavy metal content (Perkin - Elmer atomic adsorption spectrophotometer). Nutrient analysis and the definition of the water soluble ions were carried out at the MÉM NAK Institute at Hódmezővásárhely according to the Hungarian standards.

During microclimate monitoring, the soil temperature just beneath the surface, the soil temperature, the sunshine hours and the wind velocity were measured by Assmann's psichrometers, electric resistance meters, Campbell - Stocks radiation meters and anemometers respectively.

Vegetation was surveyed on several occasions on the basis of a 1 sq m grid pattern where both the species and the coverage percentage were recorded. Knowing the species, the karst vegetation was evaluated through using the ecological indicators (water budget, heat budget, soil reaction and nitrogene demand) given by Zólyomi, B.

The survey of the microflora (defining the number of aerobic and anaerobic bacteria on Agar nutritive soil) was carried out at the Microbiological department of the József A. University, Szeged.

Discussion

The relationship among soils, microclimate and vegetation was surveyed on Hungarian karst areas, since the above elements of karstecological systems exercise influence on the whole of the karst.

1. ***Karst soils*** between the exosphere and the rock layers, play an important role in the karst processes. On karst surfaces covered with soil, the decomposition of the organic materials of the karst and the root respiration produce a great deal of CO_2 surplus, increasing considerably the corrosion capacity of leaking waters (Jakucs, L. 1971). In this sense, soil can be considered as an indicator sphere of the karst ecosystem.

1. The ***physical and chemical characteristics of karst soils*** are of relevant importance from the viewpoint of the karst ecosystem changeability. Soils can buffer the extreme impacts, though in case of very strong influences they themselves serve as agents in intensifying the impacts, may they be either favourable or disadvantageous. The inner dynamism of the soil is independent (Szabó, M. 1995), since the enzymes getting into the soil stay there for long, influencing soil dynamism. It is expressed first of all in the chemical features of soil and exercise impact on the development of soil aggregates (structural soil elements). The structure and texture of soil define the soil's air, water and heat budgets. As it can be expected from the above, the chemical and physical features change depending on the biological activity.

Karst soils are not well sorted according to their ***physical quality***; they are unconsolidated, immature soils. They are developed mainly on solution residue or on loess, loess-like sediments. Their dominant fraction is slimy loam (50-60 %), while sand fraction is hardly represented in the Bükk dolines. The soils at Aggtelek are poorly sorted, too. Their clay content is 20 %, higher than that of the soils in the Mecsek karst region (Fig.-1.) This considerable clay content is due to the dolines being older at Aggtelek than in the Mecsek Mts. These soils have large water storing capacity. The thick clayey sediments can eventually become impermeable. In the karst depressions this clay sedimentation makes the karst corrosion effects move towards the edges.

The pH, hydrolitic acidity, alkality and the $CaCO_3$ content describe the ***chemical state of soils***. The water soluble anions and cations, being important from karst corrosion aspect, also represent the chemical properties of soils.

Soil reactions are slightly acid or neutral as decided by their pH values. The soils in the Mecsek and Aggtelek Mts are more acidic with 6.0 - 6.5 average pH values. The soils at Aggtelek have 0.3 - 0.4 less pH than those in the Mecsek, as it was found in the measurement records from the 80s and 90s. Of course, among the several hundred data recording sites, there were found values of 5, too, indicating the aridification process (in the summer of 1995 Calluna was found on the karst surface at Aggtelek). At the same time it is known that the chemical reaction of the karst soils formed on the non-acid limestone, is

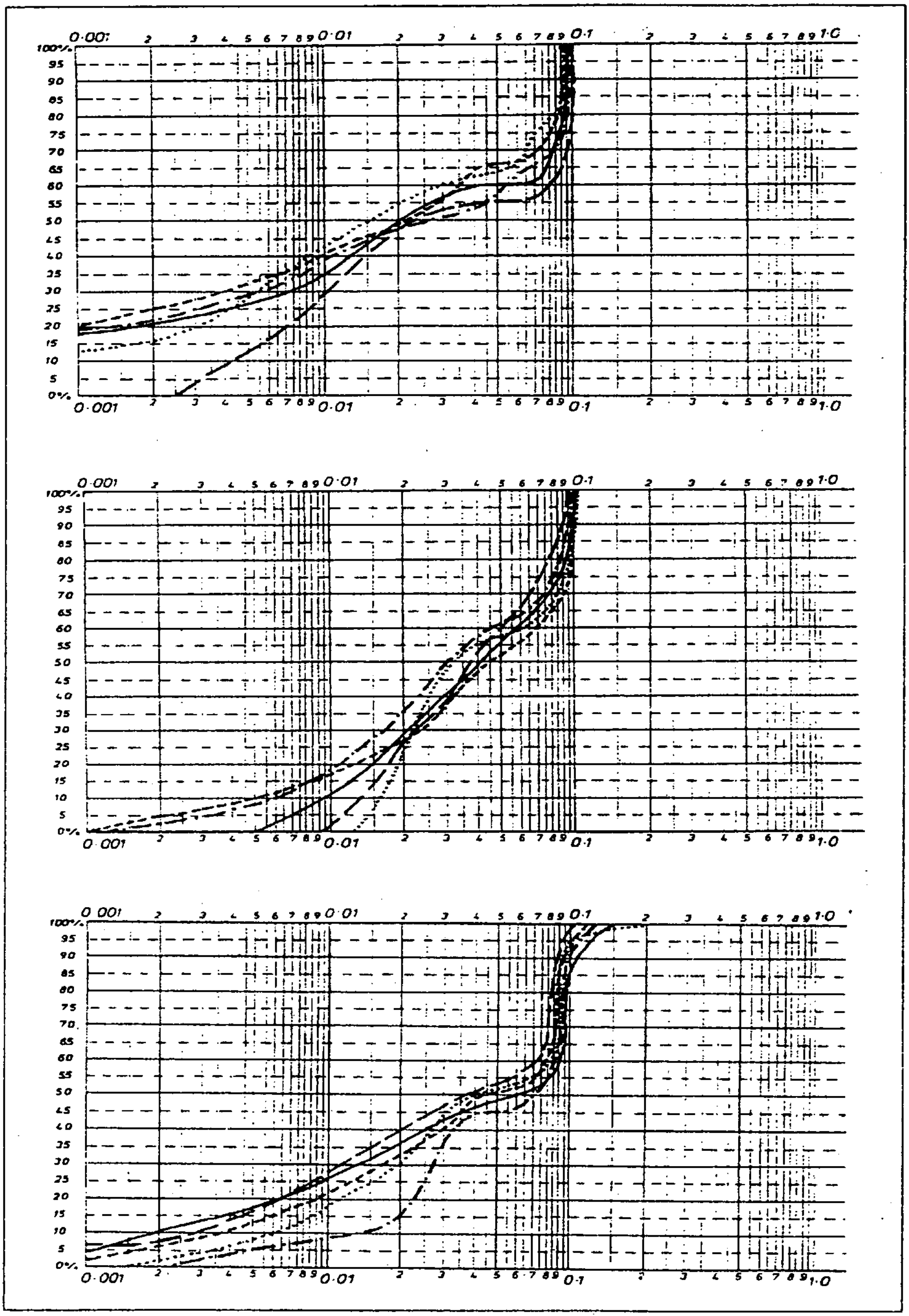

Figure 1 *Fractions of doline soils in Aggtelek-, Mecsek- and BükkMts. (depth 50 cm)*

generally non-acid. The occasionally low pH values encouraged the investigation of the difference between the soil solutions with water and with potassium chloride seperately. The increase of the difference between the two values proves the acidification of the soil (Stefanovics, P. 1981). The difference between the two pH values exceeds the limit indicating aridification in the dolines of the Bükk, Aggtelek and Mecsek Mts alike. The aridification tendency can be found at places where there is little human effect (e.g. in the Bükk National Park). The effect of acid deposition can be anticipated at these sites.

The analysis of ***water soluble cations and anions*** can be applied to describe the chemical state of the soil. Naturally, the Ca^{2+} ion content is high in karst soils, but K^+, Na^+ and Mg^{2+} ions are also abundant. Anions are represented in largest number by SO_4^{2-} but there are many Cl^-, too. There is a general tendency that both cations and anions can be found on the slopes near the edges of the dolines, rather than at their bottoms. The minimum quantity of ions deposited at the bottom indicates the intensive leaching process in this level.

The considerable amount of ***heavy metals*** accumulated in soils can indicate ecological changes. Heavy metal analyses were performed with the soil samples from Aggtelek, Bükk and Mecsek Mts. The average element concentration in limestone:

Zn	Mn	Fe	Co	Ni	Pb	Cu
23	700	15000	2	15	5	4

Heavy metal content at Aggtelek in ppm:

	Al	Zn	Mn	Fe	Co	Ni	Pb	Cu
1	23575.0	148.75	2125.0	27150.0	17.5	37.75	54.75	57.4
2	34055.0	96.25	1225.0	32115.0	24.35	36.45	38.25	18.5
3	29695.0	100.0	1587.5	30828.75	23.4625	33.6125	27.75	18.75
4	35462.5	76.25	1400.0	75873.75	35.O	33.25	162.5	28.25
5	26912.5	126.25	1487.5	29670.0	20.225	32.225	78.75	32.5

1 = N slope, 2 = E slope, 3 = W slope, 4 = depression of Lake Vörös, 5 = SW slope

Heavy metal content in the Bükk Mts in ppm:

	Al	Zn	Mn	Fe	Co	Ni	Pb	Cu
1	30767.5	105.0	1250.0	28882.5	19.4874	31.425	55.5	28.25
2	21115.0	118.75	1450.0	19413.75	12.1125	20.9125	46.25	19.25
3	25572.5	123.75	2000.0	26917.5	23.325	24.275	52.5	22.25
4	23687.5	75.0	837.5	21243.75	21.5625	21.44375	52.875	12.0
5	28082.5	211.25	2087.5	31175.25	16.575	35.325	58.25	50.0

1 = E slope, 2 = bottom of doline 20 cm, 3 = bottom of doline 80 cm, 4 = pinewood, 5 = NE slope

Heavy metal content in the Mecsek Mts in ppm:

	Al	Zn	Mn	Fe	Co	Ni	Pb	Cu
1	18865.0	67.5	737.5	22132.5	15.425	22.725	18.25	14.25
2	18470.0	65.0	787.5	22547.5	15.4	24.425	37.5	15.0
3	24045.0	76.25	400.0	32727.5	14.45	23.2	7.75	10.25
4	18990.0	70.0	662.5	22216.25	15.425	24.3	26.25	11.25

1 = S slope, 2 = N slope, 3 = W slope, 4 = E slope

The above data show that the high heavy metal content of karst soils comes from the rocks only partially. The values are higher in all the three types of karst samples than they should be if originating from rocks alone. The absorption of the heavy metals depend on the clay and organic material content and the chemical reaction of the soils. The higher the clay and organic material content, the more heavy metals are bound on the colloids. Neutral chemical reaction also supports the absorption of heavy metals. In strongly acidic soils most of the metals enter solutions.

The values shown in the tables are the highest ones for each element. Most of them are not well tolerated in the soil. The high metal content in residue terra rossa soils at Aggtelek is natural. Most of the samples come from dolines. No 4 among the Bükk samples is from forest soil on the edge of a doline. Here, with the exeption of Co, all elements have lower values than in the samples from the doline soils. It can be explained with the trees taking up more heavy metals than grass vegetation. Heavy metal content deserves a thorough ecological analysis.

2. The intensity of ***microbial activity*** is affected by the pH and ion content of the soil. There are millions of soil microbes (bacteria, ray fungi and microbial fungi) in 1 g of soil. More than two thirds of the CO_2 emitted in soil come from the decomposition of this organic material population, and only one third comes from root respiration. The most intensive CO_2 production is proven to take place in the upper 20 - 30 cm soil layer, as a result of the aerobic bacteria's activity. Bacterial activity is depending on the temperature and humidity of the soil. If temperature is low (e.g. lower than 20 °C) bacterial activity is slowed down. Low soil humidity (e.g. under 20 - 30 volume %) is also responsible for little microbial activity. The dynamism of the soil is thus manifested in a very complicated system and the least change in any of the factors might result in a very considerable feedback in whole of the karst system.

In surveying the microbial activity of the Bükk and the Aggtelek soil samples, the karst soils were not found advantageous for microbial activity (Kevei-Bárány, I. 1988.). Forest soils have 15-20 million bacteria in 1 g, being much less both in forested and grassy environments. There is a significant relation between the number of bacteria and soil temperature in the near-surface layers of the doline soils. In deeper layers, however, the number of bacteria correlates with humidity rather than temperature. Under Hungarian climate in the karst areas soil humidity under 22.2 - 24.6 °C and 14 - 25 % dryweight represents the optimum range for microbial activity.

The researches performed in the summer 1995 in the Aggtelek Karst (Fig 2.) prove the earlier assumptions regarding higher number of microbes near the surface of the soil than deeper, and the microbial activity being more intensive in forest association than elsewhere. The quantity of CO_2 emitted by microbes is a real ecological entity. The three levels of soil profiles investigated (1/1 = near-surface, 1/2 = middle level of the profile, 1/3 = lower level of the profile) are situatd in the upper 60 - 70 cm of the soil. Microbe number is considerably decreased in the lower level. The significant processes of soil dynamism take place in this profile. The near-surface physical, chemical and biological processes induxe the material and energy flows in the lower depth. Therefore the impacts on the system can cause considerable changes in the upper part of the soil. Biological processes have a feed back on the chemical properties of the soil through the decomposition of the humus materials, so the upkeep of the natural bacterial population and condition is desirable.

3. The dominant factor of karst formation and development is *climate*, but the mechanism of the ecological factors is determined by ***microclimate*** first of all.

Microclimatic systems modifying the radiation impact are formed within the mountainous and valley local climates under specific orographic and morphologic conditions in the Hungarian karsts. The independent microclimatic areas of the karst dolines are the most characteristic where the microclimate modifying effect of the exposure prevails side by side with the effect coming from the enclosure of the depression (Kevei-Bárány, I. 1985). The differentiated warming up of the different slopes results in important differences in the energy input and temperature of the soil. Differences in temperature affect both the microbial activity and the composition of the macroflora. Temperature conditions of the W and NW slopes are found to meet the demands of bacterial activity the best. The drying soils prevent the bacterial population from booming, due to the high humidity and low temperature of the S slope and the strong radiation input of the N slope. If the whole ecological system is considered, this results in a slower decomposition and transport of organic materials on the S slope than on the other ones. The slope-depending differences in daytime radiation input are not compensated for by the night-time heat emission, since the flow of the cold air causes cold-air ponds formed in the dolines. Thermal inversion is occurring. This microclimatic feature results in the specific inverse distribution of vegetation, too. Vegetation is lower in the bottom of the doline than along its edges.

3. ***Vegetation*** cover exercises a strong influence on the processes in the soils of the karst. The karst shrub woods (Orno-Cotinion) are characteristic of the Hungarian karst areas. The mountainous alteration of the Central European beechwood (Fagion medio-europaeum) covers the karst surface above 700 m elevation in the Bükk Mts. Its Central-Range-type streches down into the oak belt. There was a considerable clearing of the forests in the Central-Range in the beginning of the century. The barren lands of the karst surfaces, having appeared after deforestation still can be recognized at spots, but it is not characteristic in Hungary. The only traces of deforestation can be seen in the very slow natural re-forestation of the dolines, or in their still being treeless. In most of the dry valleys juniper occurred following deforestation as a secondary association and it shows the soils being poor in nutrients. The doline vegetation which used to have a rich variety of species is now getting uniformized. Grazing also contributed to the drop in the diversity of species. This, and the extreme temperature values of the microclimate of the dolines explain the associations getting ever poorer in variety of species.

The composition of the vegetation species of the Bükk dolines reflects the cenological features of the karst. The species mapped included those characteristic of the mountainous and submontane beech wood as well as steppe meadow, rocky and pusta grassland slopes, tufted grass and montane hayfields. The average values of the ecological indicators (water and heat budgets, soil reaction and nitrogene demand) were examined and the diagram was drawn (Fig. 3.) on the basis of sampling doline in the Bükk Mts. There is no significant heat budget difference among the vegetation species found in the Bükk dolines, but since this area is a microregion, even the 0.45 difference cannot be neglected. The higher heat budget indicating value recorded on the N slopes proves the aridity of this slope. This feature affects the development of all the other ecological factors.

The effect of the exposure is also characteristic in the analysis of the water budget indicator. Its average value is 6.62 in the N, and 3,2 in the S halves of the dolines, showing the slope-dependent distribution of soil humidity. Like heat and water budgets, the differences in soil reactions are also significant.

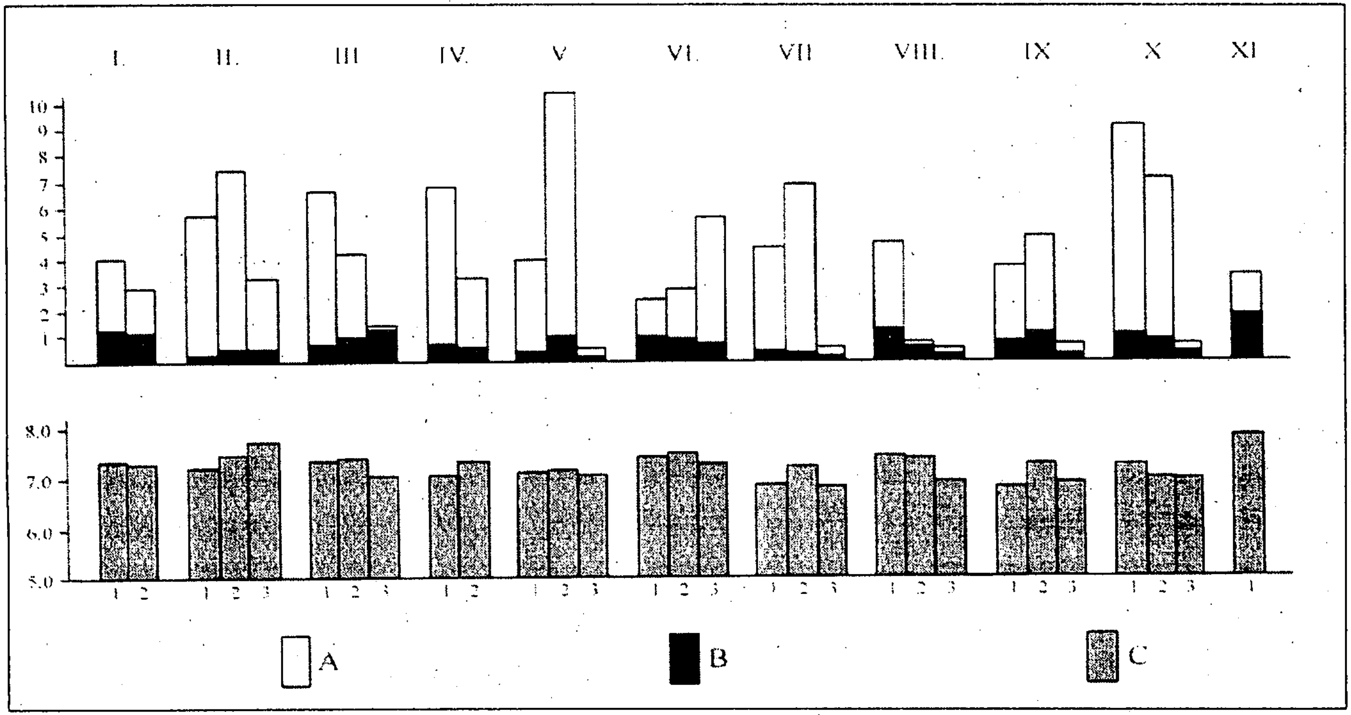

Figure 2. *Number of bacterium and pH values in soils of Aggtelek doline (1995, Hungary)*
I=bottom of doline, II=N-slope, III=E-slope, IV=bottom of W-slope, V=middle of W-slope, VI=top of W-slope, VII=wood on upper part of W-slope, VIII=top of S-slope, IX=W-slope of Szár Mts., X=bottom of E-slope, XI=middle of E-slope, A=number of aerob bacterium (10^6/g), B= number of anaerob bacterium (10^4/g), C=pH value

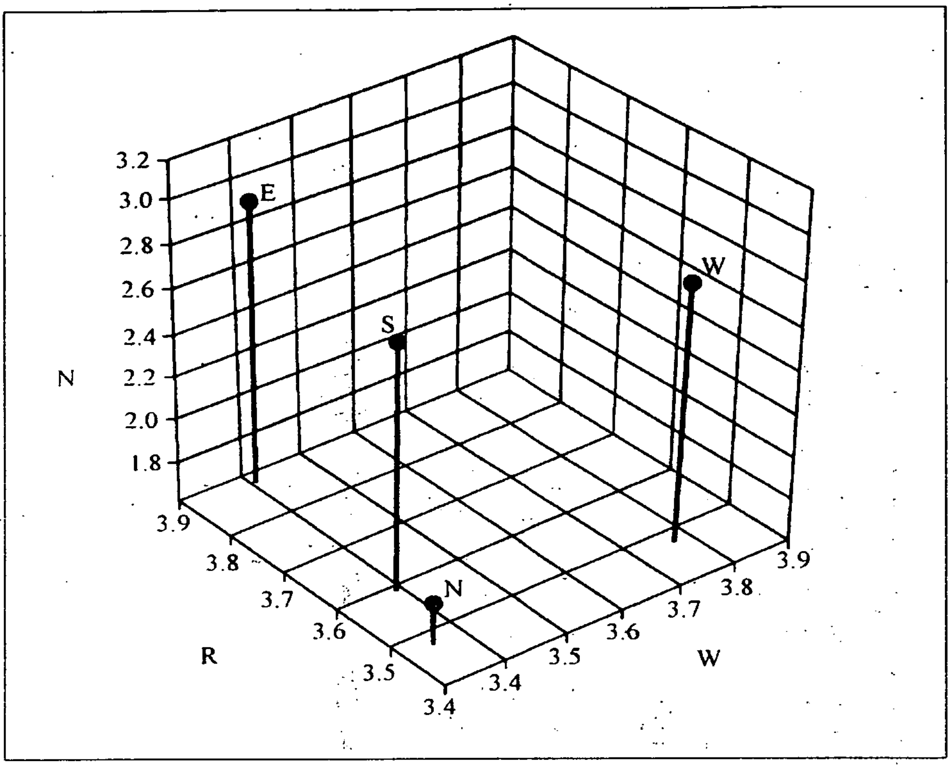

Figure 3. *Ecological indicators of vegetation in Aggtelek doline. W=water budget, R=soil reaction, N=Nitrogen demand. N= Northern slope, E=Eastern slope, S=Southern slope, W= Western slope*

The ecological values measured at Aggtelek (Bárány-Kevei,I.-Horváth,A.,1996) differ from those measured in the Bükk Mts), the species having less nitrogene are more abundant at Aggtelek. It is due to the former intensive grazing, having increased the nitrogene content of the soil. There are many species here, not being members of the original association. Temperature indicators prove the presence of the deciduous and Sub-Mediterranean climates of the temperate zone occurring over the karst vegetation. Average indicators of the water budget show temperate-fres and temperate-dry characters. From this aspect the slopes do not play as important role in making differences as in the Bükk dolines.

The distribution of the species in the doline-grass was examined according to their environmental value. Weeds and disturbance-tolerating species were found to represent 50 % of all the species and it is the sign of disturbed grassland.

After comparing the environmental values of the vegetation associations of the Bükk and the Aggtelek dolines, they were found to be much more degraded at Aggtelek.

Summing it up: the vegetation developed on karstic rocks with rendzina and clayey soils of forest soil dynamics, has very specific components. The species make up associations here that can adopt themselves to the extreme water budget of the soil. If the vegetation changes, like at Aggtelek, both the intensity of karst corrosion and the further functioning of the karst ecosystem are subjects to change. The degradation of vegetation is acting against natural processes as shown in the appearance of a few heather species along the edges of the dolines. Their coverage percent is small, but they are the environmental indicators of the change.

Synthesis

The first sphere of the karstecological system is the air just above the surface (Fig. 4), where there is a karst microclimate formed in accordance with the microclimatic factors. Macroclimate is responsible for the quantity and intensity of precipitation and microclimatic effects modify the quantity of water infiltrating into the rocks. Microclimate affects the development of vegetation , influencing in turn the quantity of CO_2 produced during root respiration. The microclimate of the air just above the surface is responsible for soil temperature and humidity. Millions of microorganisms live in the soil, changing the components of soil-air through the decomposition of organic materials and through their own metabolism. They also influence the physical and chemical soil properties indirectly. The latter result in the change of the quality of seeping water, leading to karstcorrosion processes of different intensities. The inner dynamism of soil can prevent extreme changes occurring in the system (through buffer ability and redox potential), though it cannot compensate for disadvantageous processes of long duration. The inner dynamism of soil can change on the long term, possibly leading to malefunction in the whole system. The changes due to external effects are reversible down to the rock boundary. The materials and the energies conveying them cannot be influenced any longer; when they have entered the rock layer, they become irreversible. Water in the rock layer is the transporting agent of materials and energy. This water reaches the surface again in karst springs and if it is polluted, its value of exploitation is decreased. Another irreversible process, the dripstone degradation can also be due to polluted water entering the caves (Jakucs, L. 1987).

On the basis of the above, the karstecological system is such a structured and dynamic one in which rock, soil, microclimate and macroclimate represent the abiogenic elements, while microflora, macroflora represent the biogenic ones. The interrelationship of the biogenic and abiogenic elements, along with the material and energy flux occurring in this interrelationship keep up the development and movement of the system. Its structure is defined by the vertical and horizontal distributions of its elements. It specific features include its sensitivity, the rapidity of its processes and its three-dimensional surface of effects.

The products of these interrelated processes were studied on the examples of karst dolines. The ecological survey of karst dolines is especially important, since these depressions of the karst are the most endangered points of the system, swallowing more water into the system than any other areas of the karst.

The future exploitation and management of the karst areas has to rely on the knowledge concerning the function of the karstecological system. This knowledge can only be acquired within the frame of the landscape ecological methods.

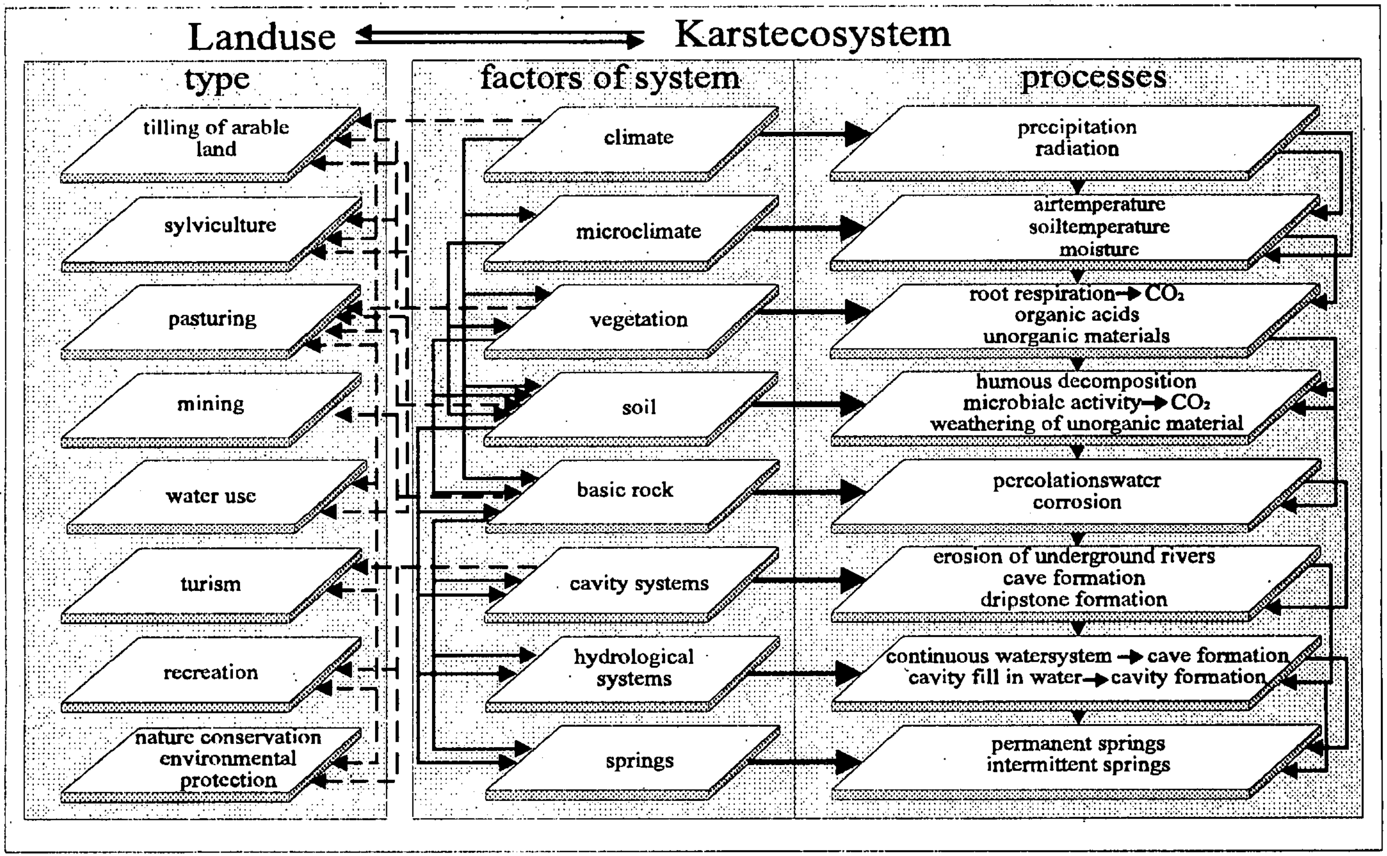

Figure 4. *Structure and processes of karstecosystem*

References

BÁRÁNY - KEVEI,I.1985. Ökologische Untersuchung der Karstdolinen unter besonderer Berücksichtigung des Mikroklimas. Acta Geographica Univ. Syegediensis.Tom.XXV.pp.109-130.

BÁRÁNY - KEVEI,I - Zámbó,L.1988. Study of the relationship between bacteria activity in karstic soils and corrosion. Ann.Univ.Scient.Budapestiensis de Rolando Eötvös Nominatae.Sectio Geogr.Tom XX-XXI.pp.325-334.

BÁRÁNY - KEVEI,I. 1992. Les facteurs écologiques dans la formation du karst. In.: Karst et Évolutions Climatiques. Hommage a Jean Nicod.Press.Univ.de Bordeaux.pp.53-59.

JAKUCS,L.1980. A karszt biológiai produktum (Karst is biological product).Földrajzi Közlemények 28.4.pp.331-339.

JAKUCS,L. 1987. Traces of effects of acid rain (sedimentation) in the re-dissolution of cave dripstones.Endins,n.°13.Ciutat de Mallorca.pp.49-57.

PFEFFER,K-H. 1990.in.: Fragestellungen. Wissentschaftliche Informationen zu Karst-Ökosystemen-eine wichtige Aufgabe für praxisorientierte Forschungen und Planungen. Süddeutsche Karstökosysteme Beitrage zu Grundlagen und praxisorientierten Tübinger Geographische Studien.pp.1-35.

RÉTVÁRI, L. - TÓZSA, I. 1996. Impact of bauxite mining on environmental management. n: Geomorphology and the changing environment in Europe. Abstracts of papers. Ed. by Lóczy, D. - Bassa, L. Bp. Geogr. Res. Inst. HAS.

ZÓLYOMI, B. 1966. Einreichung von 1400 Arten der ungarischen Flora in ökologische Gruppen nach TWR - Zahlen.Fragmente Botanica Musei Historico-Naturalis Hungarici.Tom.IV.Fasc.1 -4. pp.101-142.

Address of author: Ilona Bárány-Kevei
Department of Physical Geography, University of Szeged
Egyetem u. 2-6., H-6701 Szeged, POB 653,Hungary
Email: keveibar@earth.geo.u-szeged.hu