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The Geography of the Mures River

Dr. Mihály Andó

Summary

The Mures river, one of the most important tributary on the catchment area of Tisza river, has significant influence on the formation of flood on the southern part of the Tisza valley. The author evaluates the effects of the hydrogeographic, geologic and climatic factors appeared on the floodplain of the river. These factors are playing a very important role in the change in discharge and water regime.

Introduction

The Mures carries the inner waters of the Transylvanian basin in Western direction and it meets the Tisza at Szeged. The full length of the river is 749 km, the length of its valley is 651 km, the distance between its spring and its orifice is 425 air km. Its length and 30,000 km^2 large drainage basin make the Mures one of the significant rivers of the Carpathian basin. Most of its drainage area is covered with mountains and hills, and only a smaller proportion is plains. 25% of this territory is highlands, 55% is plateau and hill-country, 15% is river valley and 5% is lowlands (VITUKI 1975)(Fig.1).

Geohistory of the Mures drainage area

The beginnings of the hydrogeological aspects of the Mures coincide with the formation of the Transylvanian basin and its spur mountain regions in the Tertiary period. The presence of the Poiana Rusca Mountains and the Bihar Mountains was especially important in the Miocene, since these stood erect in the Mediterranean Sea as island mountains. Later the rise of the ranges of the Eastern Carpathians (Carpatii Orientali) and the Transylvanian Mountains finalized the formation of the Transylvanian basin (Depressione Transilvaniei).

The inner region of the Transylvanian basin was further formed by the slow rotation of the volcanic ranges and the inside blocks accompanying the movements in the mountain structure. Traces of the most intensive volcanic activity can be found in the Bihar Mountains and around the Mures river head, in the Calimeni Mountains, in the Giurghenhi Mountains, Gurghinhi Mountains, Cincului Mountains and in the Harghitei Mountains. The center of the basin had subsided in a relatively quick pace compared to the rise of the

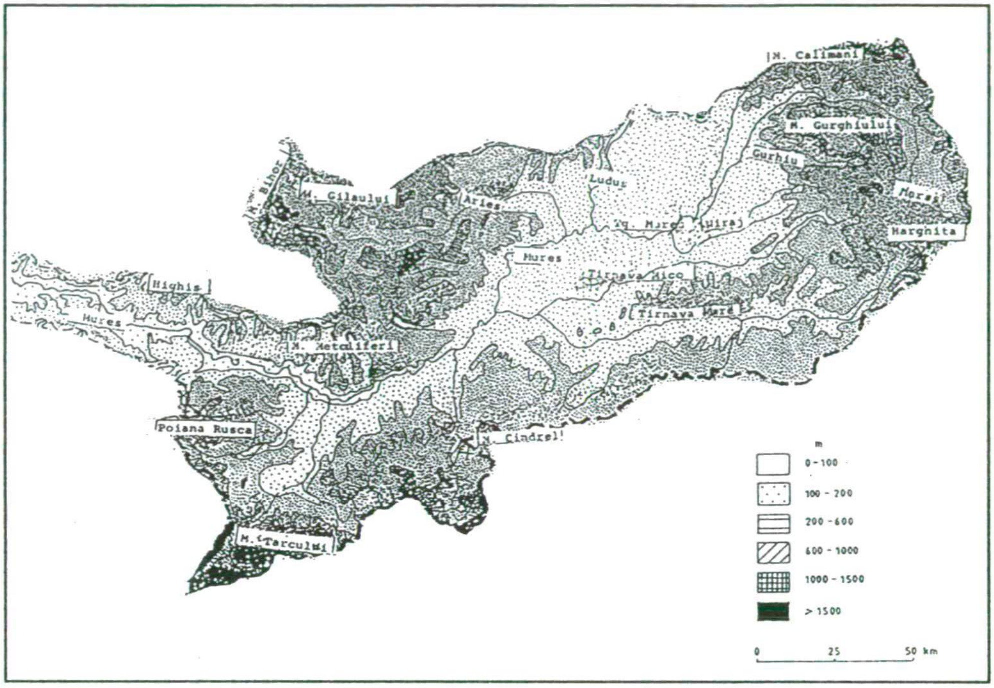

Figure 1 Surface of the Transylvanian drainage basin of the Mures (m above sea level)

mountain frame. The forceful rise of the mountain frame and the relative elevation of the basin resulted in the gradual and substantial recession of the shores of the Miocene (Pliocene) inner sea (Bulla B. 1943; Pávai Vajna F. 1914; Tulokdi J.1925).

The present Mures valley, between the Bihar Mountains and the Poiana Rusca Mountains, however, did not rise and thus the Pannon sea of the Alföld and the Transylvanian inner sea were connected for a long time. This narrowing was the Zám-pass (Strimtoarea de la Zum), the oldest element of the Mures valley and of the Transylvanian river system as well.

In the beginning of the Pliocene the lowland section of the Mures was still covered by the Miocene lake. In the central Transylvanian basin significant bay-like depressions formed. Even in the beginning of the Pliocene, it was characteristic that shorter streams started off from the surfaces of the surrounding higher mountains. Some of these streams were later taken up and further deepened by the Pleistocene Old Mures.

The Transylvanian bay formation developed into an independent closed lake and was filled up significantly only by the middle Pliocene. The alluvial fan, which determined the lowland section of the later Old Mures, started to build up from the coarse alluvium of the waters rushing down from the Highis-Drocea and Magura areas also around this time. The torrential streams also deposited a significant quantity of alluvium at the meeting of the Alföld and the foreland of the surrounding moutains (Gaál I. 1912; Oancea, D. et al. 1987).

An important rise in the drainage area of the Mures at the end of the Pliocene caused a recession in the inner lakes. By the end of the tertiary period (by the beginning of the Pleistocene,) the Mures had become a quick river, carrying the water of the Transylvanian inner lake to the significantly lowerlying Alföld.

The Old Mures left the mountains and appeared in the Alföld in the Pliocene and left a large alluvial deposit in the tectonic valley. This deposit gren as a Levantean talus, first only at the feet of the mountains and then slowly, with the further development of the talus system, it reached the talus systems of the Bega and the Crisul (Márton Gy. 1914).

The Alföld had been subsiding at the end of the Pliocene, and this process continued in the Pleistocene and even in the Early Holocene. The significant subsidence can be traced back in the structure of the regional debris of the talus sytem beginning at Lipova and spreading out fan-wise in the South-Eastern plain region (Andó M. 1976). There was no permanent surface river bed on the Mures Pliocene alluvium surface; the alluvium was spread in several branches. In the Early Pleistocene the Mures took on a definite direction that coincides with the seismotectonic lines of the rim of the Alföld. One of these directions is the "Paulis-Lipova" tectonic line, the other follows the foot of the Highis-Drocea Mountains in Northwest-Southeast direction.

During the "Günz" and "Mindel" glaciations the river formed a terrace system on its previous valley plain, influenced by the climatic change and the rise of the area, too. In the "Mindel" the Old Mures left the Lipova gorge and, producing several meanders, turned to Northwest on the talus system of the Alföld. First the river ran on the Southern rim of the talus, then, turning North, its main branch met the Old Tisza together with the Riul Crisul (Fig.2).

In the "Riss" period the talus developed mostly in the central area of the present talus. Significant surface changes occured mostly in the glacial and interglacial periods of the "Würm", when dominantly coarse and medium sand deposit levelled up the earlier deepenings of the river bed. At the same time in the Transylvanian area the usually wide but not too high terrace systems of the Mures developed; these can be traced from Reghin to Lipova (VITUKI 1975).

In the Holocene period the Mures settled in the Transylvanian basin and its horizontal bed changes became insignificant compared to the previous stages. The Holocene terrace follows the river all along with a 5-10 m height. At the same time, however, the Alföld section underwent a serious transformation that was especially due to the subsiding of the region of the Crisul river (Andó M. 1976). The oldest Holocene Mures reached the Tisza, the base of erosion (Gazdag L. 1964), at Kürtős and Kevermes. However, the Tisza moved to Northwest in a forceful process; the Mures beds followed it on fan-like taluses.
The river first followed the Békés-Kondoros, then the Kürtős-Nagykamarás-Orosháza, then the the Dombegyháza-Mezőhegyes-Makó and then the Szárazér line (Fig.3). The present bed was basically formed by the regulation of the river, since before this, in the Holocene, it also supplied the Aranka stream system.

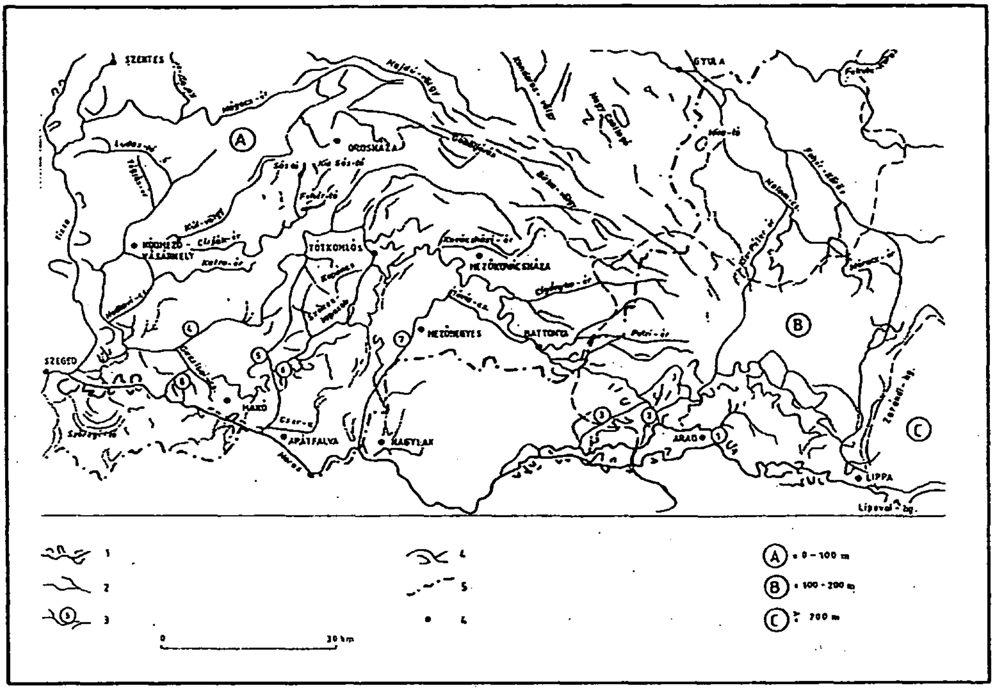

Figure 2 The river system of the Alföld section of the Mures
1. The present bed and meanders of the Mures; 2. Brooks; 3. Artificial canals; 4. Lines of Old Holocene beds; 5. Borders; 6. Town or village; A, B, C= m above sea level

Main climatic and hydrographic characteristics of the Mures drainage basin

The temperature and precipitation of the Mures drainage basin is influenced by masses of air from the Atlantic Ocean and the Mediterranean and as well as from Eastern Europe. Besides these, features of the ground also account for the regional differences; for example, compared to the precipitation on the plains, in the mountainous areas the precipitation doubles (Andó M.-Vágás I. 1973). Similarly to the Alföld, the annual quantity drops in the Transylvanian basin as well. In the case of the latter, the lack of precipitation is the result of the climate modifying influence of the Southern and Eastern Carpathians, especially in the winter semester.

Since the drainage area of the Mures is supplied with water by the Western winds, there are significant differences between the quantity of the precipitation in the "luv" and "lee" sides of the surface. This is especially characteristic on the Western expositions of

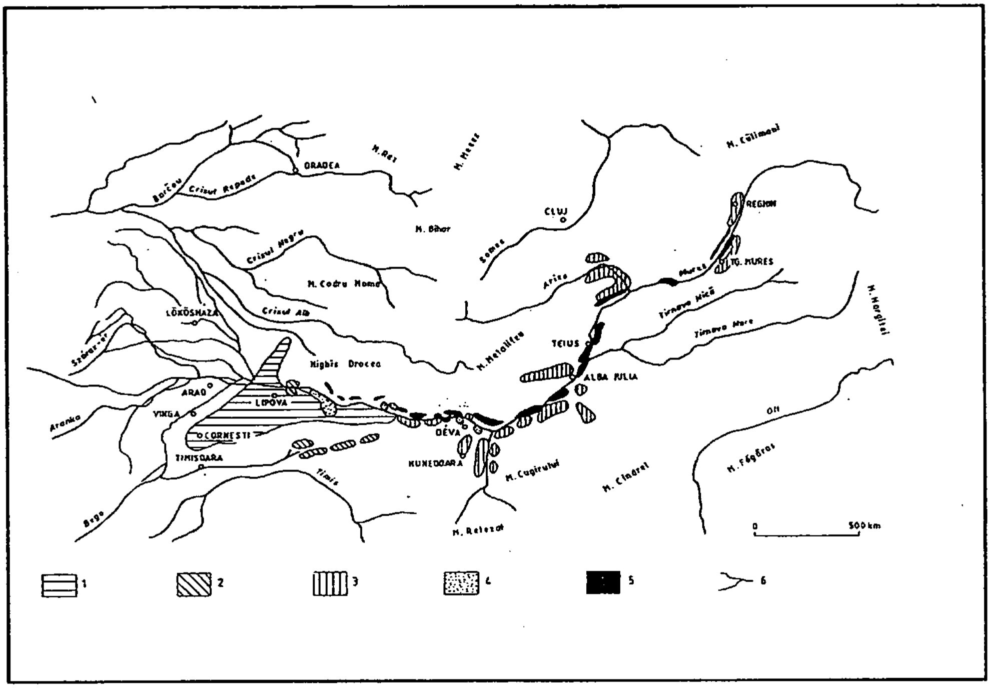

Figure 3 Terraces of the Mures in Transylvania and the traces of its old bed in the Alföld (source: OHV map)
1. Levante pebble deposit; 2. Günz terrace traces; 3. Mindel terrace remnants; 4. Riss terrace remnants; 5. Würm terrace remnants; 6. Old Holocene Mures bed lines

the Calimeni Mountains and the Gurghinhi Mountains where the annual precipitation is over 1,500 mm while in the Transylvanian basin it is only 500-600 mm and on the "luv" sides of the lower mountain areas it is 700-1,000 mm. The distribution of the temperature is similar; the annual mean temperatures are distributed according to the height above sea level. The whole drainage area of the Mures can be characterized by a 4-11 °C annual mean temperature. The coldest area is the Aranyos river region, the Mures river head and the Giurghenhi Mountains with 3-6 °C mean temperature. Most of the Transylvanian basin and in the Mures valley that is open to the West the annual mean temperature is 8-10 °C and in Szeged it is 11 °C.

Influencing the water level of the affluents, the regional water absorption is of great importance. This leads to significant regional contrasts in the different parts of the drainage area because of the great seasonal differences. For example, in the winter months the surface precipitation is mostly snow, therefore the monthly averages of the water absorption distribution can be characterized by the snow accumulation that increases with elevation. In the drainage areas especially in the mountain regions above 1,000-1,500 m the winter precipitation is not more than 15 mm. This also means that the water absorption in the drainage basins is the lowest in the winter, which is due to the accumulation of snow.

In the spring, as the snow melts from March till April, the surface water absorption highly increases. This time even 50-60 mm water quantities can occur in areas 500-1,500 m above sea level. At the same time on the Alföld and in the Transylvanian basin only 15 mm water quantity can be measured. On the surfaces of the higher mountains the water absorption begins to increase only in April, and in this period values between 100-200 mm are often observed in the mountains.

In April in the plains and hills comprising a large proportion of the drainage basin the total of the water supply comes from the rains; in the summer this is characteristic of the whole basin. In the fall the surface water absorption significantly drops and in areas 1,500 m above sea level the accumulation of snow begins, while in the Alföld and in the Transylvanian basin less than 30 mm precipitation occurs. This latter is mainly due to the Mediterranean climate connected to the Adriatic cyclones.

The data presented here suggest that the annual distribution of the precipitation is connected to periods and not certain seasons. Two characteristic periods can be distinguished: a "wet" period and a long "dry" one. The wet period sets in between April and August and the dry from September to March. The floods on rivers do not exactly correspond to this temporal distribution, since the early spring flood and the high waters in the spring are not caused directly by rains, but rather these are the consequences of the snow accumulated in the winter and now melting.

In the drainage area of the Mures the melting of the snow is a quick process which significantly raises the stock of water. When the melting lasts longer, the slow and gradual water supply does not lead to floods. The Mures has two important floods in a year (spring and summer green flood), and both are equally dangerous (Andó M.-Vágás I. 1973). In the first case the snow melts in the mountains because of the strong insolation at the end of February. The river swells very quickly, but equally fast is the retreat of flooding (8-12 days). The spring flood of the Mures preceeds that of the Tisza, sometimes reaching its peak at Szeged when the flood ware of the Tisza has not even culminated at Szolnok.

Since 80% of the Mures drainage basin is made up of impermeable layers and because of the significant differences in level and the significant slopes the Mures becomes a quickflowing river (Andó M.-Vágás I. 1973). Considering the distribution of the precipitation of the drainage basin, we can approximate the dates of the floods. In the mountains and in the Transylvanian basin the quantity of precipitation increases from January to June and decreases from July to January. Therefore there are only spring and summer green floods on the Mures, and regularly it does not have a flood in the fall, as there are nolarger and significant rains in Transylvania then.

The precipitation of the drainage area is carried away by the dense water system of the Mures, therefore the water level of the river is influenced by the precipitation and the specific runoff and the circumstances of the accumulation as well. The specific runoff greatly varies, depending on the surface features, development and edaphic conditions of the given area.

In the high mountain areas of the drainage basin the specific runoff is 30-50 $l/s/km^2$, in most the Transylvanian basin it is 1-3 $l/s/km^2$, and on the plain it is below 1.0 $l/s/km^2$. Extremism characterizes the specific runoff of the individual drainage basins of the tributaries. For example, in the riverheads of the Aries, Ampoi and Geoagin, the average runoff is between 5-30 $l/s/km^2$, but the value corresponding to the highest water discharge is 350-1,000 $l/s/km^2$, and the lowest discharge is 0.8-1.1 $l/s/km^2$. The highest runoff values are observed in the riverheads of the Sebes, Strei and Riul Mare. Here the average runoff is over 40 $l/s/km^2$, the highest discharge can be over 1,000 $l/s/km^2$, but the lowest discharge is 2.0-6.0 $l/s/km^2$ (Tulogdi J. 1925; Újvári J. 1972). The affluents are characterized by the virulent changes of water level, the quick rise and the quick recession.

Hydrographically the drainage basin can be divided into two characteristic areas, a plain section and a basin surrounded by mountains. The varied drainage basin narrows down on the plain while it broadens in Transylvania. The drainage basin is expanded with asymmetrical hydrographical characterictics especially East of Deva. The highest point of the drainage area is 2,509 m in the Retezat Mountains, the lowest point is 78 m above sea level where the Mures meets the Tisza.

The Mures is a highgradient river, running on elevated surfaces to its mouth and keeping its gradient all along. The gradient is evenly distributed. For example it falls 46 cm/km from Ludus to Alba Julia, 40-43 cm/km to Branisca, to Savirsin, to Rodna and 38 cm/km from Rodna to Lipova. In the Alföld, its gradient decreases somewhat, but the number of the bends significantly increases. The development of meanders is especially important along the sections where bed gradient is small (Periam, Perjámos; Egres, Csanád, Kiszombor, Szőreg.)

In the Alföld the width of the bed also varies, for example its average width is 150 m between Rodna and Pecica, 180 m between Pecica and Csanád, and 100 m between Csanád and Tápé. The river bed stretches out in the plains so that its water depth reduces, while at other sections it narrows down and deepens.

There can be distinguished four sections of the river bed with uneven gradients: 1. Lipova - Zsigmondháza, 39.8 km, 0.28 m/km gradient; 2. Zsigmondháza-Pécska, 23.6 km, 0.44 m/km gradient; 3. Pécska-Csanád, 52.6 km, 0,28 m/km gradient; 4. Csanád-Tápé, 37.5 km, 0.13 m/km gradient.

The environment of the riverbed is varied by different age terrace formations. Of these, the Old Holocene terrace can be found occassionally 10 meters above mean water level. These terraces are not covered even by the highest flood. The Holocene terrace is made up of mainly alluvium piled up in the Pleistocene, rinsed through and resturctured by the floods of the river. Several upper Pleistocene terraces can be observed which do not form a continual terrace system (Fig.3). These are 20 m above the river flats: A coarse pebble layer containing loess and red clay covers the Pleistocene terraces.

In the mountain valley there are several Pleistocene terrace remnants 40-60 m above the river flats. In the mountain section frequently different cliffs stand out of the river sediment. Occassionally there are no terraces and the river had deepened into the bedrock (between Deva and Lipova).

On the Alföld section of the Mures a different development of the valley has taken place from the Pliocene till now. Leaving the mountains, the river built a talus which is spreading out fan-wise. Only in the Holocene did the river took on a definite direction on the alluvial system and this riverbed usually coincides with the seismotectonic lines of the Alföld (Márton Gy. 1914).

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Geocritical Region of Environment Dynamics "The Curvature Carpathians"

Dr. Ion Mac[1]

"The scientific programme" of the International Congress Washington 1992, once more demonstrates that geography is the "science of multiple approaches" (Taillefer,F. 1972). However, upon sharp opservations we can distinguish two fundamental trends: a., global examination of terrestrial cover; b., spatial organisation of this cover.

Terrestrial (geographical) cover represents "an extremely complex sphere" on the upper part of the crust where a strong interdependence works between abiotic, biotic and human elements.

However, the direction and intersity of these exchange processes differ from one place to another on the geographical cover. As a consequence the Earth surface has a great physionomical and functional diversity, generating distinct spatial system which are working between specific territorial limits, that is to say, geographical regions.

From the very beginning until today, geography has had one scope: the knowledge of territorial realities (globally or partially) as the "home of man" (Ritter,C. 1859). Today this scope is essential, as the deterioration of the environment has become considerable.

The relationship: geographical cover-society means "total environment" or "global environment and matrix of life" (Rosu,Al. 1987).

The regional coordinates of geographical cover determine functional subtlety and an extremely varied dimension of human activity. It is exactly on the regional level of geographical cover that the complementarity between resources (abiotic, biotic and atropic), stock and human need becomes evident. That is why the ambiental favourability or geographical optimum can exist only on the regional level of organisation.

In the context of geographical organisation and participation to environmental research and our objective being the regional level one can raise a question: What kind of a region is the geographer dealing with? The reason of this question is the fact that geography operates with the following categories of regions (Mihailescu,V. 1964):

- geographical region, that means natural region transformed by man;
- physical geographical region, that is a geographical region seen in its physical components;

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-economic geographical region which is a geographical region seen in its social and economic components.

Accordingly, the envirenmental research supposes to define a new region. That is why we suggest the term: environmental geographical region for a concrete territory where the strong relationships between the human collectivity and the integral geographical environment are manifested.

Consequently, when the geographer has to study the environment he has as a first objective the environmental geographical region. This region has to be studied from the structural, functional, dynamic and typologic point of view.

Starting with the definition of environment, that represents a unity of natural and human factors ensuring the evolution of natural and social life on Earth, the geographer has to establish the way in which these factors fulfil their role. That means to estimate "the state of environment" of one given region. The quality of this state determines the character of environmental geographical region. There are two basic categories: environmental geographical region in balance, and critical environmental region. The former has a balanced territorial relationship between society and environment; while the latter can be characterized by aggressive manifestation of environment by society.

The character of such regions is expressed not only by the display of a single component (natural or human) but by the regional association and interrelationships of parts which "aim" at a territorial equilibrium.

Human efforts to reduce the friction between environment and society are very often fustrated by risk. A risk phenomenon represents a feature of the critical regions.

Human communities react differently to the potential negative effects of environmental processes. The necessity to control critical phenomena and ensure its future existence determines the cautious actions of the population.

The ancestral experiences determine that the regional economic activities from the critical territories should de viewed very often, as an extention of the state of environment.

Taking into consideration the origin of the critical factor, the geographical environmental regions can be classified as: geocriticalgenerated by the natural factors aggressiveness; and sociocriticalas a result of the negative and voluntary manifestation of human communities.

Therefore if we apply the principle of determining factor we can define the critical nature of the regions. The geographical research of these territories represents a condition of better understanding of realities. Consequently, the development of environmental regional geography, a very useful discipline, is very badly needed. A prime necessity is to give emphases to the typical critical regions.

The Curvature Carpathians from Romania (know as Carpathians and Subcarpathians) situated between Trotus Valley and Prahova Valley represents a unique geographical region in the Alpine-Carpathian System (Fig.1). The essence of the model is based on the nature of interrelationships and of temporal-spatial juxtaposition between the factors of mobility. Its particular features are determined by fragility of the environment and are reflected in the architecture of human communities. The natural susceptibility to environmental lack of balance derives from a couple of controlling variables.

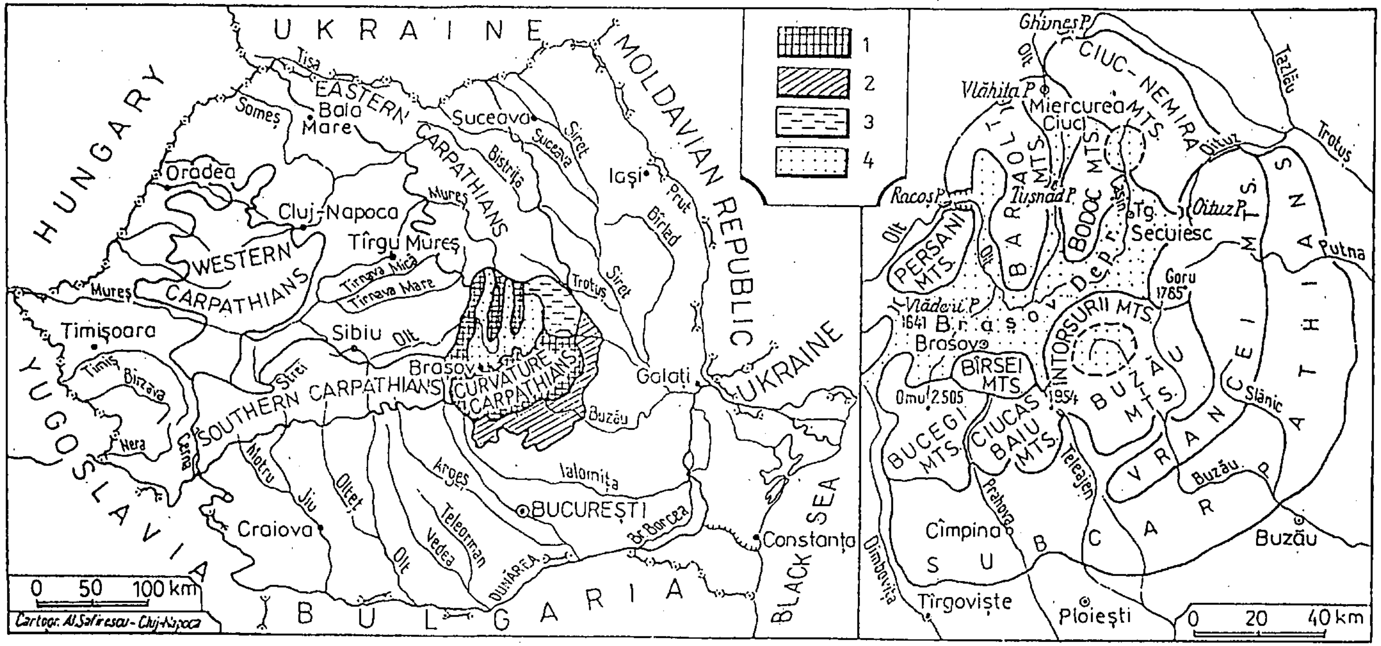

Figure 1 Location of Curvature Carpathians in Romania (a) and its subdivisions (b).

Thus the extremely active geodynamics, caused by plate collision: Euroasiatic plate, Transylvanian plate, Moesic and Black Sea plates and the compression of Carpathian substratum (Fig.2) between the other plates (Socolescu,M. et al 1975) determine frequent earthquakes followed by faulting and mass movements. Between 1100 and 1977 there were on an average three earthquakes in Vrancea, seven degree on Richter scale (Constantinescu,I.-Enescu,D. 1985). Very favourable supports for active morphodynamics are the petrographic making up (flysch and molasse) and extremely diverse geologic structure on a restricted area (hog-backs, thrust-sheets, folds).

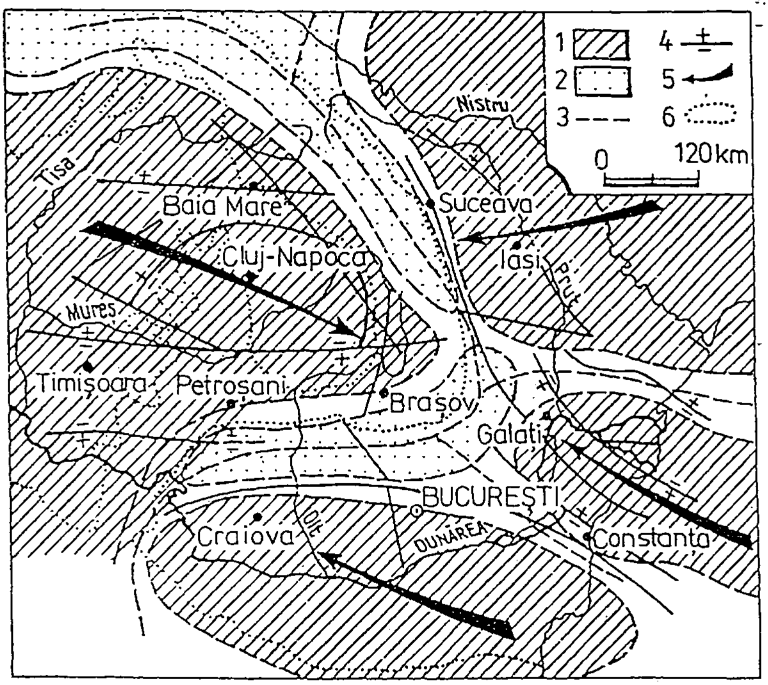

Figure 2 The sketch of reflected plate segments using the regional gravimetic anomaly (Airinei,1977): 1.regional anomaly of maximum (plates); 2.regional anomaly of minimum; 3.axes of minimum; 4.field of crustal faults; 5.direction of plates and microplates movement; 6.mountain area limit.

The intense vertical movements of uplift (+2.0 - +4.0 mm/year) or even (+4.0 - +6.0 mm/year) in the folded area (Visarion,M. 1977) or subsiding movements on mountains basins (Brasov basin: -2.0 - -4.0 mm/year) and on adjacent fields (Rimnic Plain -0.5 - countributing to the maintenance of the critical ambiental state.

Also the new surface (Paleogene-Quaternary) with high relative relief (over 58% from the territory is between 150-600 m), high drainage density (over 3/4 from the area has values between 0.5 and 2.8 km/km^2) and high gradients (frequently over 35°) are extremely favourable for processes with the highest erosional rates in Romania. Sediment discharges for some drainage basins of 5 and 10 km^2 are over 4,000 m^3/km^2/year (Ichim,I.-Radoane,M. 1987).

The meteo-climatic conditions are full of contrasts and characterise the entire region. It is here that the lowest temperature in Romania was registered: -38.5°C in the Brasov Depression (Bod, January 27, 1942), corresponding to the highest temperature in Romania: 44.5°C registered in the Braila Plain (Ion Sion, August 10, 1951) on the exterior margin of the Curvature. Anotherextraordinary phenomenon is the presence of "warm" periods in winter in the Subcarpathian belt in comparison with the outer region having very cold weather. This is explained by air-pressure evolution and foehn phenomenon. Rainfall quantities: 600 mm/year in Brasov Depression 1,100 mm/year on Curvature Mountains and only 480 mm/year on Curvature Subcarpathians together with their torrential regime (80-200 mm/year in May-June) stimulate an extremely active morphodynamics on river beds and hillslopes.

On such petrographic, relief and climatic conditions, the river network, runoff régime and underground wathers presents spatial and temporal changes over: all year humid surfaces (Brasov Depression) and surfaces with seasonal water deficit (exterior Subcarpathian belt).

The natural vegetation (forests and grassland) together with soils were unrationaly exploited so that they are now on different stages of degradation (more than 60% from Curvature territory are degraded surfaces). On a wide stretch of this belt there are many vegetal associations without any economic value (brables, derived birch forests).

The geographical cross-road position and its varied resources (oil, natural gas, salt, forests, pastures, wine-growing and fruit-growing terrains) represented the reasons for an active geo-economic appeal which led to a graded but strong human impact which is characterised, today, by a rapid degradation of the natural support of human communities.

The bad-lands or "bad Buzoian land" are the expressions of environmental degradation and the lack of urban settlements in Vrancea together with a weak development of communication system are the expressions of precarius stability.

Environment fragility in this geocritical geographical region frequently manifests itself in risk phenomena (earthquakes, massive landslides, intense fluvial erosion, accelerated erosion on hillslopes, muddy volcanoes) has both immediate (short time) and distant (long time) consequences.

This geocritical region has a binary spatial structure with distinct nuclei of manifestation: the Brasov Depression nucleus with a strong critical character due to climato-hydric factors together with the human factors having massive population concentration around Brasov (200 people/km^2); the Vrancea land nucleus with a critical profile due to earthquakes, morphodynamic, climate and population features. There are still strong socio-economic relationships between these two regional nuclei.

The fact that the geocritical environmental region of Curvature Carpathians is densely populated since ancient times, explains why we witness today the "exhaust" of the last forms of landscape resistence to risk phenomena.

Under such circumstances there are only two alternatives: the elaboration and sustaining of a regional plan for rational exploitation, or human amplification of the critical character until global degradation stage wich will lead to a gradual depopulation of some territories (especially in Subcarpathians) and to growing poverty.

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A Study of the Karst-Ecological System on the Example of the Bükk Dolines

Dr. Ilona Bárány-Kevei

The early research on karst morphology examined primarily those phenomena that lead to results unfavorable for mankind, for example, collapses of caves, floods of the poljes, erosion of the soil. Since the beginning of scientific karst research in the mid-eighteen hundreds the field underwent a considerable development. Today the inspiration of progress is still the human perspective, but from the opposite direction. Today the focus of research is not primarily how karstic development influences mankind, but on what influences of human activities have on the karst system.

The karst committee of the International Geography Union founded in 1984 in Paris (Mans Impact on Karst Area, then Environmental Changes in Karst Areas) proposed to study the impact of human activities on karst areas. The presentations and the discussions reassured my earlier concept that there is a growing need for interdisciplinary studies which would describe the full ecological system of karst. The examination of the entire karst system is the task of the karst morphologist, as the external environmental influences effect the surface or the subsurface in one part of the geographical area, where the geographical or, in a broader sense, ecological regularities govern the processes. The study of karst-ecological systems is complex, requiring the application of the established methods of other fields and the synthesis of the information gathered for the whole of the system.

Daoxian, Y. (1988) reviews the major elements of the karst environmental system. He regardesd the karst as the system of the rock, the soil, the living organisms and the energy working within them. Goudie, A.S. (1988) traces the development of the surface of limestone ecosystems back to the bedrock, the climate and its actual effect and the human activities. Viles, H.A. (1988) distinguishes three components of karst ecosystems: the subaeric limestone surface, the soil-covered limestone surface and the system of caves formed. This view separates the elements of the karst-ecological system.

In my view, the karst-ecological system begins with the air level contagious with the surface and the vegetation covering the karst area, and it ends with the karstwater system and where it reaches the surface, the karst springs. The karst system is open, as the flow of matter and energy is unrestrained through the soil towards the rock (Fig.1). This process is reversible till the boundary of the rock and soil, and external interference can reduce the unfavourable effects. Under the weathered level of the rock the effects become irreversible,

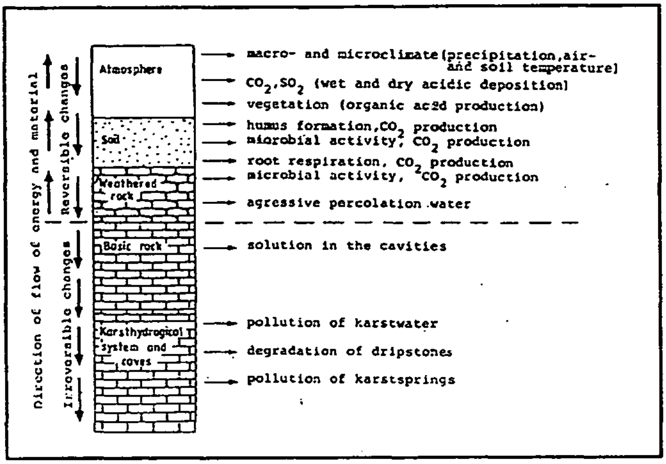

Figure 1 Scheme of karst-ecological system

with only a minimal possibility of their modification in the cave system. Until then, however, the natural processes can alter in the rock borders in ways that can be expressed in morphology. I think here of the considerable alteration of the aggressivity of the solutionwater in the soil, which, in an extreme case, would reach the dripstone formations and could induce degradation phenomena.

Karst-erosion is basically of biogenic character, and this also justifies the importance of karst-ecological research. The impact of living organisms on thekarst formation is more substantial than on the decay process of other rocks. Karst-ecological research is needed, on the other hand, because karsts are open systems, where external impacts, including those of human activities, show their effects very rapidly, there is no time for the soil or the rock to buffer these outer influences.

In my earlier studies I examined several ecological factors from the point of view of the development of solution dolines. I consider the climate as the most important exogenous factor. Among the constituents of climate, precipitation and temperature has the most important influence on karst development. In microareas the microclimate becomes the fundamental factor concerning karst solution. The differences of microclimate greatly contribute to asymmetric doline-development (Bárány I. 1967,1985; Bárány-Kevei I.-Kajdócsy 1976).

Fig.2 shows the formation pattern of air temperature in the microregion of a Bükk doline during some clear summer days. The soil temperature was also extreme in the doline. The daily amplitude of the soil close to the surface was 15°C on the Eastern slope, but at the same time it was 5°C on the West-Southwest slope of the same doline.

It is also interesting to examine the tendency of the heat transmission processes of the soil temperature towards the deeper layers. Following the $y = a+bx+cx^2+dx^3$ formula, I plotted the approximate curves of the maximum and minimum soil temperature of different slopes depending of depth (Fig.3). The inflexion points of the slopes denote the points in the soil where the speed of heat transmission changes. Both the maximum and minimum values show the greatest divergence between the Eastern and the Western slope.

This difference influences the vegetation covering the surface as well. Species preferring moisture thrive on the Western and Southern slopes, but elsewhere species more

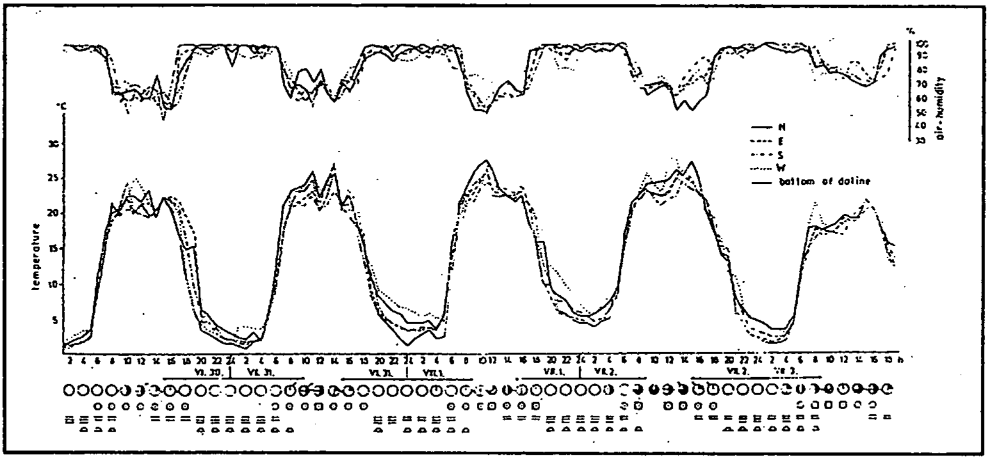

Figure 2 Air temperature and air-humidity in a Bükk doline (Hungary)

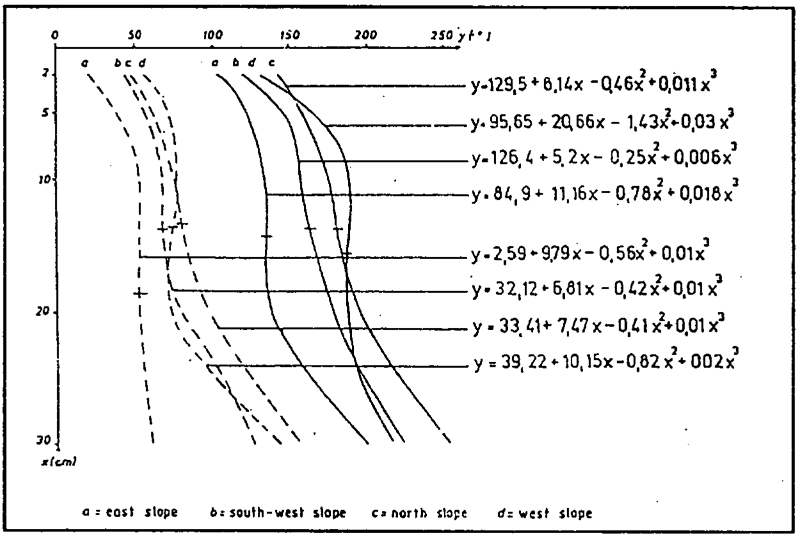

Figure 3 Maximum and minimum soil temperature on different slopes

resistant to drought can be found.

On the soil-covered karst surfaces we consider hidden karsts (Bárány-Kevei I.- Jakucs L. 1984) the impact of the micro-climate and vegetation is present through the soil. The thickness, permeability, physical and chemical characteristics of the soil play a determining role in the solution under the soil (Bárány-Kevei I. - Mezősi, G. 1978; Bárány-Kevei I. 1980; Bárány-Kevei, 1987).

The chemical characteristics of the soil are largely influenced by the content of the water soluble cations and anions, therefore their examination is necessary when studying solution under the soil. Fig.4 present the water soluble anion and cation contents of Bükk dolines. For the purposes of comparison, I also present the relevant data of some Dinaric

Karst soils (Fig.5). The low anion and cation content of the Bükk dolines is notable, especially compared to the Yugoslavian data.

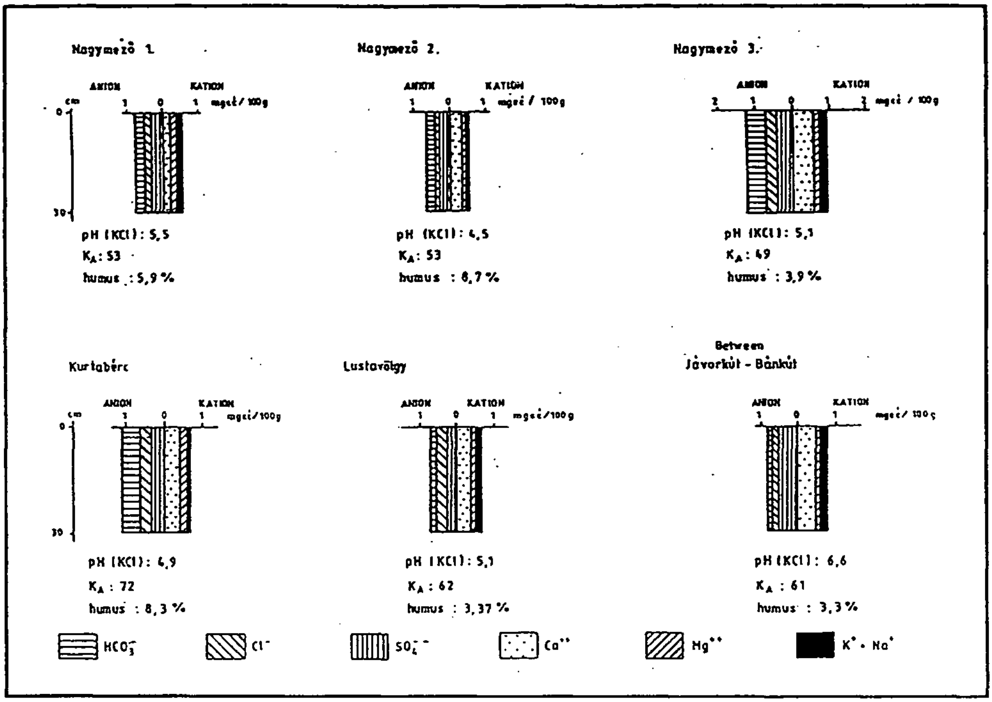

Figure 4 Water soluble anions and cations in the bottom of doline (Bükk Mountain, Hungary)

The soil plays an important role in karst-corrosion as the medium of the biogenic factor. Besides the carbon dioxide the roots of the macroflora generate, the microorganisms living in the soil also produce CO_2 when decomposing organic matter and modifying the chemical characteristics, thus influencing the aggressivity of the solutionwater (Bárány-Kevei I. 1990). The microbial activity is prominent at 0.5-1.0 m depths, resulting in considerable carbon dioxide production. In the deeper layers of the soil the activity of the microorganisms decreases, only to increase again on the soil-rock border.

The density of the bacterium population is closely connected to the humidity, pH value and cloudedness of the soil.

The exogenous ecological factors discussed so far can have both advantageous or disadvantageous impacts on the processes of rock solution. In this level some interference is still possible to lessen disadvantageous (polluting) influences. The impact of the water reaching the rock border, however, cannot be moderated, the reactions it induces are irreversible. Such reactions include for example the degradation phenomena of the

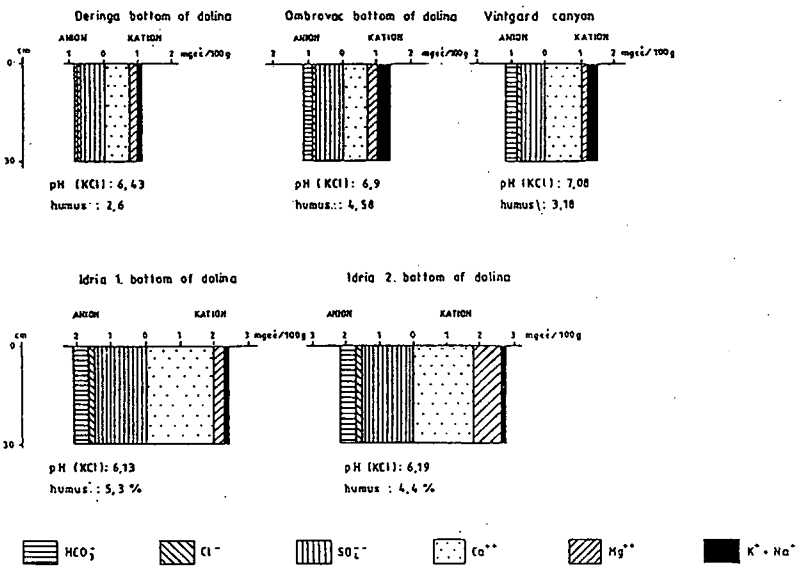

Figure 5 Water soluble anions and cations in a karst soil in the Dinaric Karst (Croatia)

dripstones we described in some European caves or we can even mention the pollutants appearing in the karst water system, which then proceed through the karst system and appear in the karst spring.

The overview presented here can convince the researcher that one of the major tasks in karst research is the exploration of the ecological system of the karsts. Only by knowing these processes can we correct the irreversible disadvantageous impacts of human activities on the development of karst systems.

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Chronological Problems of the Szemlak Fossil Soil Profile

Róbert Géczi[1]

In Transylvania, the buried paleosoil seqvences can be found on the terraces of major rivers, the Szamos, the Maros, the Olt. Of the exposures, the Szemlak seqvence is suitable for stratigraphic correlation.

The studied exposure is situated in the Quarternary fluvial deposits, five kilometers Southwest of Szemlak, on the right bank of the Maros (Fig.1). In the Holocene the flow of the Maros shifted further North, by-passed its own talus and occupied its present position North of the Vinga plain, in the Lippa-Arad depression. The bahada-type Vinga sediments also appear as enclaves on the right side of the Maros. This explains why the Szemlak plain of 110-114 m above sea level is surrounded by a lower (92-108 m) plain to the North, West and Southwest. West of Arad the Maros River filled the area with Levantean and Pleistocene pebbles alternating with clay and sand. This fluvial alluvium is covered by Eolithic dust and loose deposit. These latter formed the loess and red clay seqvences.

Examining the texture of the layers of the profile, cycles of alternating loess and red clay can be observed. The texture of the latter is finer as a consequence of the pedogenetic conditions during their formation and deposition. The texture of the loess and sludge seqvence reveals a typical loess texture in which the cementation of the finest particles resulted in 2-20 micrometer diameter aggregates. It mainly consists of clay (37.8%) and silt (28.8%). The proportion of the sand fraction is insignificant.

Red clays are usually fossil soils formed in humid climatic conditions, or can be considered as the "B" zones of these soils. Their textures are of a more varied compound: clay (38-51%), silt (24-29%), fine sand (26-30%), coarse sand (0.1-0.5%).

The humus content is low: 0.4-0.6 % in the buried soils and 0.15-0.4 in the loess pockets. The greatest part of the organic matter has oxidated.

The vertical distribution of the carbonate content is uneven. It is low in the buried soils, but high in their accumulation levels and in the loesses (10-16%). As a result of the climatic change during loessformation the carbonate content considerably changes within the loess pocket. The silt horizons can also be mentioned here, as they practically lack lime.

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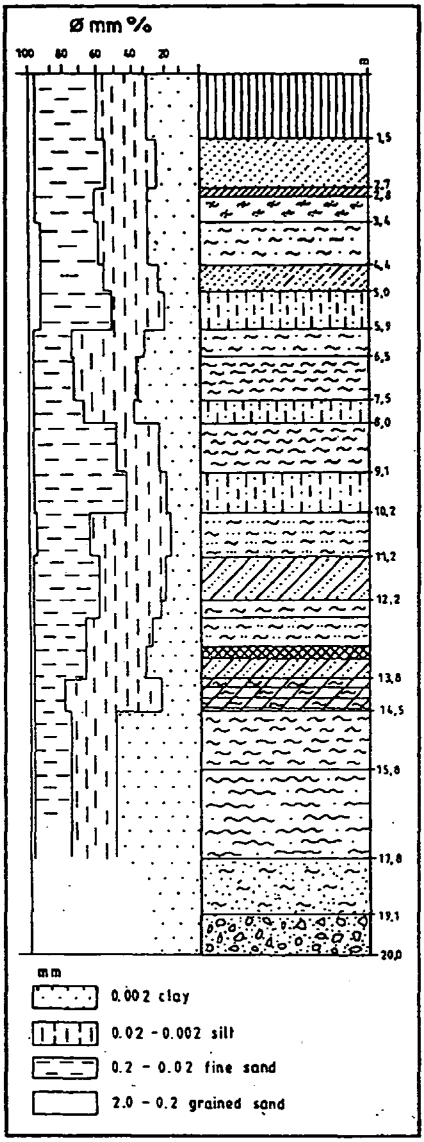

Description of the profile:

In a 16 m seqvence four red clays are alternating with loess:

0.0 - 1.5 m	weakly developed chernozem-type soil
1.5 - 2.7 m	loess
2.7 - 2.8 m	loess-like substance
2.8 - 3.4 m	light, clayey loam
3.4 - 4.4 m	yellowish brown clay
4.4 - 5.0 m	loess with lime concretions
5.0 - 5.9 m	brown silt
5.9 - 6.5 m	yellowish brown clay, containing manganese oxide
6.5 - 7.5 m	red clay, containing manganese oxide
7.5 - 8.0 m	compact silt with clayey texture
8.0 - 9.1 m	red clay, containing manganese oxide
9.1 -10.2 m	silt
10.2 -11.2 m	yellowish clay, not containing $CaCO_3$ concretions
11.2 -12.1 m	loess, with lime concretions
12.1 -12.6 m	red clay
12.6 -13.3 m	brownish red clay
13.3 -13.4 m	cemented lime accumulation level
13.4 -13.8 m	loess
13.8 -14.5 m	grey, very dense substance
14.5 -15.8 m	red clay, containing lime and manganese oxide spots
15.8 -17.8 m	purple clay
17.8 -19.1 m	sandy clay
19.1 -20.0 m	coarse sand and small pebbles

Figure 1 The Szemlak Fossile Soil Profile

Conclusions

A widely accepted explanation for the alternating buried soils and loess seqvences is that the former substance formed in the interglacial and the other in the glacial phases (Popovat, M. et al. 1964; Fotakieva, E. 1972). Others (Florea, N. et al 1965) argue that the soils formed in the humid glacial and the loess in the dry interglacial (interstadial). The formation of a soil or soil complex cannot always cover a whole interglacial or interstadial. These prove the presence of erosion gaps in loess exposures in spite that "older loesses never display an unbroken layer sequence." (Pécsi M. 1991)

Concerning the climatic conditions of soil formation, the exclusive consideration of the research results lead to the conclusion that the drier the climate and the closer the original location of the substances carried away by the wind, the coarser the texture of the eolican layers. The high proportion of the carbonates also points to a dry climate. The chernozem-type soils form under the influence of dry climatic conditions, while the formation of well-developed B level forest soils and the reddish loam soils require humid climatic conditions. Characteristic of the humid and cold climate are the podzol-type soils and the frost phenomena (which are more prominent in the loose sandy-pebbly sediments because of the high groundwater level.)

The formation of the permanent and successive soil and loess series is the result of the perpetual climatic instability. This basically reflects the glacial-interglacial phase changes of the end of the Quarternary. We can suppose that these young loesses and the fossil soils between them are the remainders of not only the Würm, but also the Riss-Würm glaciation and warming up. Compared to the earlier ones, these two glacials are more closely connected. The chronological periodization and correlation of the loess and the buried soils are disputed questions even today. The formation of the soils conform to the climatic types described as subtropical by Bacsák (Bacsák Gy. 1942) and as moderately oceanic by Barriss (Barriss, 1991). In contrast, the loess and silt horizons are characteristic of the glacial (Bacsák) and the strongly oceanic (Barriss) climatic types.

We can conclude that the Szemlak seqvence reflects the Quarternary climatic instability. Its presumed age is presented in Table 1. on the basis of grain size and pollen analyses and its geomorphological position.

Table 1 Paleographical interpretation of the data

depth	name Barris	climatic Bacsák	type	pollen content	presumed age	Ka
0.0- 1.5	weakly developed chernozem-type soil	SDP	st	Artenisis,Almus,Quercus,Pinus,Ulmus	Holocene	15
1.5- 2.8	loess	SO	gl	Compositae,Ulmus	Würm III	15-30
2.8- 4.4	brown forest soil	MC	st	Pinus,Quercus,Compositae	Würm II-Würm III	30-50
4.4- 5.9	silt	SO	sa	Tilia,Quercus,Compositae	Würm II$_2$	50-60
5.9- 7.5	brown forest soil with clay washed in	MC	st	Pinus,Quercus,Tilia,Compositae, Gramineae	Würm II$_1$-Würm II$_2$	60-70
7.5- 8.0	dense silt	SO	sa	Tilia, Fagus	Würm II$_1$	70-80
8.0- 9.1	brown forest soil	SDP	st	Tilia,Ulmus,Quercus,Juglans,Almus, Acer,Pinus,Gramineae	Würm II	80-100
9.1-10.2	lehm	SO	sa	Tilia,Quercus,Chenopodiaceae,Polygonaceae	Würm I	100-115
10.2-12.1	loess	SO	gl	Pinus,Acer,Alnus,Quercus,Tilia,Compositae	Würm I	115-120
12.1-13.4	forest soil	MO	st	Pinus,Quercus,Acer,Betula,Tilia,Compositae	Riss-Würm interglacial	120-150
13.4-13.8	loess	MC	gl	Gramineae,Tilia,Salix,Umbelliferae	Riss-Würm interglacial	150-160
13.8-15.8	forest soil	MO	sa	Tilia,Quercus,Pinus,Compositae,Gramineae	Riss-Würm interglacial	160-170
15.8-17.8	purple clay	-	-	-	pre Riss-Würm interglacial	-
17.8-19.1	sandy clay	-	-	-	-	-
19.1-20.0	coarse sand and small pebbles	-	-	-	-	-

Legend: gl = glacial; sa = subarctic; st = subtropical; SDP = small different from present;
SC = strongly continental; SO = strongly oceanic; MC = moderately continental;
MO = moderately oceanic

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New morphometrical parameters for explanation of karst development

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As it is known, either because of the sparse water network of karst areas or part because of the difficulties in determining the order numbers and water course densities of the subsurface water systems in addition to other properities, we cannot examine the morphometric conditions of a karst region with the method developed by Horton and Strahler (Williams, P.W. 1975, La Valle, P. 1968). In our previous studies (Mezősi, G.-Bárány, I. 1978, Bárány I. - Mezősi G. 1979, Bárány-Kevei, I. 1990) the morphometrical investigations of the micro- and mesoforms eg. springs, swallow-holes, dolines, karren were examined in Aggtelek and in Bükk Mountains (N-Hungary). We proved that the swallowhole density can be given by the value $D^s = \Sigma S/A^a$, where ΣS is the number of swallow-holes and A^a is the size of the area examined. The decrease of the number of swallow- holes per unit area confirms the more developed nature of the area. In similar way we can also give the number of springs per unit area: $D^r = \Sigma K^r/A^a$, where ΣK^r is the number of springs. The quotient swallow-hole/spring ($R = \Sigma S/K^r$) indicates the magnitude of the extent of the subsurface flow. We have established the regularity in case the autogenic - A-type (Jakucs, L. 1971) karsts the value of R is less than 1; in the case of allogenic, erosional - B-type karsts R is greater or equal to 1. This can be explained in the B-type erosional channel network is fed only by the swallow-holes of the convergence zone, but other swallow-holes of the karstic terrain too. At the same time, in the divergence zone every karst spring is mobilized only in the case of a large amount of water.

In the present study a morphometric investigation of dolines, which are the most important forms of karst, is given for the above mentioned territory from the point of view their genetic questions. It is known that in many case the morphometrical results must not utilize to solve genetic problems, so we tried to control our conclusion in many respect.

More than 80 dolines from Aggtelek and Bükk Mountains have been studied. First the elongation ratios (ratios of the largest and smallest diameters) and the orientations (azimuths of longer axes of the dolines) were investigated. The elongation ratios and extents of dolines depend on the variations in geological, hydrological and ecological elements of landscape. From the aspect of the elongation, the most important role is the structural preformation (the longer diameters of the depressions are parallel to the breaks of fractures). Here the most effective infiltration permits more effective corrosion or more intensive karst development for a certain time. It was found that in Aggtelek Region the uvalas are characterized by an elongation ratio larger than 1.65 and in Bükk Region over 1.25.

The direction of the main axis of the dolines - the orientation - in both regions is NE-SE or W-E. The proportion and direction of elongation as well as the proportion of the internal relief are roughly the same and this means that a general tendency referring to genetics is expressed in the asymmetry.

While the orientation is connected to the tectonic or fracture directions, the assymmetry is mostly the result of the expositional differentiation of ecological factors. The decisive exogenic factor in the development of dolines is climate, which roughly controls the impackts of the ecological factors. The dolines modify the radiation effects creating an independent microclimatic system. The different slopes further dissect the microclimate of the doline within the microclimatic area resulted from the closedness of the karst depression. The symmetry axis of the air temperature in N-S segment shifts in the direction of slope facing S. The minimum temperatures shift in the direction of slopes at night in case of fog (Bárány-Kevei I. 1985).

The microclimate results in considerable differences in soil of the dolines depending on their exposition. The microclimatic changes can influence relation of humidity, micro-biological processes, flora, fauna, intensity of corrosion of the soil. This altered parameters may influence the morphometry of dolinas (Bárány-Kevei,I. 1987).

The relief ratios of the dolines may be measured with the depth/average diameter quotient; this has already been employed by Cvijic. We found that the relief ratios of the tectonically more directed "row-dolines" are smaller (generally beeing below 0.1) than the "plateau-situated" or tectonically not directed, ordered dolines (above 0.1). The apparent contradiction arising here - for it would be expected that the deeper dolines would be found in the area with the more extensive tectonic effect - seems to be solved in following way. The row-dolines of the temperate zone (which may occupy a tectonically preformed fracture, or earlier river valleys) display more effective development, because of the more intensive infiltration than the isolated "plateau dolines".

Our investigations verified the following assumption. Whereas karst corrosion is promoted by redeposited soil cover that is not very thick, it is strongly hindered by very thich soil (mainly washed down to the bottom of the dolines) because of the impermeability of the red clays. The dissolution will then be most effective on the doline rim. Hence in the continental regions the development of dolines proceeds by widening rather than by deepening. With a decrease in absolute height of the surface or the col between the dolines. The dolines covered by thinner soil cover are mostly developing lingeringer than the thicker soil cover ones.

In comparison of row-dolines in Bükk and Aggtelek Mountains we have described some new morphometric parameters. We have drawn relative levels with level differences in one meter in the dolinas investigated, than we have determined the size of areas belonging to certain level and intersected by that (A^1, A^2,...) and we have measured intersected margins by certain levels too (P^1, P^2,...), see Fig. 1.

1. At first we have compared the size of areas and peripheries (above mentioned) to the depth (d). The quotient of A/d proved to be 1.0 - 1.15 in case of Bükk Mountain and 0.9 - 1.0 in case of Aggtelek ones (Table 1 and 2).

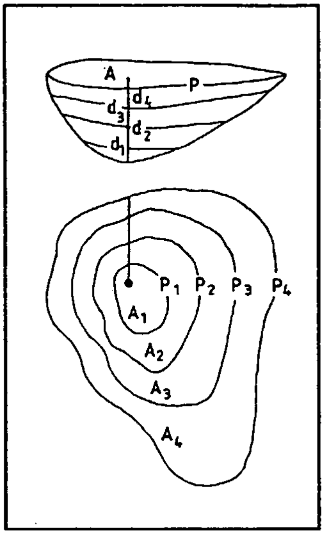

Figure 1 The A^i and P^i parameters of the dolinas

2. An other characteristic quotient could be established when A^i is compared to A^j. In the change of quotient we have observed a characteristic feature. On the slopes of the dolines of Aggtelek Mountains on their slopes from up to down the quotient is increasing moderately at first, than decreasing slowly or stagnates.

3. We have introduced a new quotient for the determination of assymmetry of dolines. We have compared the total slope length of a certain direction of cardinal point. This means we have calculated the quotients in the following manner:

$$N / N + S , E / E + W \quad \text{etc.}$$

The representation of the average quotient in a systemcoordinate (where the point of intersection is center of symmetry) may result in the following conclusion: the E-W component of the dolines in Bükk Mountains are much larger than the Aggtelek ones (Fig. 2.).

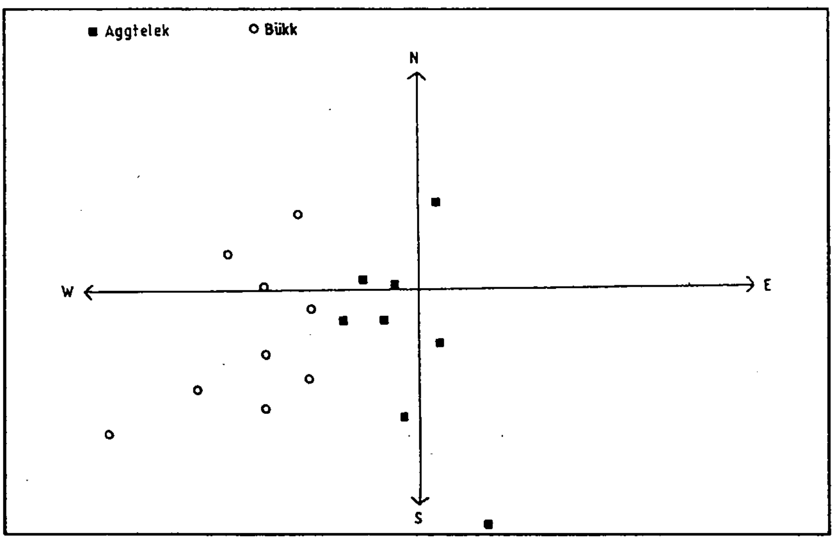

Figure 2 The deviation of the axis-components of the Aggtelek and Bükk dolines from the symmetrical

To distinguish between the doline types on the Aggtelek Karst Region a most obvious task is to establish the number and total area of the dolines. In this region we differentiated three doline types, mainly on morphometric and lithological basis. These three groups were examined from a morphometric aspect, at present on the basis of the following three indices:

a/ the number of dolines per km (doline density)

b/ The percentage ratio of the total area of the dolines to the size of the given karst surface (this is reciprocal of the index of pitting used by Williams)

c/ the average area of the dolines.

Our results are listed in Table 3. and on Fig. 3.

Table 1 Morphometrical parameters of typical dolines in Aggtelek Mountain (N-Hungary)

Parameters	Dolines							
	B1	B2	B3	B4	B5	B6	V1	V4
1.	45	157	7	73	56	51	35	157
2.	10	13	11	14	14	8	10	18
3.	108	115	185	120	95	120	185	320
4.	78	101	83	54	29	61	31	137
5.	93	108	134	87	62	98	108	228
6.	21060	37748	42226	22680	9642	14640	14337	197280
7.	1.80	1.09	2.25	2.19	1.08	0.86	1.08	1.48
8.	0.11	0.12	0.09	0.08	0.16	0.10	0.14	0.10
9.	54630	73781	113143	48149	24756	51069	73564	327476
10.	0.98	1.40	0.98	0.98	0.99	0.88	0.98	1.03
11.	0.84	0.83	0.80	0.81	0.86	0.78	0.58	0.87
12.	0.75	0.65	0.70	0.64	0.76	0.76	0.70	0.78

Parameters: 1- Asimuth(°), 2- Deep (m), 3- Diameter (m), 4- Diameter As+90 (m), 5- Average diameter (m), 6- Volume (m), 7- Elongation ratio, 8- Relief ratio, 9- Area (m), 10- A/d ratio, 11- P/d ratio, 12- A/A ratio

Table 2 Morphometrical parameters of typical dolines in Bükk Mountain (N-Hungary)

Para-meters	Dolines							
	S1	S2	S5	S6	S7	S8	G2	G5
1.	145	85	72	136	92	128	35	14
2.	9	10	9	11	8	21	23	13
3.	72	107	72	78	54	102	120	84
4.	33	72	38	36	46	75	111	54
5.	52	90	55	57	50	88	115	69
6.	5346	19260	6156	7722	4986	40162	76590	14742
7.	1.08	0.85	1.01	1.27	0.95	1.09	1.01	1.17
8.	0.19	0.16	0.18	0.21	0.16	0.23	0.20	0.20
9.	17235	51182	19251	20784	15901	50017	84714	30430
10.	1.88	1.00	1.09	1.02	1.09	1.06	1.00	1.16
11.	1.09	0.85	0.85	0.87	0.89	0.97	0.87	0.90
12.	0.72	0.67	0.61	0.62	0.58	0.68	0.77	0.65

Parameters: 1- Asimuth(°), 2- Deep (m), 3- Diameter (m), 4- Diameter As+90 (m), 5- Average diameter (m), 6- Volume (m), 7- Elongation ratio, 8- Relief ratio, 9- Area (m), 10- A/d ratio, 11- P/d ratio, 12- A/A ratio

Table 3 Doline types of the Aggtelek Mountains.

	row-dolines	plateau dolines	
		dolomitic	limestone
doline density	11 - 13	32 - 36	7 - 9
total area of dolines as % of karst surfase	23	32	31
average area of dolines (km)	0.01	0.002	0.016

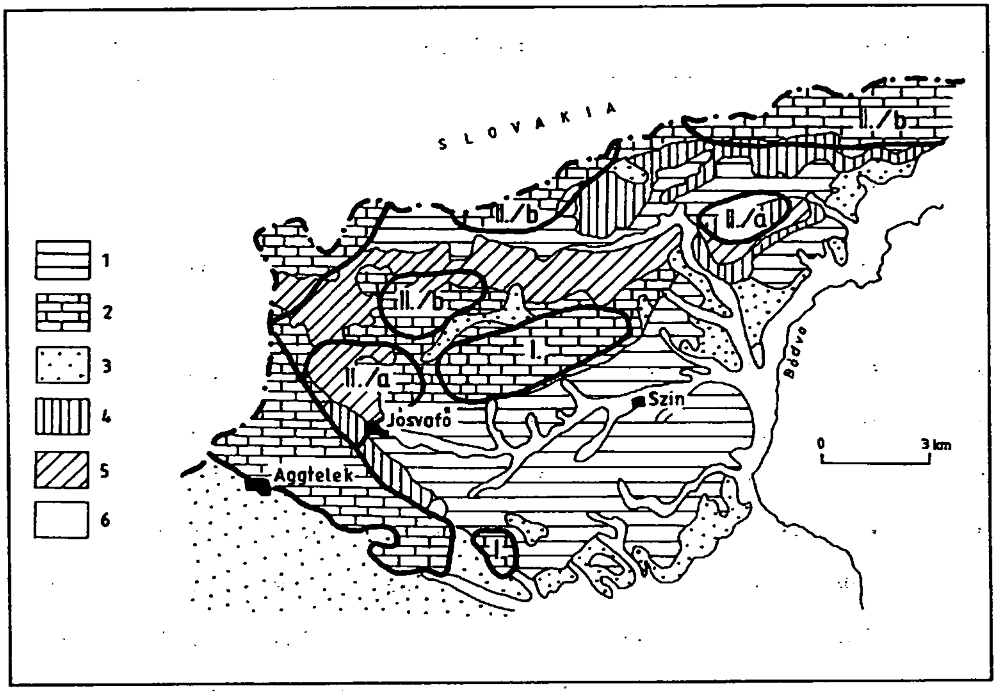

Figure 3 Geological map outline and doline types of the Aggtelek Hills
1 - Lower Trias limestone, clay slate; 2 - Lower Anisus (Gutenstein) limestone, dolomite; 3 - Wetterstein limestone; 4 - Wetterstein dolomite; 5 - Pliocene sediments; I - row dolines; II - plateau-dolines; a - dolomic types; b - limestone types;

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The Sensitivity of Karst Areas in 34 theses

Dr. László Jakucs

1# The appearance of every natural area expresses the impact of complex influences of the cycle of events manifested in the functional interrelationships and order of the geomorphic factors active in the past and present in the area. These factors also include, of course, the special crustal structure and rock province types of the area, since the territorial varieties of tectonics and rock quality are the results of the regionally variable crustal effects just as the aggregation varieties of the impact of exogenic energies.

2# The present geomorphological appearance of the land is formed by external factors with greatly differing effectiveness and durability in the present and in different periods of the past. A good example here is the high mountain regions of the Alps under the impact of Quarternary glacial effects, or the surface of the Canadian shield which has been eroded by an inland ice sheet, where hardly anything remained of the formations that existed before the glacial period. On rocky oceanic shores the effectiveness of abrasion can be sufficient destroy all previously formed coastal forms in a short time. Of course, there are beautiful examples of geomorphological conservation as well. We can refer to the development of the tracks of the Hungarian drainage network for example, that were not influenced in the least by loess formation, the most remarkable geomorphic factor in the region. This shows and proves that different geomorphologic properties **can have extreme capacities for resisting** the impact of subsequent surface forming phases.

3# We have to regard **sensitive land types** those that react sensitively to the morphogenetical factors making their special impact today, which are characteristic of the Recent, that is, under the influences of these factors sensitive land types change their trend or rate of development. We are hardly mistaken when we assert that there is only one geomorphic factor that had no part (since it could not have any) in the geomorphologic land formation: the exponentially increasing land energetic role of human society, the **anthropogenic impact**. Therefore the recent degree of sensitivity of different land types can be sufficiently analyzed in terms of the degree, the modes and results of the interactions of the land and the anthropogenic effects.

4# It would be far beyond the objectives and scope of the present study to assess the role of the anthropogenic effect in the formation of all major land types. I believe that this is the most important international duty of the present and of 21th century science of analytical geomorphology. At the same time, this is also an inevitable moral responsibility to the future of mankind. All I can assert now in the light of my research results is that **karsts are one of the most sensitive land types of the Earth.**

5# The extreme sensitivity of karsts is due to the fact that most karsts are **land ecological systems functioning in very complex ways**, that comprise sensitive balances connecting to and depending on each other. The karst as a land ecological system is defined by the **combinations of the interactions** of several petrographic, tectonical, climatological, hydrographical, macro- and microregional chemical, physical and biological factors. These factors are greatly variable in themselves, too, both in space and time. Therefore we had to dismiss the traditional definitions of the karst as a geomorphological notion, which all agreed in the simplicity of regarding the rock of soluble base (usually limestone) and the solvent (usually lime-aggressive) water interacting with it as the genetic conditions of different karst phenomena. This, karsts formed where the long interaction of water and the surface (or subsurface) rock resulted in special i.e. corrosion (solution) forms, that is, karst phenomena. These traditional definitions of karsts, however, do not account for all the processes and phenomena of the karsts, since for example they do not take into consideration the dynamics of the interaction of water and the rock surface, or the temperature of the interacting solid and liquid (sometimes solid and solid or solid and gaseous) phases, or their characteristics.

6# In my book **The Morphology of Karsts** (1971, pp 13-16) I have dealt with the issue of the different **karst definitions** and I have pointed out that it is very difficult to establish a proper definition because karsts are natural features constituted of many factors. Accordingly, they have several variations, where besides the role of water as solvent (or even without this factor) sometimes other karst forming factors can play a role, sometimes even with dominant or exclusive magnitude. Therefore the notion of karst formation **cannot be attributed only to dissolution of rock by water**, since we know such karst phenomena (collapsed-dolines, erosion limestone valleys and caves) where the condition for the formation is not the solubility of the rock in water. For example, a great number of hydrothermal karst phenomena also belong to this group.

7# The traditional understanding of karsts is very poor and ambiguous in shedding light on the corrosion karst processes as well, because it has attributed the formation of the karst phenomena to the dissolution of rocks by rainwater. The essence of this concept, still prominent in textbooks, is that the water falls on bare limestone rocks and escapes in its fissures and joints, then, due to the carbon-dioxide it receives from the air, it dissolves the limestone acting as weak carbonic acid. As a result, special formations appear on the surface rocks, **karr fields** are formed, and, as a result of the joint-widening effect of the solution, repeated limestone crumbles appear, forming dish-shaped, cauldron-like depressions, **dolines** on the plateau. The waters filtering deeper and deeper meet in the depth, and their concentrated, increased solution results in spacious alveoles, cave water passages. That is, the traditional understanding explains all special forms of limestone mountains, from surface dolines to caves in the depths, with the rock-solving impact of rainwater. **This model of karst genetics, however, does not hold any longer**. Today it is unjustifiable, groundless.

8# The classical karst theory received the first attack when researchers, on different continents and almost at the same time, started to examine the changes in the chemical composition of the rainwater filtering into the rock. It was asserted that the rainwater filtering into the joints of the rock becomes a decalcified solution very soon, **in a depth of almost only a few meters**. The **saturated lime solution** proceeding deeper, however, cannot dissolve more rock, except under very special circumstances. Thus the water reaching down to the caves in a hundred meters or more depth is, in most case not solvent. The 'karstwater', rather than dissolving, **deposits** the minerals dissolved and carried down from above. Dripstones build up from the lime deposit of the millions of falling waterdrops. So the vesicularization of the cave **can in no way be originated** in the dissolving work of the karstwaters.

We had to realize that the vesicular system itself is always washed out by the current of another, external water course **of a foreign water basin** in the inside of the of the limestone mountains, primarily by means of **scouring, abrading** of the solid alluvium of the streams (rivers) flowing in the karst. (The water filtering into the joints of the karsts essentially does not have such solid and hard deposits.) That is, **the cave is not the result of solution** but it is an **erosion stream-valley, a riverbed under the surface**. Thus a grand cave system is **not** necessarily a karst phenomenon, since it can form only in karsts which have a system of water courses receiving supply from outside and carrying along solid alluvial particles as well.

9# The stroke of grace for the traditional explanation of karsts came also from the chemical analysis of the filtering waters. The explicit chemical analyses confirmed that the average carbon dioxide content of the atmosphere of the Earth is only 0.03%, that is, so minimal, that rainwater cannot absorb even 1 mg of carbon dioxide per litre from the atmosphere. The carbon dioxide absorbed from the free atmosphere **does not increase** the limestone dissolving appetite of chemically clean (distilled) water, which is thus sufficient for the dissolution of only 10-15 mg limestone per litre. Had it been only for this amount, the wonderful solution karst phenomena of the limestones would hardly have formed, as the loss of 10-15 mg rock per litre is insignificantly small. Every other rock, even granite is soluble in water to an almost similar degree.

10# The water samples collected from the network of carbonate joints or from the inside of the caves, however, show something different. Their dissolved lime content reaches several hundred, sometimes even thousand (!) mg per litre.

Where does water absorb so great an amount of carbon dioxide that makes it possible to dissolve such amount of limestone? Studies have proven that it comes from the soil in all cases. Where the rock is covered by a layer of soil, the rainwater first has to filter through this soil cover. Only after this can it reach the limestone. In the gas compound filling the pore space of the soil, however, there is more CO_2 than in the air. The proportion of this gas here is almost always more than 1%, but it can frequently exceed 10%. That is, compared to the atmosphere, **soil-atmosphere** concentrates at least thirty, and not infrequently three hundred or even many times more carbon dioxide.

Therefore it seems certain that the karst waters with high carbon dioxide contents dissolving large quantities of limestone receive their aggressivity from the soil covering the karst and not from the air. The more carbonic acid develops and is stored in the soil, the quicker and more effective the deterioration by the dissolution of the limestone, or the karst development, will be. Consequently, karst development is not the result of the interaction of rock surfaces and rainwater poor in carbonic acid, but **it is the product of the interaction of the rock, the covering soil and the lime-aggressive compounds developing it, which happens through the mediation of water**.

11# Carbon dioxide in the soil is produced by the millions of **microorganisms** (soil fungi and bacteria) living there. In other words, this means that, beside the quantity of the filtering precipitation, the speed of karst development in an area is primarily controlled by **the activity of the biological processes of the soil** covering the surface. That is, the dissolution of the limestone or **karst development is, in essence, the formal reflection of the biological and chemical developmental phenomena of the soil covering the rock in the soluble base rock.**

12# The plausible statement of the classical karst schools (Cvijić, Cholnoky, and others), that the Dinaric Karst Mountains became karsts because following the deforestation the soil was also washed away by rain and thus precipitation can now freely dissolve the barren limestone, is shown to be incorrect. The statement is true in the other way round: the formation of the karst phenomena, the corrosion of the dolines and the development of the bizarre forms of the karren occurred **during the forest- and soil-covered period** of the mountains, and the denudation of the slopes only revealed this, at the same time slowing down the dynamics of karst development. An analogy here could be the development of the skeleton of a cat. It would grow only as long as it is covered by living animal tissues, that is, until it is invisible for the eye. When the skeleton is exhibited in the biology laboratory for everybody to see, we can be sure that it is not growing, not developing any more.

13# The bioactivity of karst soils is not limited to the carbon dioxide production of the bacteria and fungi populations only, but the chemical impact of the **roots** of the grassy, bushy or arboral vegetation reaching down, or the composting of the organic waste and leaves, the disintegration of animal carcasses in the soil and many other processes can also be contributing factors in the production of carbon dioxide and other acids. Soils with greater bioactivity can be compared to real chemical factories, where mostly several kinds of organic acids are produced. The most important of these are formic, acetic, oxalic, lactic, propionic acids, different fulvo- and crenic acids, humus and humic acids etc. Besides the most important carbonic acid these also participate in the dissolution of the limestone, since the water filtering through the soil dissolves these, too, and takes them to the limestone base.

14# In the network of the roots of different plants, grasses, shrubs, trees, etc., in the **rhizosphere**, different microorganic populations appear according to the different plant species. Consequently, there will be qualitative and quantitative differences between the chemical processes of the neighbouring rhizospheres or soil areas, resulting in different acid and gas concentration in the neighbouring areas of the soil. A real plant species adequacy emerges, which is characterized by the well distinguished CO_2 production in the soil of the rhizosphere of each plant species, the maximum of which is associated with different periods of the vegetation period. The ventilation of soil depends on the fixed, moist nature and aspect of the soil surface, the thickness of the bioactive soil layer and on many other factors, and this also influences the concentration of the accumulating liquid and gaseous compounds. Thus great **divergences** can occur in the chemical composition of the filtering water even within a few centimetres. This difference in aggressivity is then reflected in the irregular solution forms of the rock, in the bizarre forms of the rock **karren.**

15# The bacterium population of the soil is always denser around the roots than elsewhere. Therefore the roots pushing into the joints of the rock will, in time, to widen the narrow fissures into spacious solution canals, mostly round or oval profile meandering conduits. The limestone perforated by root-canals is the **root-karren**, while the vast, barren rock surfaces that have lost their soil are called **karr fields**.

In the tropics, where both the vegetation and the hidden organisms of the soil develop more dynamically, the impacts of biogenic karr development are naturally greater. The canals of the root-karren frequently reach down to 20-25 m into the limestone, while root corrosion can result in even 60-70% solution rock losses. The **varying intensity of biogenic karst development** can be shown remarkably by the example of trees crushing through thick layers of limestone. In Cuba, but elsewhere in the tropics as well, there are several caves through the thick ceiling of which trees have grown, in canals they themselves deepened.

16# The invisible organisms of the soil have their favourable and unfavourable life conditions just like the organisms we know. The vital functions of the organisms of the soil react sensitively to the **changes in temperature**. The change of the number of bacteria sensitively follows even daily temperature fluctuations. On the basis of long experiments and data collected through observation, however, we also know that the optimal temperature is not a sufficient condition in itself to enhance the microorganism population of the soil. This can only be ensured by **the simultaneous impact of optimal temperature and soil moisture**, naturally complemented by the proper conditions of soil ventilation. An increase or decrease in any of these conditions would lead to the drastic, immediate decrease of the number of bacteria. That is, the acid factory of the soil is extremely **sensitive to climatic changes**.

In the tropical soils with optimal temperature and moisture, therefore, a hundred or several hundred times more carbon dioxide and other organic acids form than in the soils of karsts under temperate climates. But the carbonic acid production of the karsts under temperate climates is the multiple of that of the poor soils covering the karsts in cold climates or the cold surface karsts of the high mountains. It is obvious that there are vast differences between the **intensity of karst development** of the different climatic zones (Tropical wet, Desert, Mediterranean, Oceanic, Moderate, high mountains and other cold regions), for the dissolution aggressivity of the water, will become **dependent of the climate** itself because of the climatic sensitivity of the biogenic factors. We can be sure that these differences explain the striking variation in size and the special regional morphological differences of karst forms found in distant parts of the Earth.

17# Under our climate, that is, in the temperate climatic zone, biogenic solution is a major genetical component of **dolines** as well. These dish-shaped or cauldron-like surface depressions are sometimes only some meters in diameter and depth, but sometimes they can be several hundred meters wide and 40-60 m deep. Researchers in the near past thought them to be simple rock disintegration regarding them as the crumble phenomena of the caves and solution caves underneath. Recently it turned out that dolines and caves have not much to do with each other.

The crumble origin of dolines was also contradicted by the fact that the rock layers almost always keep their **original** strike direction and dip angle on the sides of the dolines, that is, during the formation of the doline the situation of the layers in which it develops does not change.

The reconciliation of the contradictory observations and the modern interpretation of doline formation was made possible only by the discovery of biogenic karst development, which claims that the doline is a **rock solution surface depression** that comes to existence on every karst plateau where the soils covering the rock become the most active. The loosely structured, humus-containing soil particles of the higher reliefs easily merge in the initially flat rock solution incurations, thus the **locations of optimal corrosion** start to concentrate in more restricted areas. With time, the soil-mediated rock solution process will be increasingly concentrated in hollows corrosion ensues precipitation washes away the soil more and more effectively from the crests between the dolines that also function as local sediment reservoir basins. The relatively quick deepening of the doline is further reinforced by the fact that karst development slows down with the deterioration of the vegetation on the ever steepening ridges and on the saddles separating the dolines.

18# Among the bioecologically regulated karst phenomena we find not only solution forms. We had to realize that the formation of most **karst-accumulation phenomena** were initiated by organic activity, and this is also what defines their dynamics and sometimes the quality of their forms. The different aspects of limestone deposits in caves, calcite stalactites and stalagmites, different encrusting dripstones, the travertine tetaratas developing as transversal dykes in the beds in cave channels and the travertine appearing on the surface of the valley near karst springs (thus for example the vesicular travertine hill under Hotel **Palota** in Lillafüred or the famous and beautiful waterfall travertine dams of the Plitvice Lakes), but also the travertine curtains of the ridges of the tropical karsts - in fact these all are biogenic karst phenomena.

This concept is not in the least modified by the fact that we find among these karst sediments of **indirect biological regulation**, where only the aggressivity of the solution and the phases of the solution had been dependent on bioecological processes (for example cave limestone deposits, dripstone formations,) but there are such among them that reflect the activity of organisms a **second time** as well, during precipitation from the solution, in which case for example the mode of the lime separation phase is also regulated by plant assimilation. (Among others, the travertine accumulation of karst springs and karst brooks can be mentioned here.)

This explains why there are no dripstones in the caves of the polar regions covered by abiogenic surfaces and of the high mountains where there is no vegetation, and this is why the karst springs and brooks do not build travertine either. In the karsts of the rich vegetation tropics, however, magnificent dripstone formations appear, covering and turning the intertwined green vegetation of liana, tendril and clamatis of the steep rock walls into a stone idol.

19# The natural appearance of the karsts of tropical and temperate zones is, therefore, limestone mountains covered with soil and vegetation. **The denudation of the limestone surfaces** in these climatic zones always means **a disturbance in the natural balance of the karst-ecological conditions**, the definite denaturalization of the process of karst development, its real decay. We can find naturally formed bare karsts in intrazonal location only in deserts, or in the regions of adverse climatic conditions in high mountains and polar regions. Therefore the denuded karst, for example on the Balkan or in Hungary, is an expressly extrazonal occurrence, an unnatural phenomenon, sometimes exhibiting anthropogenic reasons that can be analyzed in detail.

20# The occasional radical and irreversible denudation of the karsts of the temperate climates of Europe is most frequently caused by **overgrazing**. The main reason of the almost endless bare karsts of Greece, Montenegro or Dalmatia is the extensive goat keeping of the Medieval societies of these regions. Especially in Albania and Greece, hundreds of years ago the number of goats increased and they were even running wild in so high numbers that they could consume the buds and foliage of the sapling of the woods ruthlessly and entirely in whole regions. Thus they induced the ageing, then the extinction of the woods, and, with this, the erosion of the soil deprived of the network of roots.

Of course, the destructive processes of the soil were intensified by the mechanical agitation of the **trampling of the herds**. Soon the increase of stray goats and its undesirable impacts reached such a magnitude in this region that not only the animals could hardly find food for themselves, but there did not remain enough soil to be able to provide the basic minimum level of the agricultural and timber production, even though this had been low before as well. This is why we can find so many ruined towns in the mountains of Dalmatia and Montenegro, deserted by the inhabitants as the earlier sustaining potential of the land vanished because of the mistaken choice of concept for land-use. Thus the earlier population density of 77 people/km^2 of Montenegro decreased to 33 people/km^2 by today.

21# It is also a well-known fact that the enormous amount of timber needed for the construction of Venice, of the Adria trawlers and then the early modern commercial galleys was the death warrant of the forests of the Croatian and Dalmatian coastal karsts. The unlimited and complete logging of the woods was of course followed by intense soil erosion and the soil degradation of the steep ridges soon led to the unlimited and irreversible denudation of the region. The interference with the ecological balance of the karst without considerations resulted not only in upsetting the biological balance, but the complete change of surface conditions, a decrease in the productivity and sustaining capacity of the land as well, and it made new qualitative aspects expressed in the geomorphological development of the land.

22# Denudation, however, also had **another reflection in karst degradation**. Karst soils covered with woods or even grass-associations secure a groundwater output balanced out toward the limestone base before the periods of degradation. This is in connection with the natural water preserving capacity of the soil, which is capable of absorbing and storing sometimes great quantities of rainwater. When this happens, most of the interspace between the soil particles are filled with water and the soil might even significantly swell.

In contrast to this, precipitation rushes down from the karst surface, usually with the help of the joint network of the karst and thus one or two hours after summer storms the limestone surface may be completely dry again. Consequently, we can observe in dripstone caves in Hungary and abroad that the relatively balanced output cave dripping points that are active all year round are always found under the forest covered karst reliefs while the distinctively alternating dripping intensity stalactites are found in the cave parts under barren karst surfaces. Among the latter dripstones we can often find ones whose water supply periodically or even completely stops.

23# There are other sensitive correspondences between the aspect of the vegetation and the related soil conditions of the surface and the nature of the karst process. Thus sometimes there are remarkable differences between the **dynamics of dripstone accumulation** of cave parts under covered and uncovered karst surfaces. Compared to the ones under the degraded planinas, observation shows the growth rate of the dripstones under forests in given time periods to be many times greater. Especially the comparison of shorter periods showed significant differences in the degree of dynamics, sometimes even the order of magnitude of thousand. This is understandable, because in the barren karsts it is usual that some cave water drippings stop periodically.

24# As the water preservation in the soil and the infiltration-balancing effect of the surface radically decreases in denuded karsts, the mentioned factors also lead to a **degradation in the reliability of the water supply of the karst springs**. The water output of springs in denuding karsts becomes fluctuating, and, corresponding to the degree of denudation, **extremities** will be characteristic of them in the output and even in the composition of the water. Before the general soil degradation the differences between minimum and maximum outputs were at most of the order of magnitude of ten. After denudation, the maximum output can increase hundredfold or more compared to the small water output. This is an unfavourable phenomenon that naturally affects the cleanness, filteredness of water and the possibility of bacterium contamination.

25# The denudation of the karst drainage results in a certain quantitative growth of the annual average water output of the karst springs because the proportion of constant filtering precipitation increases. At the same time, however, the **extremities of output fluctuation** and the **pollution of the water** are highly unfavourable in the case of springs supplying human settlements with water. Therefore forestation is a social priority in the catchment of karst springs providing drinking water for an area or town (for example Miskolc, Pécs or Borsodnádasd in Hungary). Neglecting this, or disregarding the degradation processes pointing to the opposite direction or even amplifying these would inevitably result in the degradation of the reliability and quality characteristics of the spring, that is, the deterioration of the drinking water base of the settlement.

26# There are other sensitive **karst-process** indicators of the anthropogenic degradation of karst soils. Such are for example the **colour changes of cave dripstones** which are perhaps the finest registers of the present and past changes of the rate of degradation.

The general **red colouring** of the wall coatings and the dripstones in the caves under limestone planinas with terra rossa subsoil of high ferric oxide content indicates the degradation of the soil and the vegetation, as the balance of several thousand years had been upset in the karst surfaces where the forest vegetation deteriorated and the waters wash the eroding soil into the caves through the joint network of the limestone. By comparing the maps of the caves and the surface we showed that for example in the area of the *Vörös-terem* or the *Kőgombás-kapu* of the Aggtelek Béke cave, where the red surface colouring of the cave formations is especially frequent, denudation took place in the last one hundred years because of **clearcuting**.

27# At places clay can be washed in so fast in the depths of denuded karsts that during even a few hundred years the inactive cave sections can become silted up significantly or sometimes completely. The silting up of the *Mese-ország*, the *Arany-utca*, the Retekág upper corridor of the Baradla cave, and several syphon by-passing upper corridors in the Béke cave, etc., in the last centuries (in the period of the general surface degradation of the areas) resulted in thicker clay accumulation than that had accumulated in them in 3-4,000 years.

28# In karst caves we extensively find the traces of such dripstone deterioration processes that were caused by corrosion, that is, **the subsequent dissolution of the substance of the dripstone**. The corrosion dripstone deterioration, may have several reasons, and we know quite well the interrelations of the developed degradation symptoms and their causes and the pattern of impacts. There are several known types of corrosion dripstone degradation which have genetics **independent of age**, that is, they can occur in any phase of the development of the cave system, the conditions of their formation have been given in the past of the cave (or its certain periods) as well as today. However, my research data shows that (unfortunately) there are such corrosion processes which destroy the dripstones **only in the present**, but which had never and nowhere been present on cave formations before the last one or two decades and which, therefore, are called **new dripstone degradation syndrome**.

The deformations are caused by the corrosive effect of the karst waters dripping on the dripstones. The spread of the syndrome is general in Central Europe, though it occurs in caves of different natural potential with different amplitude.

29# The **symptoms** of the new dripstone degradation syndrome are: irregularly shaped craters with sharp, hackly edges, 'calderas' with compressed sides, sharp edged, bed-like trickle ditches, areal dripstone surface recorrosion in the spray zone of the waterdrops falling from above, in certain cases almost total dripstone solution and, not rarely, the subsequent mollification of the material of the dripstone so that it becomes creamy.

The new dripstone recorrosion is the degradation symptom usually of the youngest dripstone formations that are light (often white) in most cases and have an active water dripping even today. It can be found only in certain sections of the caves. The degradation occurs usually in groups, but there are stalagmites not showing degradation symptoms in the immediate environment of the degrading dripstones.

30# The new dripstone degradation syndrome occurs almost exclusively at the points of the most stable dripping in the dripstone caves. Similar transformations can never be found in the older layers or surfaces of the same formations. It is especially easy to control this correspondence in the caves which have been known and visited for a long time and in which during the period of torch-visits (up to the beginning of the 20th century) thicker or thinner **soot-coatings** settled on the dripstone and rock surfaces then. **Under** the soot-coatings the new dripstone degradation is nowhere present. That is, we can distinguish a 'pre-soot' symptom-free development lasting several hundreds of thousands of years and a very short, maybe a few decades long 'post-soot' active degradation period, which imprinted effective recorrosion marks on the surface of many cave dripstones and in some cases it has destroyed the whole dripstone formation.

31# The research to identify the reasons is underway, but it seems we have enough evidence to assume some relationships in the impacts. These are the following:

- The recorrosion or the dripstone is caused by the very same cave water dripping that augmented, built the dripstones (primarily stalagmites). The fact of degradation is therefore the proof of a change in the chemical, physicochemical, or perhaps microbiological character of the water dropping on the stalagmite.
- The thicker the bioactive and permeable soil covering the karst rock and the deeper the roots of the (broadleaved, woody) macrovegetation, the more frequent or greater the new dripstone recorrosion. It is also likely that the role of pine forests is somewhat different than that of broadleaved forests such as for example oak, beech, hornbeam, etc.
- There can be shown a certain inverse ratio between the frequency of occurrence of the dripstone degradation syndrome and the **depth under the surface** of the cave section. This means that, the closer to the surface a cave system is, the more frequent the new dripstone degradation can be in it.

32# We have extensively analyzed the relationships of the pH value, microbiological and compositional characteristics of karst soils and the observed degradation phenomenon. It was established that compared to the data of the retraceable 1929 standardized water-analysis the dripping water of the same cave points **the sulphate content of the karst water has increased** 400-600%, and there is a fluctuating, though smaller, increase in nitrate and chloride contents as well. In those caves and on those dripstones where dripstone recorrosion is especially significant, the sulphate content of the karst water is even greater than the average. Therefore the new dripstone degradation can occur in connection with the significantly increased sulphate content of recent karstwaters, or it can be caused indirectly by one of the reasons that also induce this increase.

33# As in the composition and microbiological relations we can document the trends of change in connection of the acid settlings of the atmosphere (for example the decrease of the pH values of the soils by one grade), it seems confirmed that the modifications of the chemical characteristics of the karst water have a kind of (likely indirect) relationship with the trends of physicochemical changes of the karst soils and the present day distortions the ecological systems of the microorganisms of the soil. Therefore the new dripstone degradation syndrome basically indicates **the impact of acid rains and deposition** in the deeper karst horizons **in a complex system of a chain of impacts.**

34# I consider the scientific arguments and evidence detailed in 6-33 to be sufficient for the acceptance of the statements of the 4th and 5th theses, namely, that the **karst is a land ecological system with very complex functioning**, which comprises correlated and interdependent delicate balances. The karst as land ecological system is defined by the **combination of the interactions** of petrographical, tectonical, climatic, hydrographical factors and macro- and microregional chemical, physical and biological factors and these are greatly variable in themselves as well, both in time and space. Because of these reasons, the karsts are perhaps the most sensitive land types with regard to the anthropogenic impact.

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Acidification of some soiltypes in Bükk mountains

Dr. László Mucsi

INTRODUCTION

During the investigation of genetic soil-types in the area of Odorvár I recognized different processes connected with soil acidification. These natural and anthropogenic processes do not show to the naked eye, therefore we have to apply distinctive physical and chemical methods. The most important factors in the acidification are the following:

- pH of the precipitation
- buffer capacity of the soil
- chemical and physical properties of the base rock.

I took samples from 4 different soil-types in 1987 and in 1991 and I have investigated their physical and chemical properties in connection with changes in acid properties.

Acidification in acid, nonpodzolic brown forest soil

The acidification in brown forest soil is a natural, nonanthropogenic process. This soiltype is formed on shale, phyllite, porphyrite and hydroandesite. In contains clay minerals formed before the beginning of soil formation. These minerals significantly lose in their colloidal properties. The brownish-black illuvial layer is rich in humus, its structure is crumbled and grained. The pH value ranges from 3.5 to 4.5. We can always find aluminium and iron ions among the exchangeable cations. In the alluvial layer acidification is a significant process as well (Stefanovits P. 1981).

The acid property of brown forest soil is traceable to the quality of disintegrated remnants of dark grey shale, which is the base of the soil formation. The rock debris is poor in basic materials and therefore conditions are favourable for acidification (Máté F. 1987).

I examined the changes in pH values in 1987 and in 1991. The following figure (Fig. 1.) shows the pH values in three layers (5, 10 and 30 cm depths). The pH(H_2O) values were 6.2, 5.5 and 5.3, while the pH (KCl) values were 5.5, 4.4 and 4.0. If the difference of distinctive pH values in a special layer (for example pH(H_2O)-pH(KCl)=1.3 in 30 cm) is greater than 1, then it indicates intensive acidification.

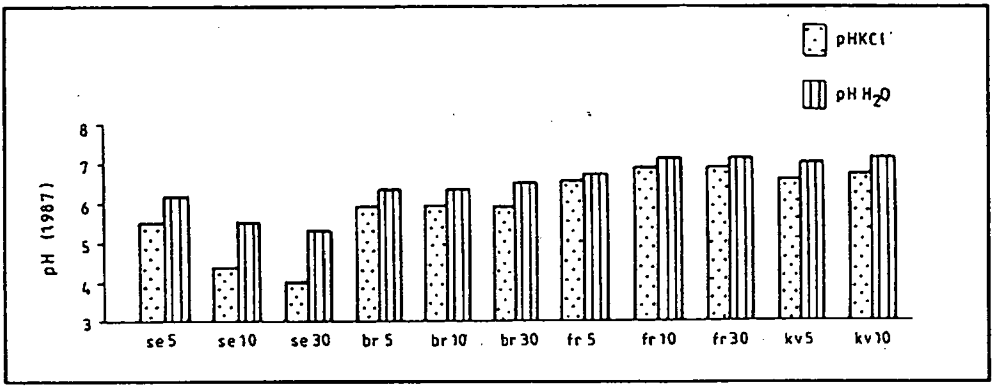

Figure 1 pH values (KCl and H_2O) in different soiltypes in 1987
se=acid brown forest soil   br=brown rendzina
fr=black rendzina   kv=skeletal, stony soil
5, 10, 30 = depth of soil sample in cm

We can say that the acidification in brown forest soil is basically due to the chemical properties of dark grey shale, but this process may become harder due to the immission of acid materials of the atmosphere. Therefore I have investigated the sulphate and nitrate ion contents in soiltypes. These materials are immitted onto the Earth's surface by dry and wet immission and they are washed down into the lower soil layers by precipitation.

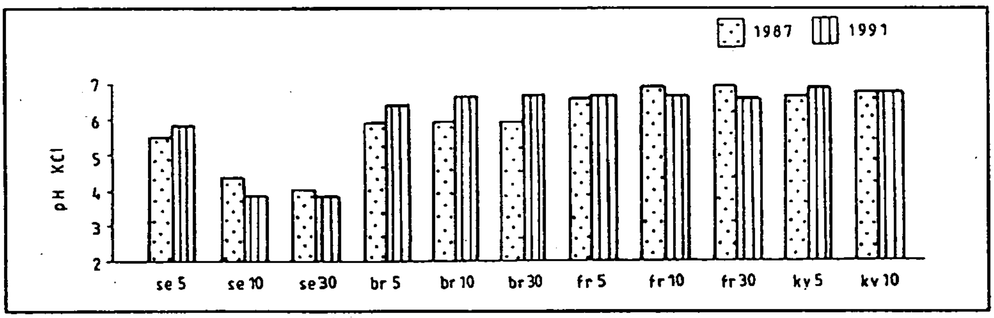

Figure 2 pH(KCl) values in different soiltypes in 1987 and 1991
se=acid brown forest soil   br=brown rendzina
fr=black rendzina   kv=skeletal, stony soil
5, 10, 30 = depth of soil sample in cm

In connection with the buffer capacity of the soil I have found lower nitrate content in the lower layers, while the distribution of sulphate ions was more uniform in the whole soil profile. In 1987 the nitrate contents in different soil layers were 8.3, 2.3 and 1.5 ppm, while in 1991 the ion contents were 8 times greater than four years before (64.7, 11.5 and 4.8 ppm). The sulphate content increased too but not so significantly. In 1987 the sulphate contents were 10.8, 11 and 25.4 ppm, while in 1991 they were 18.6, 16.6 and 22.1 ppm (Fig. 2-3.).

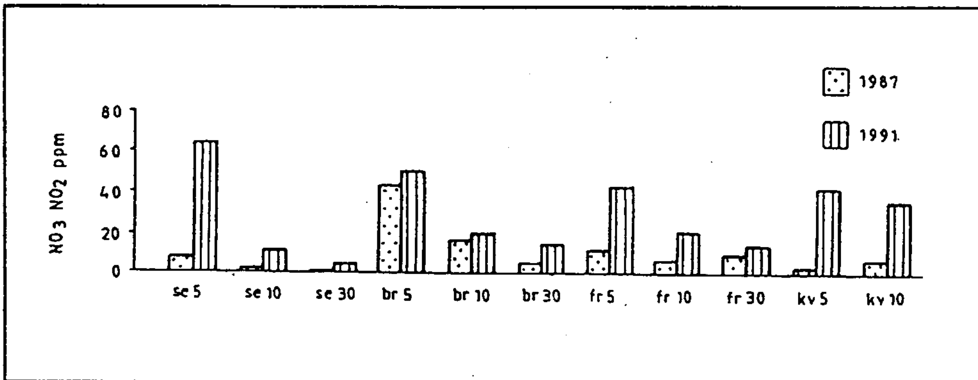

Figure 3 NO_3 and NO_2 contents in different soiltypes in 1987 and 1991 in ppm
se=acid brown forest soil br=brown rendzina
fr=black rendzina kv=skeletal, stony soil
5, 10, 30 = depth of soil sample in cm

The development of acid brown forest soil shows that the acid rainfall strengthen the process of soil acidification. Due to the moderate buffering capacity this tendency will continue.

Process of acidification in soiltypes formed on limestone

By the side of geologic composition of the area of Odorvár the acidification is modified by climatic conditions. Basic materials are washed out from the upper soil layer by seeping precipitation. In the first stage the most soluble ions of alkaline metals and later their hydrocarbonates are carried away.

Minerals are dissolved in precipitation and in groundwater which contain carbon dioxide. Positive ions of metals are carried away together with anions and negative bicarbonate ions by seeping water down to the lower soil layers. If later the sulphuric acid gets into the soil then magnesium and calcium ions are carried away by sulphate ions.

While the sulphate solution transport the cations, hydrogen ions remain in the soil and these are the cause of the acidity of the soil (Mohnen, V. 1988).

The seeping water contains organic acids formed during the microbiological decomposition of plant residues, which play a very important role in the acidification (biogenic factor). Acid organic materials arisen from the formation of humus combine with calcium ions into salt and calcium humate if there is sufficient calcium carbonate in the soil. The chemical reaction of the soil solution does not change by acid and basic influences as that of the distilled water, because of the buffer capacity of the soil.

Different soiltypes were formed in limestone on the area of Odorvár. The skeletal, stony soil is the erosional residue of black rendzina. The fragments of limestone and the calcium ion content of seeping water are the cause of the high buffer capacity of this soil-type. The surplus hydrogen ions are absorbed in the soil containing calcium and magnesium carbonates and chemical reaction of the soil layer is regulated by the

$$CaCO_3\text{-}Ca(HCO_3)_2\text{-}H_2CO_3$$

buffer system in accordance with the following

$$CaCO_3 + (H^+ + HCO_3^-)_2 \rightleftharpoons Ca^{++} + 2HCO_3^-$$

$$CO_2 + H_2O$$

chemical reaction (Filep, GY. 1988.).

Therefore the pH value of the soil solution is not decreased while there are sufficient calcium and magnesium carbonate in the solid phase of the system. Calcium and magnesium ions can be washed out by seeping water if they are in solution.

Skeletal, stony soil does not cover the limestone surface continuously on the eastern, southeastern and southern slopes of Odorvár. The precipitation upon the covered and uncovered surfaces can be considerably acid.

The chemical reaction of the precipitation which absorbed free carbon dioxide content of the air is about 5.6, but the pH value can be 4.5 or lower if it dissolves air pollution emitted by industry (Mészáros E.-Horváth L. 1980) . Dissolution of limestone by runoff starts in spite of rapid infiltration (rillen karren). If the seeping water is not saturated, it is able to absorb further calcium ions in the joints of the limestone or in the soil. The process is intensified by humic acids created by the decomposition of organic materials. The humus content of black rendzina ranges from 5.5% to 10% (Fig.4).

The most important factor in the soil acidification is the acid rain. I have found enormous differences between the sulphate and nitrate contents in soil samples gathered in 1987 and 1991. The sulphate contents in 1987 were 8.4 and 3.5 ppm. I had to sample from two layers because this soiltype is strongly eroded. The sum of the nitrate and nitrite contents was 2.9 and 6.6 ppm. In 1991 the sulphate contents were 20.4 and 19.2 ppm in the samples, while the sum of nitrate and nitrite ions was 42.5 and 5.5 ppm (Fig.5).

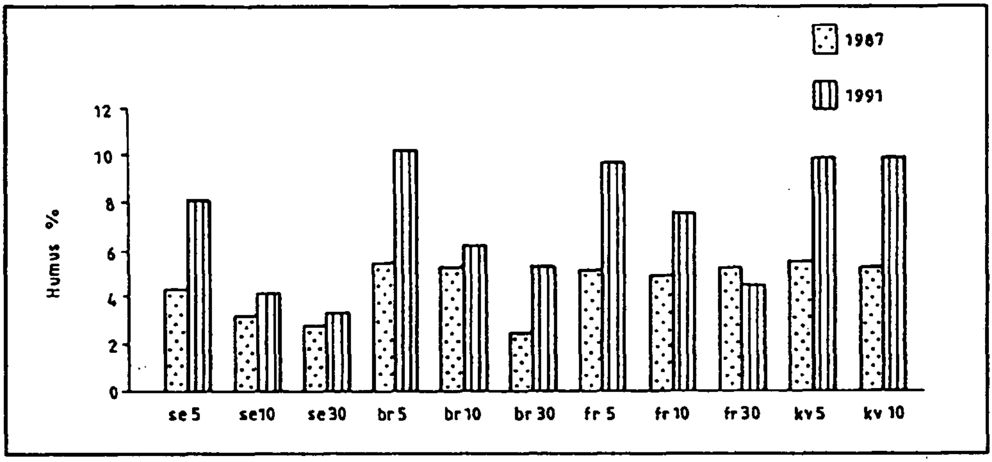

Figure 4 Humus contents in different soiltypes in 1987 and 1991
se=acid brown forest soil br=brown rendzina
fr=black rendzina kv=skeletal, stony soil
5, 10, 30 = depth of soil sample in cm

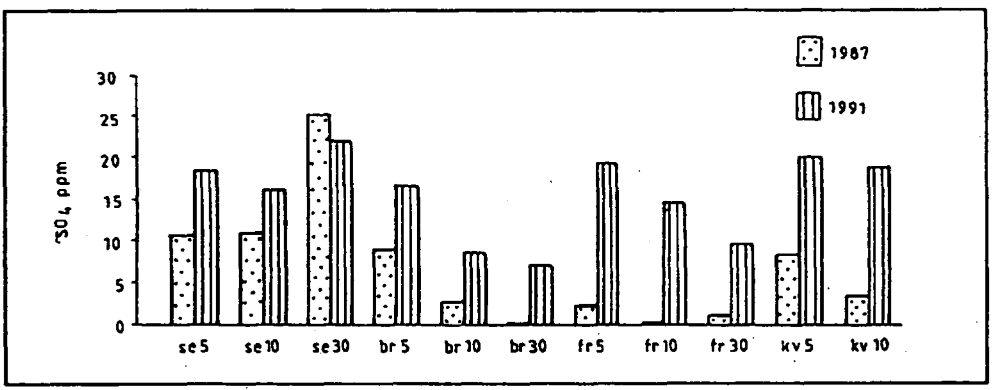

Figure 5 SO_4 contents in different soiltypes in 1987 and 1991 in ppm
se=acid brown forest soil br=brown rendzina
fr=black rendzina kv=skeletal, stony soil
5, 10, 30 = depth of soil sample in cm

The distribution of these anions shows that this very thin soil layer can absorb the acid factors of precipitation by its high buffer capacity. The increasing sulphate and nitrate contents prove that more and more anions are being absorbed on the colloid surfaces. If the sulphate and nitrate content of the precipitation will not decrease the buffer capacity of the soil will reduce. If it ensues, the seeping water will not be saturated and it can dissolve the dripstones formed in the caves. In the area of Odorvár we can find a very thin limestone layer over the Óriás Chamber of Hajnóczy Cave. The degradation of dripstone phenomena can be traced back to two reasons:

a, there is a lower relative humidity (80-85 % of other chambers, therefore the dripstone layers are broken off from the stalagmites,

b, the other reason for degradation is the guano of bats living in the cave. The dropping water is sinking through the guano, which can be 10 cm thick, and the seeping water becomes aggressive again.

CONCLUSIONS

1. The cause of the acidification in brown forest soil is the chemical property of dark grey shale, and this process is intensified by the acid rain.
2. The dark grey shale is eroded by external forces, its thickness is decreased and calcium content and the buffer capacity of the soil increase.
3. The buffer capacity of skeletal, stony soils and that of the black rendzina is good enough, but more and more anions are absorbed on the colloid surfaces.
4. Acidification in soiltypes formed on limestone is accelerated by acid rains.

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Morphometric investigation of dolines in Bükk mountains

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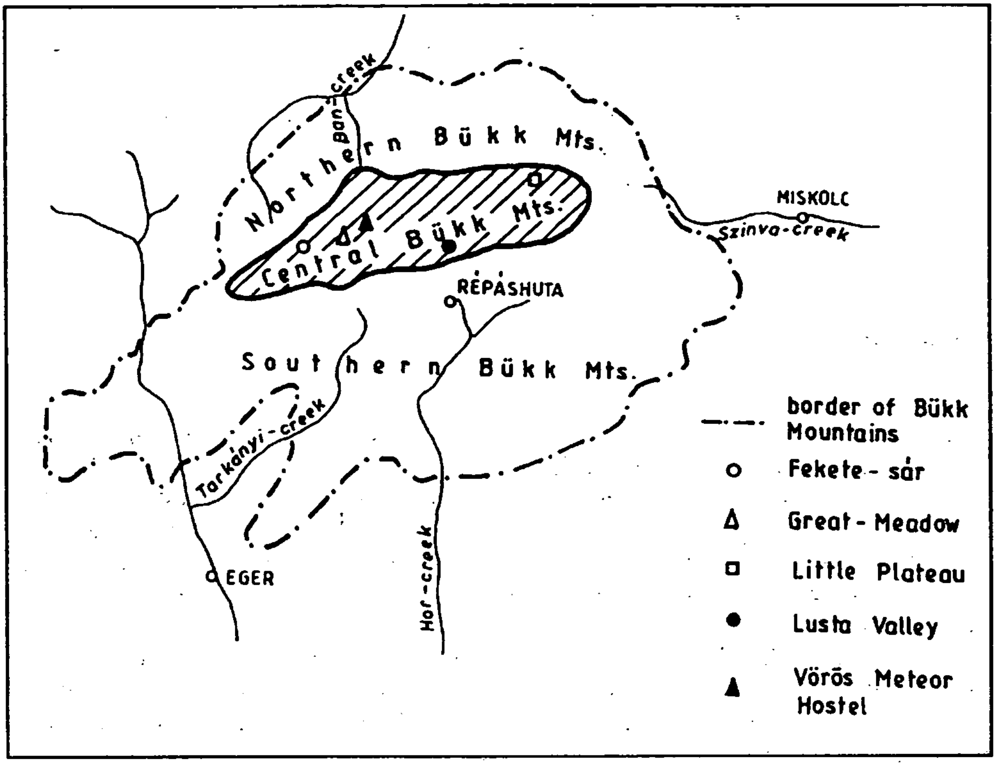
INTRODUCTION

The content of geomorphology, its methods as well as the aim of the investigation have significantly changed in last decades. These changes developed in accordance with social claims for engineering geomorphology, landscape ecology and model investigations. The fundamental question of each new conception is the exact terrain measurement and evaluation. Terrain classification based on its quantitative analysis followed former descriptive terrain evaluation. This effort was the basis of the elaboration of the morphometric methods.

Morphometry follows the theoretical and the practical investigations. The morphometric terrain analysis is significant from theoretical point of view, because with the help of morphometry the landscape elements can be studied with optional accuracy, which is always defined by the required aim of the study.

The dolines are the characteristic forms of the karst process and there were some experiments to analyze their morphometric properties. Veress, M. and Péntek, K. (1988) examined the so called "ideal dolines" (ideal=symmetrical) which can be derived from the original doline by certain topological transformations. With mathematical methods applied, they typified these ideal dolines and they did not take the variety of dolines in accordance with aspect into consideration. On the basis of the location of the inflexion point of slope, they divided the dolines into two groups: dolines which develop into doline (in the original sense), and the second type of dolines including dolines developed into sinkhole. Other authors investigated the development of dolines from a quantitative point of view. The development and the shapes of different slopes significantly differ from each other depending on the intensity of microbiologic processes carried out in the soil determined by the aspect. We also have to take these differences into consideration at the classification. Williams,P.W. (1989) called attention to the importance of the asymmetrical development of dolines.

During this study, we have carried out the morphometric analysis of 27 dolines located in Bükk Mountains. The groups of dolines (Map 1) can be found on region of Fekete-sár (9 dolines), on Little Plateau (10), on the surrounding of Vörös Meteor Hostel (5), on Great Plateau (2) and on Lusta valley (1). The aim of this study was to find a method to re-evaluate the fundamental ideas of both above mentioned conceptions.



Map 1 Location of the investigated dolines

METHODS

For the classification of dolines, we had to choose parameters which describe both vertical and aspective properties exactly. The application of mathematical statistics seemed to be the most favourable method. In the first stage, we considered dolines as the fundamental unit of the measurement, but we were not able to find parameters which can represent the shape of dolines in every aspect because of the spatial variation. A second problem was the comparison of shape of different dolines, because using variables with more than 2 dimensions the shapes cannot be compared with each other.

Both problems can be solved if we choose the "slices" of a given doline as a unit of the statistical investigation instead of the whole doline. Each of these slices are 1 m thick and delimited by the contour lines.

We supposed that the dolines can be well represented with their slices and this supposition can be proved by the following facts: the T(x) function, applied to dolines, expresses difference in the top and bottom area of the slice x, can be well approached by exponential function; **T(x)=l*e$^{\mu x}$** (Veress,M. - Péntek,K. 1988). Then the ratio of T(1) and T(2), where T(1) and T(2) are the top and bottom areas of the given slice, can be expressed by the following way:

$$\frac{T(1)}{T(2)}=\frac{T(x_0+1)}{T(x_0)}=\frac{l*e^{\mu(x_0+1)}}{l*e^{\mu(x_0)}}=e^{\mu}$$

consequently the value of the T(1)/T(2) ratio is independent from variable x_0, therefore it can be explained as a value well expressing the vertical development of the given doline.

In our statistical examinations, we have used parameters which express the vertical development or the aspects of the dolines. We did not use variables in which these above mentioned properties are represented at the same time.We used the following parameters to express the vertical development:

- ln(T(1)/T(2)), where T(1) and T(2) are the top and bottom areas of the slice,
- K(1)/K(2), where K(1) and K(2) are the top and bottom perimeters of the slice.

To describe aspects of the dolines, it is expedient to investigate the shortest and longest directions of extension. Since in the case of the mapped dolines, these parameters coincided with the most important aspects (N,E,S,W), we used the following parameters:

- αN, αS, αE, αW, where αA means the steepness of slope (A aspect)

The location of the deepest point of the doline is characteristic with respect to the shape of the doline and its location can be very important from the point of view of the development of doline (Zámbó,L. 1986, Williams,P.W. 1989). Therefore we examined the characteristic formation of the distances from this point (or from its rectangular projection on slice) in accordance with the aspect, i.e. the values of N-S and W-E eccentricity had been considered at the classification:

- eccNS= N/N+S;
- eccEW= E/E+W,

where N,S,E,W mean the distance from the location of the deepest point in the given aspect on the given level. We can calculate from these parameters the value of extension of the given slice:

- extension = (N+S)/(E+W).

Each slice can be characterised by vectors expressed with the above mentioned parameters. Spatial groups of these vectors represent same slices, consequently they can represent slices the same origin. The structure of groups can be examined by the complete method of the test sites. The most important task is the determination of those factors which are responsible for the differences between the groups. This problem can be solved with the help of discriminate analysis between the groups.

RESULTS

According to the results of the complete method, we can say that the samples can be divided into two groups (A,B) and one of them can be also divided into two subgroups (A_1,A_2). The simplified picture of the final dendogram can be seen in Fig. 1. The most important difference between the group A and B is that the elements of group B represent only the lower 1 or 2 slices of the dolines, while group A contains the upper slices. The elements of group A_1 and A_2 can be well distinguished from each other according to their

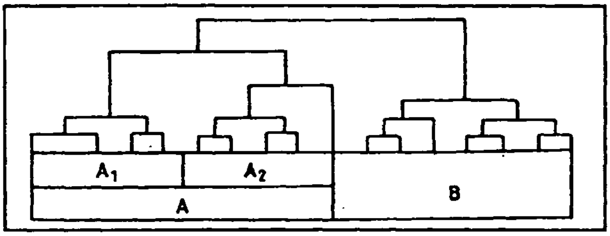


Figure 1 Sketch dendrogram of the investigated slices of dolines

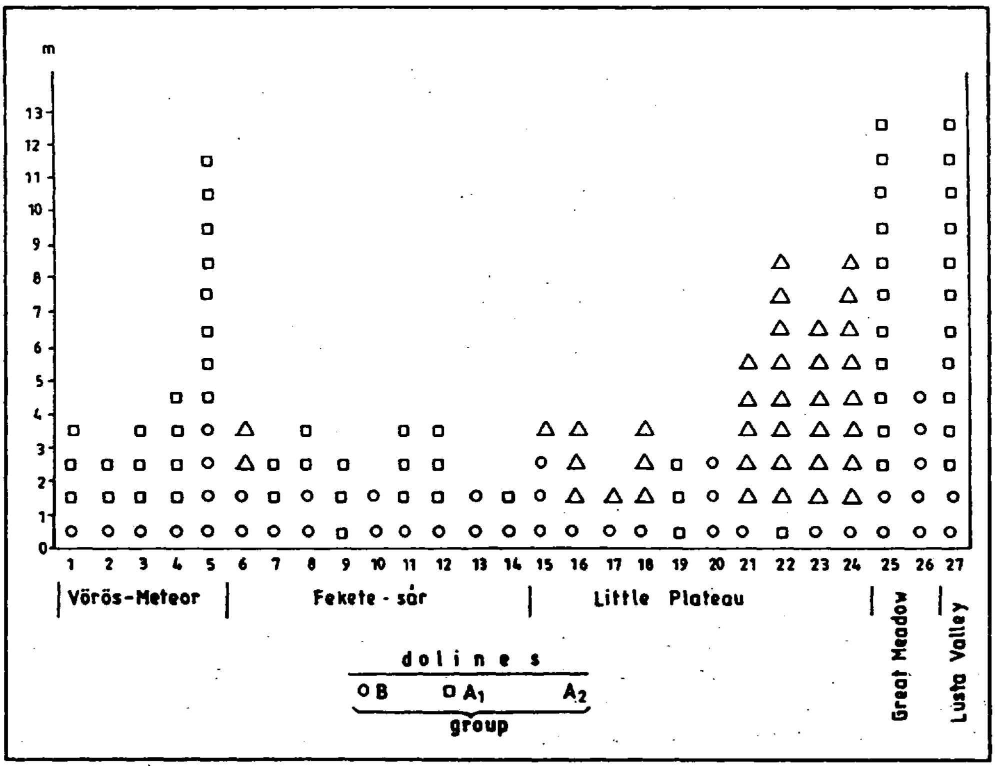


Figure 2 Groups of slices based on complete method

geographical locations. Subgroup A_1 includes the slices of dolines situated on Kis-mező. We summarized (Fig.2) the arrangement of slices due to the results of the complete method. Since the complete method referred the slices of the dolines to the same groups without exception we supposed that in the chosen space of parameters, the slices well represent the dolines statistically.

According to the results of the investigation we can say that the most important morphological difference appears between the lower and the upper slices. On basis of the results of the discriminate analysis, the reason for this fact is in the parameter ln(T(1)/T(2)) and K(1)/K(2), which characterizes the vertical development of dolines.

The values of both parameters are much greater than those of samples in group B, i.e. at the bottom of the doline the decrease of the area and the parameter is greater. It is in connection with the fact that the bottom of the doline can be concerned as an alluvial surface, where the development is rather lateral as vertical (Jakucs,L. 1971, Zámbó,L. 1986). If we investigate the number of slices in a given doline in group B, then we can conclude to the direction of the development of doline (doline or sinkhole). In this manner, dolines No. 5 (at Vörös Meteor Hostel) and No. 26 in Great Meadow (Nagy-mező) fall into group I, while doline No. 9 (Fekete-sár) falls into group II.

We determined the parameters to distinguish subgroups of group A by discriminate analysis. From this point of view, the most important parameters were the eccEW, the αE as well as the extension. The eccEW and the αE are significantly correlated with each other (0.71) and they show that there is a significant difference in the state of development on the eastern and the western slopes (especially on the eastern slope) in group A_1 and A_2. This fact is more conspicuous if we represent the values of eccentricity in a N-S-E-W coordinate system (Fig. 3). In the case of group A_1, the dolines are elongated in eastern

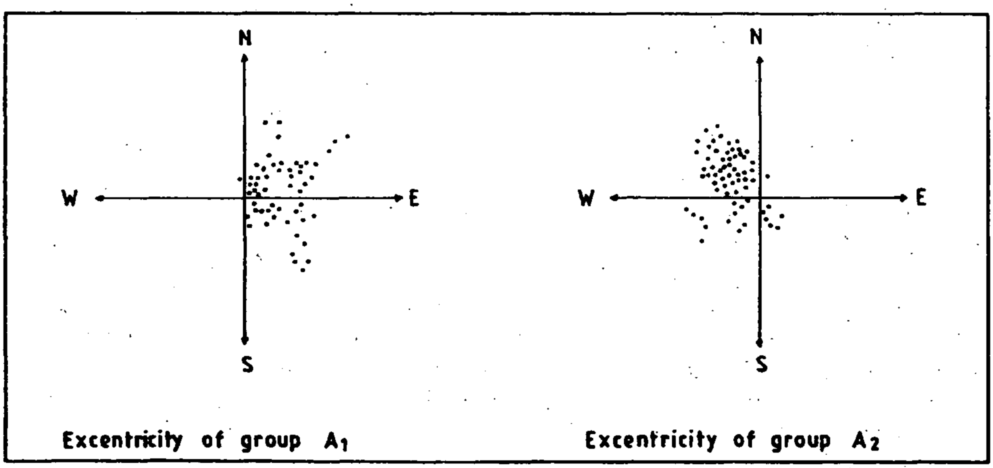


Figure 3 Characteristic values of excentricity of subgroup A_1 and A_2
(Origin is at the point (0.5,0.5))

direction, while there is not significant differences in N-S direction. In the case of group A_2, definite western and northern eccentricity can be determined. This latter property is well correlated with the fact that, due to the microbiological processes appeared in the soil, the western and northern slopes (eastern and southern aspect) of the dolines develop in faster rate (Keveiné Bárány, I. - Mezősi,G. 1978).

The value of extension was also used to distinguish these subgroups. Almost in all case, the following interesting facts can be claimed:

(1) from the bottom to the top, the values of north-southern extension decrease gradually,

(2) in the case of the dolines situated on Kis-fennsík (Little Plateau), the extension will be east-western definitely at a given altitude, while in other cases it remains north-southern.

In Fig. 4 we represented 6 different characteristic curves of extension depending on the depth. In our opinion, the reasons for the initial north-southern extension can be (a) the local tectonical factors and (b) local morphological factors. At higher levels, the differences in microclimatical conditions can become effective on distinctive slopes and due to the effect of these differences, the values of the initial north-southern extension decrease gradually. In the case of dolines, measured in Soros-töbör (töbör=doline) (Little Plateau), the reason for the lack of the north-southern extension is the east-western tectonic alignment of the valley.

SUMMARY

The morphometric classification of the dolines from 5 different areas of Bükk Mountains has been done with the help of the methods of mathematic statistics. We cut the dolines into 1 m thick slices by the contour lines and these slices were the fundamental units of our statistical investigation.

The results show that the doline slices well represent the original shape in the chosen space of parameters. The weighting of the vertical and aspect parameters was difficult in the morphometric classification of dolines. We can say that the most significant differences are in the bottom slices and the slices found above them. The ratio of them can refer to the development of the doline. If we take the differences (connected with the orientation of the slopes) into consideration a more detailed classification will be possible.

In the first case, general regularities of the doline development are the determining factors, while in the second case, the local tectonical, petrological, ecological and morphological parameters play a significant role in doline development.

Further investigations are necessary (1) to define the reason for the distinctive development of the dolines on Little Plateau), and (2) to find the reason for the regular change in the extension connected with the depth.

We would like to thank Dr. Márton Veress making his data from his field measurements and mapping available for us.

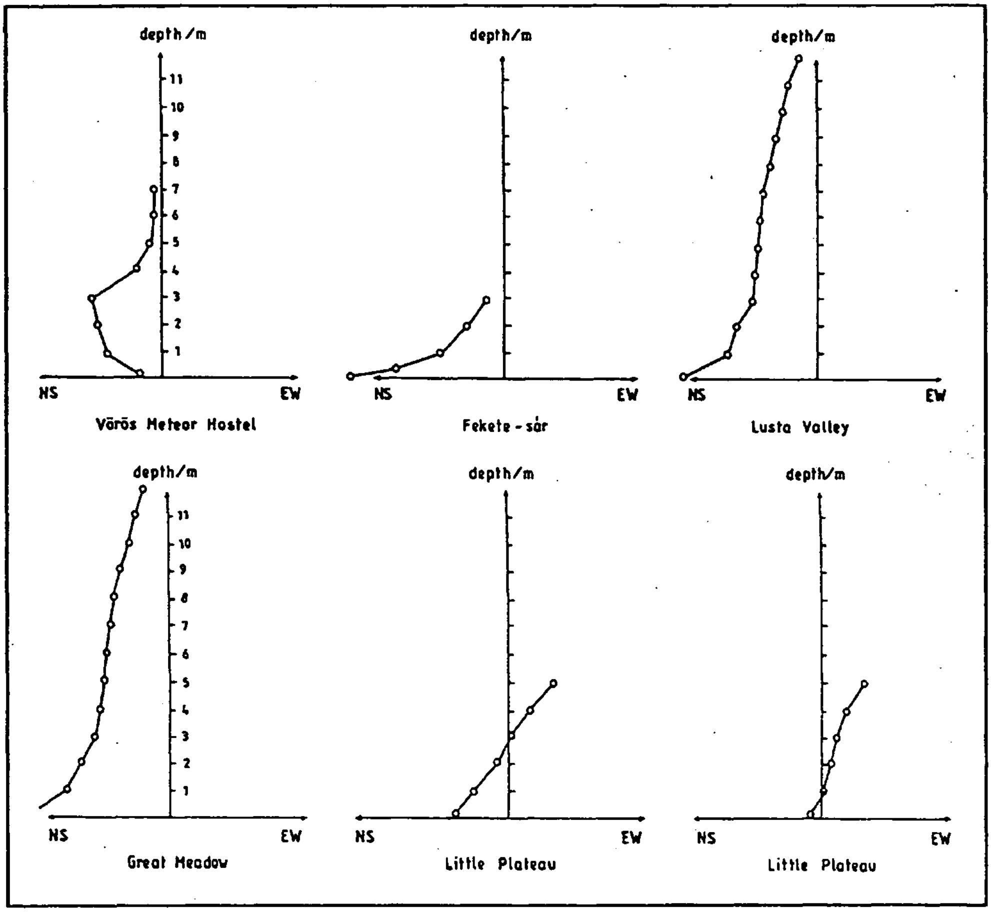


Figure 4 Connection between the extension and depth

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GIS based land use optimization in Hungary

Dr. Gábor Mezősi

INTRODUCTION

In our study we investigated how and to what extent is the ecological potential of a region (in Hungary that means the productivity of the soil and availability of water), the average yield of the cultivated plants, the land use of a certain area and the degree of the applied agrotechnology are correlated. We tried to establish where and how it is possible to increase or to improve the crop production through an optimal selection of the habitat. In our conception the landscape typological units particular consideration the soil qualities covering the country surface like mosaics were considered as regional reference areas. Namely, taking into account their net primary production, they may give approximately the same values being genetically and ecologically similar. By their use a more precise ecological classification could be made. The division of the regional typological units into plain types was plotted in detail, while the hilly and mountain types were summarized (Fig. 1).

The investigations were carried out with maize as a reference standard considering that in Hungary the agrotechnical and economical factors are the most similar in maize growing. This was a very suitable plant for the comparison, because it covers about the same percent of the landscape units. Being warm season annual plant the vegetation period and the harvest is in the same year, so the calculation is easier.

Maize is the second most important plant of grain crops in Hungary. The highest extension of its crop area during the past 50 years was recorded at 1.4 million hectares in 1974. Its area declined in line with the increase of yields between 1974 and 1984; the yield of maize was 4.24 t/ha in 1974 and 5.6 t/ha in 1984, which led to the increase of quantity of maize for feeding and export as well, despite decline of its crop area.

Maize is the most important corn fodder in Hungary, and 82 per cent is produced by large farms. After the introduction of new hybrids, maize-growing produces its highest yield in Transdanubia due to the higher amount of precipitation, while the greater part of its average crop area is still found in the Great Plain, where pig-breeding is generally spread. This activity is maintained for the sake of animal husbandry on the areas having poor average yields.

The development of the most favourable crop structure and the most favourable agricultural utilization of an area does not absolutely mean a maximum primary production far above the potential productivity in spite of a preference system advantageous for crops

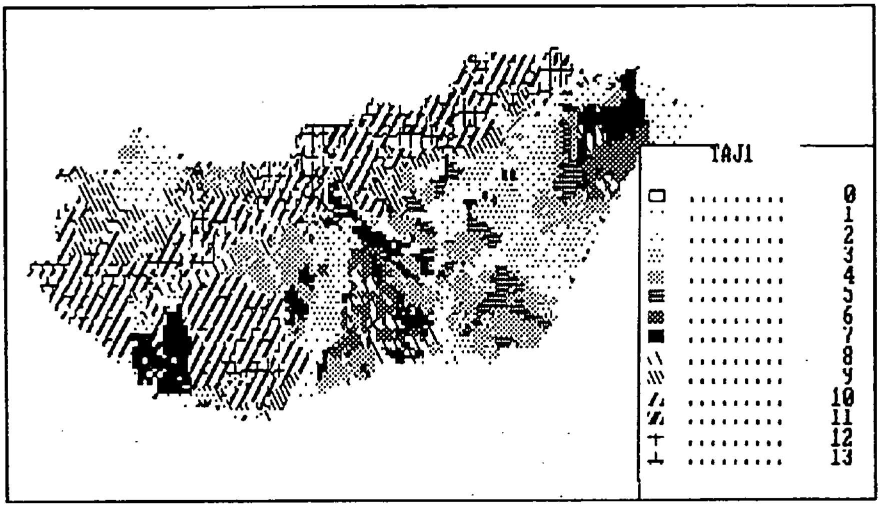

Figure 1 Landscapes types in Hungary
1 - alluvial plain with cultivated grassland;inundated flood-plain along rivers with alluvial soils and remnants of groves and marsh forests; 2 - poor drained flood-plain, alluvial plain cultivated grassland with meadow soil and peat-bog; 3 - alluvial plain; cultivated grassland predominantly with groundwater table at medium depth meadow chernozems; 4 - alluvial fan mantled by loess; loess plain; chernozem or meadow soil; 5 - terraced and loess plain with lowland chernozem; 6 - fixed sandy plain with mosaical Astragalo-Festucetum rupicolae acacia and poplar forests, vineyards and orchards; 7 - fixed sandy plain with chernozem; cultivated grassland; horticulture and arable land; 8 - interdunal depressions with high groundwater table, marshy or salinic meadow soils; 9 - alluvial fan on basin margin; cultivated grassland of dense drainage network; mosaical remnants of Quercetum petraeae-cerris forests chernozem and forest soils; 10 - smaller hills in intermontane basins; cultivated grasslands with remnants of Quercetum forests and deep groudwater table; 11 - independent hilly regions dissected by erosion-derasion valleys; mostly cultivated grassland remnants of mixed forests; 12 - forested landscape types in mountains of medium hight; 13 - major valleys within various hilly or mountainous landscape types

with high primary productivity. It seems to be much more important, especially in regions with poor ecological conditions, to develop a crop structure better adjusted to the ecological conditions and based e.g. on industrial plants assuring the highest income.

METHOD

Thematic maps from the National Atlas of Hungary (1989) served as input data. The digital technology of the graphic material was based on the AutoCAD software. To manage and to manipulate the data we used MAP for the PC (Sandhu et al. 1987) program. According to our aims and possibilities all data are stored and elaborated too, in a raster, which can be used very simply. For this method a raster-raster and a vector-raster transformer is needed (e.g. to build remote sensing data digitally into the information system). The transition and/or the transformation between the vector-basic AutoCAD and the raster-basic MAP were ensured by MicroGIS (Kertész,Á. - Márkus, B. -Mezősi,G. 1990). In the MAP a resolution of 2.5 x 2.5 km could be reached. At the vector-raster transition calculated by Switzer method the mistake was 7.5 %, just within the acceptable accuracy (there is some difference from map to map).

RESULTS

Net Primary Production

The investigation of the NPP is one of the most important tasks of ecology since the material and the energy potentially available for heterotrophs are concerned here. It is much easier to assess NPP than GPP as the latter requires data on the intensity of photosynthesis and on active radiation. Assessments of NPP have been made since over 2 decades. Most of them are empirical formulae using the measurable relationship between climate parameters and NPP. For regional investigations the "Miami" (1) and the "Thornthwaite Memorial" models (2) (Lieth, M. - Box, E. 1972) are used. The "Miami" model describes the effect of the two most important climatic factors: precipitation and temperature.

$$P_p=3000\,(1-e^{-0.000364P}) \qquad (1a)$$

and

$$P_T=1+e^{1.315-0.119T} \qquad (1b)$$

where P_P and P_T=NPP (g/m^2/year), P=average yearly precipitation (mm), T=average yearly temperature (°C).

$$P_E=3000\,(1-e^{0.000969\,(E-20)}) \qquad (2)$$

where P_E = NPP (g/m^2/year), E=actual evapostranspiration (mm).

For the assessment of former (1) the actual evapotranspiration and for (2) the regional precipitation have to be known. On the basis of investigations carried out in test areas (Kertész, Á. - Mezősi, G. 1989), the results obtained in the (2) case seemed to be better. In our further calculations this correlation was applied. We can use these models to assess the NPP of a larger area, so only the trends and tendencies of the change of these NPP values were taken into account (Fig 2.).

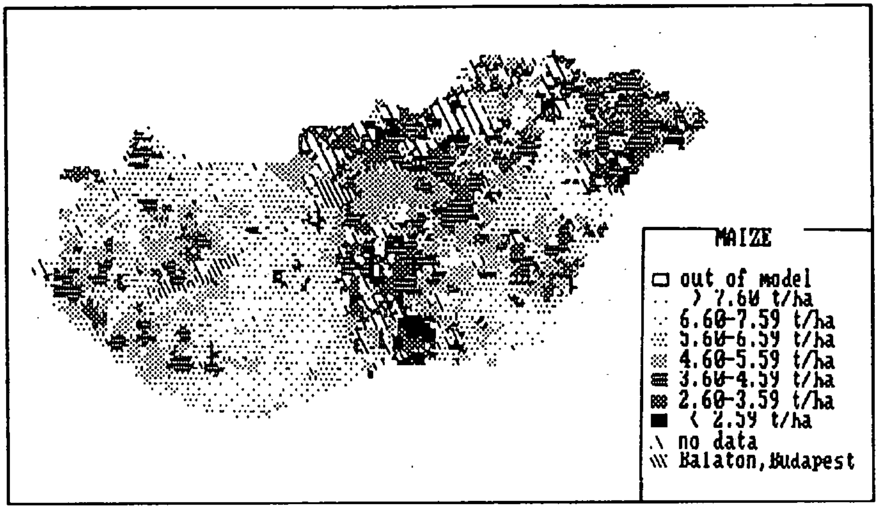

Figure 2 Net Primary Production in Hungary (calculated with Miami model) t/ha

Conflicts between the ecological factors and the yield of maize

In Table 1 it can be seen that in the case of landscape types asterisked with a star there is contradiction between the greet NPP values (it means a good availability of water) and the yield which does not reach even the average value. This is the most striking in the south-western part of the country where the landuse of the meadows, pastures and forests is relatively significant, too, in addition to the arable land. (More than 50 % of the country surface is covered by arable, its 14 % by pastures and meadows, and its 18 % by forests.)

Besides the availability of water an important factor, which influences the average of the crop is the soil score value (land capability index). The 100-score common in Hungary, began to come in general use in the last years (0 is the worst value, 100 is the best one) and involves correction factors of reliefs and climate, as well. The relationship between the soil score value and the average yield (as well as the NPP, too) is shown in Table 2. It car be seen that the average yield decreases simultaneously with the deterioration of the quality most considerably in the two last categories.

Table 1 Primary productivity (NPP) and the maize production (YIELD) for different landscape types

Landscape types (Fig. 1.)	Area %	Average YIELD for years 1980-84 t/ha	NPP ±0.2 t/ha	Conflict
1	16.46	6.03	10.24	-
2	5.06	4.75	9.88	-
3	5.72	5.53	9.91	-
4	10.41	5.95	10.12	-
5	2.21	6.22	9.86	-
6	4.30	3.85	9.77	+
7	8.29	4.42	10.41	+
8	2.96	4.17	10.16	+
9	6.64	5.73	10.35	-
10	24.40	5.40	10.57	-
11	1.28	4.05	10.27	+
12	5.04	4.64	10.39	+
13	7.74	4.81	10.41	+

Table 2 The NPP and the yield (maize) for soil score value (SSV) in Hungary

	SSV (point)	Yield t/ha	NPP t/ha
1.	>80	6.25	10.28
2.	65-80	5.75	10.22
3.	50-64	5.27	10.81
4.	35-49	4.33	10.32
5.	20-34	4.10	10.39

Use of fertilizers

The use of fertilizers and also the applied agrotechnology can significally modify the corn. The amount of the used fertilizers and the average yield of the maize (and the NPP) are compared (Table 3).

Consumption of fertilizers and the use of chemicals in farming in general played a dominant role in the growth of yields (Table 4).

Table 3 The yield (maize) and the NPP for different fertilizers application category

kg/ha	Area %	Yield t/ha	NPP t/ha
< 150	21.4	4.71	10.15
150-200	20.7	4.85	10.19
201-250	24.8	5.25	10.28
251-300	16.1	5.50	10.36
301-350	10.1	6.15	10.46
351-400	4.3	6.47	10.45
> 400	2.6	6.59	10.48

Table 4 Fertilizer application with different yields

Yield t/ha	Area %	Fertilizer kg/ha
7.60	7.5	304
6.60-7.59	11.9	285
5.60-6.59	20.8	255
4.60-5.59	19.5	224
3.60-4.59	14.9	210
2.60-3.59	8.5	184
<2.59	4.5	157
no data	12.4	Proposals

The results show that there is a conflict between the NPP values and the ecological conditions. Yields best correlate with the applied farming technique. In one hand we suggested that in Hungary an area marked out for maize growing should be situated in some of the landscape types plotted without an asterisk in Table 1. This amounts 71.4 % of the country surface. On the other hand, it should be met the soil quality categories from 1 to 3 of Table 2. Supposing that maize growing is the same in every landscape unit, the average yield can be increased by 5.2 % - from 5.38 t/ha to 5.66 t/ha - merely optimal selection of the landscape types, not more than 28.6 % is excluded (Fig.3). On other hand it should be met the soil quality categories from 1 to 3 of Table 2. The quantities of this soil types cover 74.7 % of the whole surface. Using this soil types the yield can be

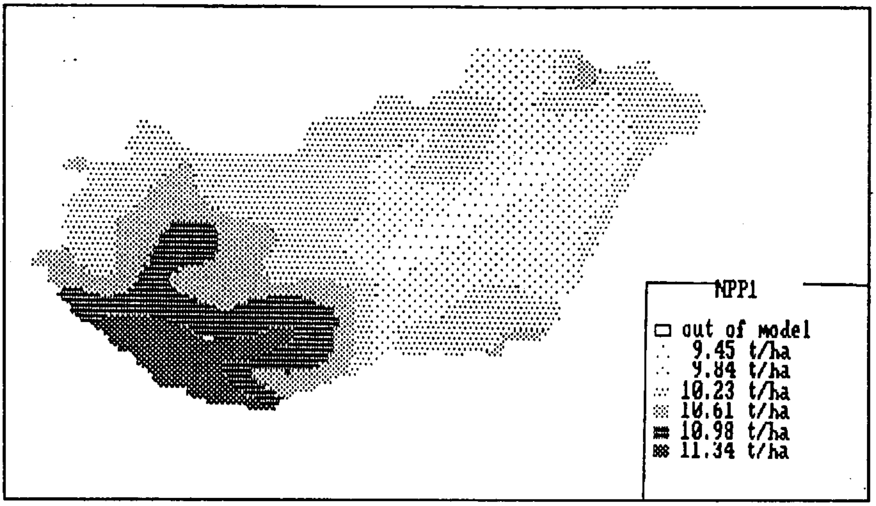

Figure 3 Maize production in Hungary (1984-89)

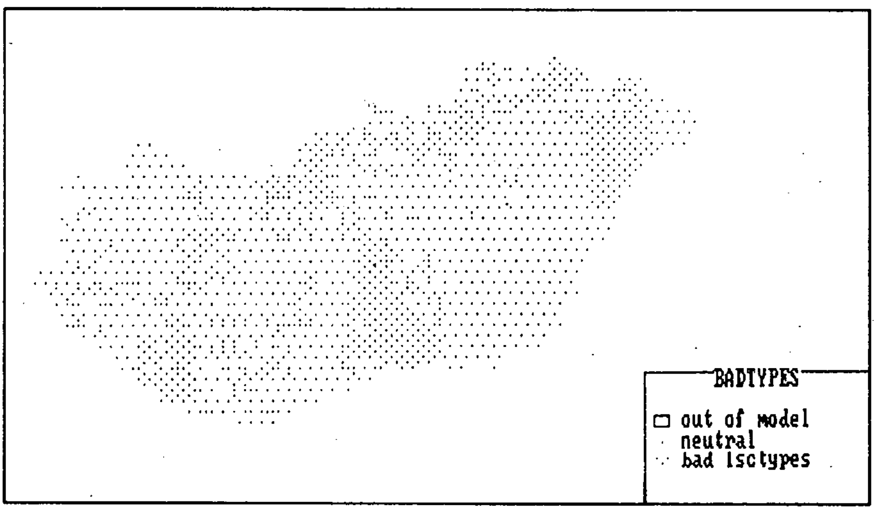

Figure 4 The situation of bad and neutral soil types from the point of view of yield

inceased by 6.4 % - from 5.29 to 5.63 t/ha (Fig.4). 28.6 % of excluded landscape types and 25.3 % of the excluded soil are situated in the two-third part of the same area. The residual soils and landscape types with favourable producing capacity - 64 % of the surface - may result in a similar increase - 0.41 t/ha, this is 7.6 % (Fig. 5).

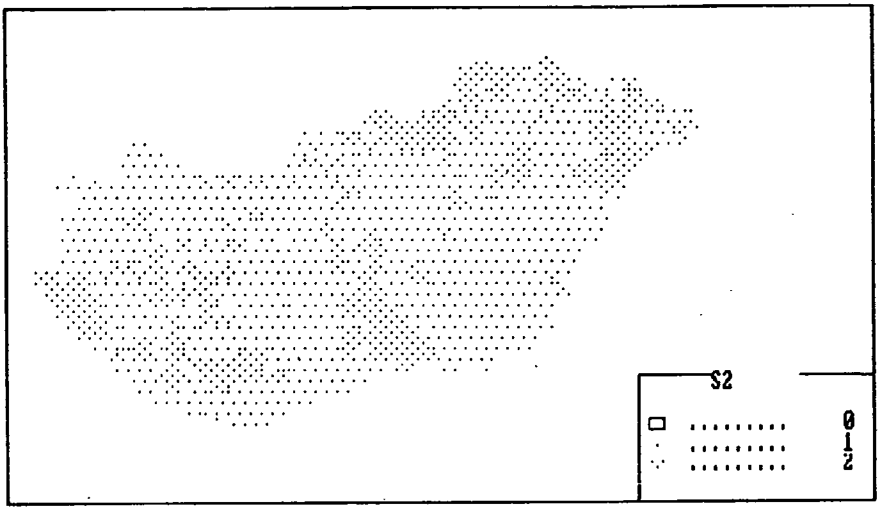

Figure 5 The residual soil and landscape types with a favourable -1 and unfavourable -2 producing capacity

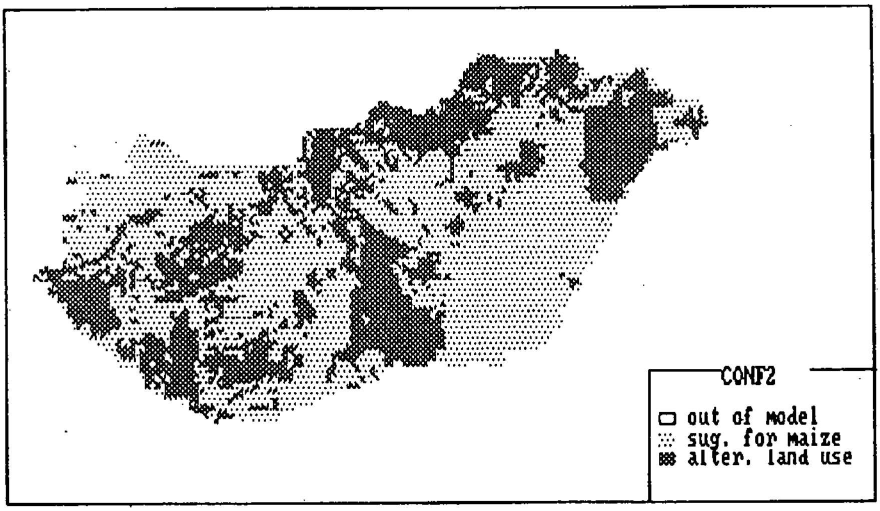

Figure 6 Areas suggested for maize production and alternative land use utilization

Data from literature prove (Szász, G. 1989) that the chemical fertilizer is more effective (+10-35 %) in these areas. To sum up it may be stated that by concentrating the cultivation in the areas plotted in Fig.2., the increase of the crop capacity may exceed 10 % . The real increase of yield depend on plant, soil type and climate, so it is very difficult to quantify exactly and predict regionally the growth. Using average data a prediction is shown on Fig. 6. The excluded areaś are suggested to be developed in the first place as forests.

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First results of GIS based geoecological mapping

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INTRODUCTION

The increasing stress on the geographical environment, its changing conditions, quality and potentials has drawn attention to the importance of the internal relationships within the geoecological system. This can be investigated from three distinctive points of view:

- an approach with a biological (ecological) aim, where the biotic factors of the environment or the structure itself are emphasized,
- a geographical approach, where the investigation concentrates on abiotic factors or the revelation of functions,
- a technological or planning approach, which analyzes the economic-technological background of effects.

According to the suggestion of H. Leser, (bio)ecology and geoecology are used as names for the distinction between first two approaches above and the disciplines connected with them. The distinction between these concepts lies in the judgement of the role of abiotic and biotic factors. Without underestimating the role and importance of biotic factors, it can be claimed that the abiotic geofactors determine the biotic adaptation.

In the last decades an intention is observed to approach the functioning of the natural environment and the investigation of abiotic factors by the use of geoecology. Meanwhile the problems of the structure and organization of the environment were solved by the methods of landscape ecology. Some authors do not distinguish between these concepts (Spãth, H. J. 1976, Treppl, L. 1987, Wein, N. 1985). We hope that the following series of investigations call attention to the fact that these concepts are not rigid categories. For example, geoecology can be used for the study of structural features, while landscape ecology can give solutions to functional questions of the natural environment. The confrontation of the concepts of geoecology and landscape ecology seems meaningless from this point of view.

In our opinion, the distinction of geoecology from landscape ecology, which has undoubtedly more detailed content and traditional background, is reasonable by the following facts:

- questions connected with the functions of natural environment have come into prominence,
- the establishment of the partial potential of the natural environment,
- a special collection of data based on field measurement, and other more direct practical claims.

The German literature solves this problem mechanically. It claims that geoecology investigates the abiotic factors, while landscape ecology investigates the biotic and abiotic factors (Leser, H. 1986,1988). The English language literature solves this problem differently (Naveh, Z. 1984). The concept of geoecology was introduced into the technical literature by C. Troll (1971) who used the term synonymously with landscape ecology, but in other practical approaches it can be traced back to the works of C.O. Sauer et al. (1919).

In our view, geoecology can give answers to numerous geoscientific questions, such as the mitigation of natural and environmental hazards (e.g. waterlogging, floods, soil erosion) weighting of the effects of the changes in land use, and the evaluation of environmental impacts. In addition, geoecology can be the base of political decisions and regional planning if the decisionmakers take ecological data into consideration.

METHODS

In our view data are the most important in geoecology, since the assessment depends on the authenticity of the data. Therefore, we used the methods of the German geoecological mapping and field measurement in the mid 80's (Leser, H. 1984,1988, Richter, G. 1985). Geoecology investigates the functions and management of the natural environment. During geoecological mapping, normally primary sources of data become secondary importance, specifically the genetic and chronological factors. There are two innovations in our method which help us through the most critical points of mapping. On the one hand we used remote sensing data in the interpolation of simple data and on the other hand, we ensured the complexity of maps in such a manner that these geoecologic maps were divided into distinctive layers from a thematic point of view (e.g. physical properties of soils, DEM, etc.). These layers were stored in a GIS. The catchment area is the evident unit in the geoecological investigation.

In spite of the long history of geoecology and of geoecological mapping we cannot find existing geoecological maps in literature. The reason for this is that the functional connections investigated by geoecology are difficult to map. The structural patterns and their connections, namely the result of the ecology and landscape ecology, can be more easily mapped. Certain researchers envisage the geoecological map to be an overlay map, representing all of the abiotic factors simultaneously (Leser, H. 1986). In our opinion, the geoecologic map may appear similar to a virtual map. The geoecologic maps can be divided into three groups according to their degree of integration:

1. Analytic, analysing only one factor,
2. Complex, analysing more than one factor, or

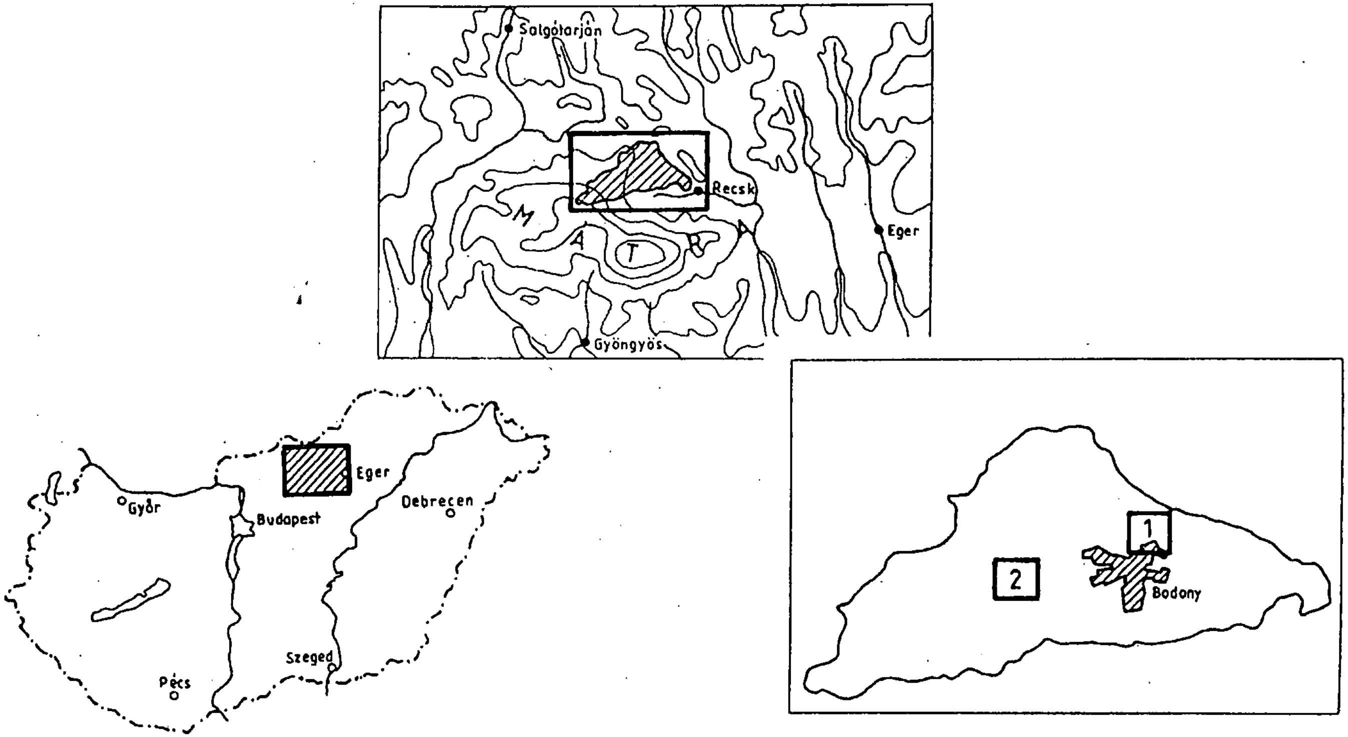

Figure 1 Location of the test sites in Hungary

3. Synthetic, combining multiple evaluations.

Naturally the geoecologic map is expected to satisfy the latter condition, but it may have other e.g. cadastral function.

In 1990 we started the geoecólogical mapping of various catchments. Longterm data series are necessary for exact analyses. Below we will attempt to answer those geographic questions which are answerable at the beginning of the investigation.

The catchment area of Katarét stream is situated in the Mátra mountains and is about 20 km² (see Fig.1). The relief, land use and rocks of the catchment are very diverse. We have chosen two characteristic test areas, 1 km² each. The first problem studied is in connection with the reclamation of partly cultivated surfaces and the development of the optimal land use. In the second part we analyze the effects of the environmental hazards, especially the areas endangered by soil erosion and the third one deals with recreation.

The maps were digitized using AutoCad and ArcInfo softwares and data processing was done by the GIS of ArcInfo and Idrisi.

RESULTS

1. We sought to answer the following questions: What kinds of foci can be found on the catchment area from which the natural vegetation can spread out again? Where and how can a better land use be designed in this area with respect to the geoecological conditions?

First, it was necessary to estimate the ecological stability of the present vegetation and to delimit those areas where we were able to coordinate the transition, considering the condition of the vegetation and the trend in its development. The potential corridors and barriers could be indicated which may influence the tendency of the transition. We analyzed the connections between the present, actual vegetation and the natural vegetation expected under the given geoecological conditions. In this way, we could identify areas where there was a major conflict between the present and the potential vegetation.

1.1. The investigation of a successions of plant associations gives important information about the trend in landscape development. The environmental factors control the rate of this development. The development of the succession can be divided into three phases: the initial phase (I), the optimal phase (II), and the degraded phase (III). The development is progressive from phase I to II and regressive from II to III.

We divided the plant associations into categories according to the values of the environmentally protected species (Simon T. 1988) living in the area (Fig.2). The points of the categories gave the catchment patterns. Since most of the area is under cultivation, the majority of the patterns belong to the third (degraded) phase.

The following associations fall in to this type: disturbed grassy association; clear-felling; cleared woodland; grassland; uncultivated field; acacia forest and a mixed forest with planted pine. The forests are situated between the optimal and the degraded patterns and their development may be either progressive or regressive. The initial plant associations appear as narrow ecological corridors between degraded and optimal associations. At present these areas are in the regressive phase. If human activity decreases in areas

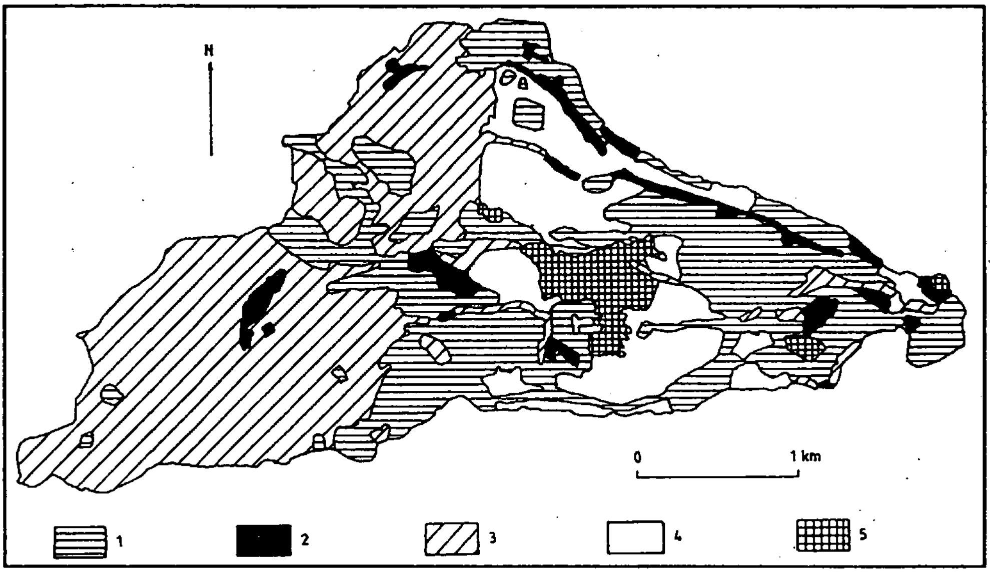

Figure 2 Series of plant assotiation in the catchment area
1 - degraded; 2 - initial; 3 - optimal; 4 - cultivated area; 5 - settlement

progressive development will be possible. The optimal (II) association is the oak-forest with hornbeam as well as submontane beeches situated on higher surfaces. We also consider the alderforest on the wet surfaces and grassy associations on slopes an optimal association. The pattern of the area shows that the former homogeneous biotopes of the plant associations were divided into smaller spots isolated from each other. This process is called "fragmentation" in ecology. Usually, fragmentation is unfavourable for the development of the living beings in a given area. We supposed that a fragment is optimal if the ratio of its area and its perimeter is favourable; at the same time this ratio indicates the stability of the association. Usually we can state that the earlier series of successions have smaller stability than that of the climax phase. But the stability may be high if successions promote a natural development. Instability is always the consequence of some kinds of interventions into the natural processes. The effects of these processes are inestimable.

1.2. We have calculated the ecological stability of the plants on the test sites. At first we used the following method. The stability of a given pattern is equal to the ratio of the area and the perimeter. But this number does not give a correct expression of pattern properties derived from its shape. If there are two patterns with the same shape, but different areas, the index of stability remains equal; conversely there may be two patterns with the same index of stability but with different shapes. Therefore, we had to find a new of index of stability. This new method is based on the elementary rules of geometry. The aim of this method is to express numerically the regularity or the irregularity of a pattern. The index of stability is the ratio of R_1 and R_2, where R_1 is the radius of a circle whose area is equal to the area of the given pattern, while R_2 is the radius of the circle whose perimeter is the same as the perimeter of the pattern.

$$\text{Index of stability} = \frac{R_1}{R_2} = \frac{\sqrt{4\pi T}}{K}$$

The R_1/R_2 ratio always ranges from 0 to 1 if we disregard any exceptionally deformed patterns. If the pattern is of circular shape the index of stability approaches 1 (for example the index of stability of a square equals 0.886).

1.3. If we compare the ecological stability and the calculated index of stability of a given pattern, then the plant associations can be divided into three groups. We can say that the plant association is unstable if its index ranges from 0 to 0.3, of medium stability if its index ranges from 0.3 to 0.6, and stable if its index is higher than 0.6.

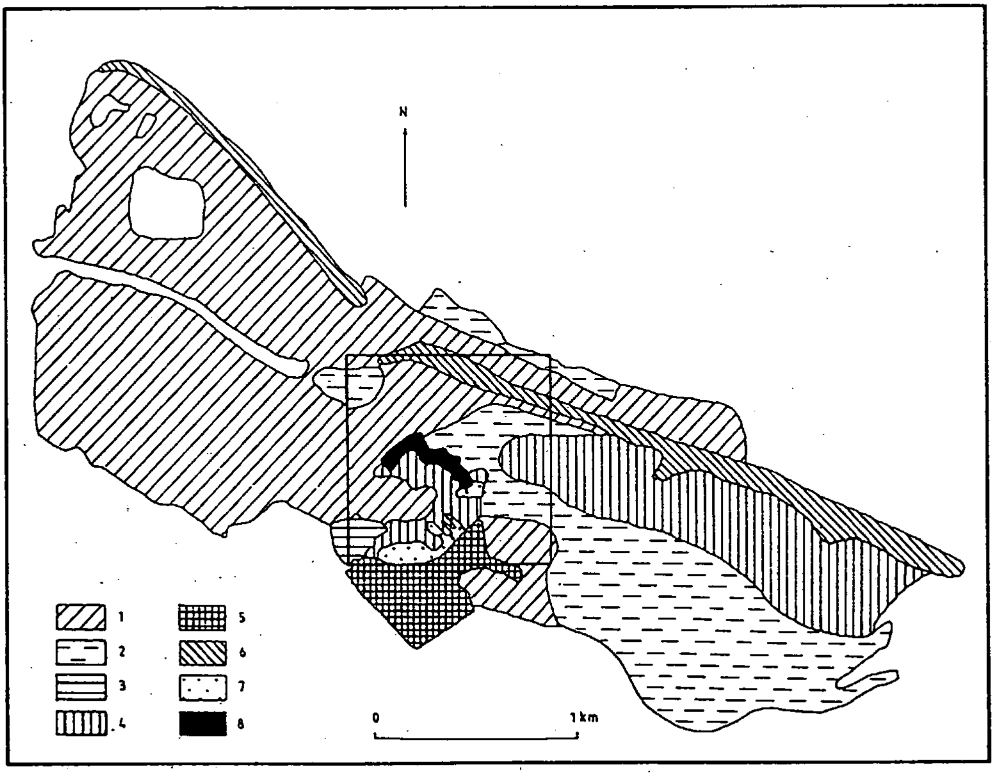

Figure 3 Plant associations on test site No.1 (near Bodony)
1 - cultivated area; 2 - pasture; 3 - mixed forest (pine); 4 - meadow, grassland; 5 -settlement; 6 - hydrophyte assciation; 7 - orchard; 8 - acacia grove

On the first investigated test site (Fig. 1, No. 1), the forest association and the meadow-grassland are the most stable plant associations (Fig.3). On the cultivated surfaces, e.g orchards, the index of stability is lower (regressive development). Especially the pastures have a high index which are the continuations of stream-bank successions. The junction of the ecological corridors with these areas (beside reducing agricultural lands) makes the advance of the ancient succession of meadow possible. But this process can become progressive if the area of cultivated land decreases. The index of stability of the cultivated areas ranges from 0.2 to 0.5. If we examine the index of stability on the land use map it can be claimed that the forests, row plants and graincrops have high indices (higher than 0.6). It is to be noted that these data are relative and they cannot be compared with the index of stability of the plant associations because the natural conditions have been changed by human activity.

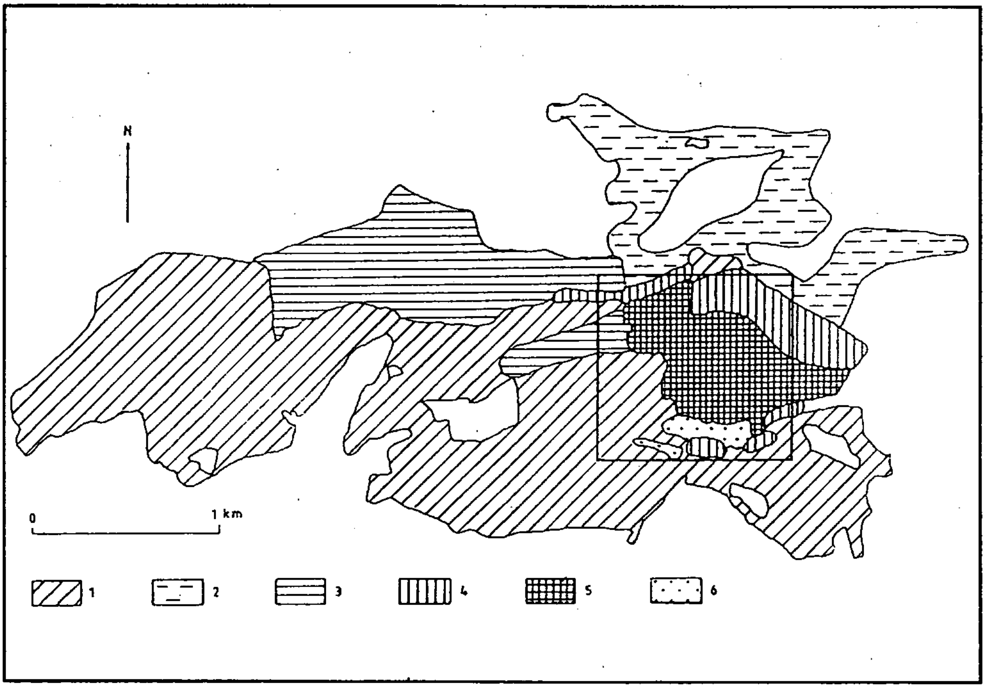

Figure 4 Plant assotiations on the test site No. 2 (Kecske-hill)
1 - oak forest with hornbeam; 2 - hydrophyte association; 3 - mixed forest (pine); 4 - meadow, grassland; 5 - acacia grove; 6 - mixed decidous forest

On the other test site (Fig. 4), there is a high index of stability for the following plant associations: mixed broad-leaved forest, meadow, grassland and bushes. The test site is situated at the interface where the natural association is disturbed by planted vegetation (e.g. acacia grove). The geometric properties of the artificially planted vegetation have not yet changed basically, but the index of stability of the mixed broad-leaved forest and the oak hornbeam forest is high enough. On one big pattern, the meadow-grassland indicates the advance of natural vegetation (high index of stability, greater than 0.7).

On this test site, progressive development can be revealed in comparison to the former test site. The progressive development leads to the increase of stability of the plant association. The succession of the plant association develops from the meadow (initial phase) to the optimal association. The index of land use better represents the reality since in all but one case it is lower.

Collectively the areal differences in index of stability are synchronous with the above presented deviations in the development of the succession.

1.4. It is known that species have welldefined ecological demands, e.g. water budget of the surface (W), soil reaction (R), nitrogen-content of the soil (N) and temperature (T). The average values of these factors for a given group of plants are known (16). Usually the value of a factor ranges from 0 to 5 (or 10). During our investigation we substituted the W factor with soil texture, the R factor with the pH value of soil, the N factor with thickness of humus layer and the T factor with aspect. We evaluated the measured real geoecological conditions and the geoecological conditions which are claimed by the plant associations found on the test sites. According to literature the common value of the W and R factors occurs with a weight of 2/3 and the value of the N and T factors with 1/3. The possible directions of the development can be estimated by the help of the above mentioned method (ef. 1.3.). Our results are presented in Fig. 5. (data refer to test site No. 2, which is mainly covered by natural vegetation).

	1	2	3	/value/
W	clay	sand	loam	
R	4.5-5.5	7.2-8.5	5.5-6.8 pH	
N	<60	60-100	>100 cm	
T	northern	flat	southern	

The natural plant association on the area is the oak forest with hornbeam trees. Bigger patterns occur under favourable conditions if we look at the true geoecological conditions (2223). Here the true condition is the same as the ecological requirement of the plant association. On the smaller isolated area, the value of the W factor is lower and the clay content increases in the soil. The development of the succession is regressive and the index of stability is of medium value. At the mixed broad-leaved forest, there are lower real conditions (1133 or 1223) on significant lands than the ecological demand of the association. The index of stability is very low. Here we can find the degraded (III) phase and the development is regressive.

The development can be progressive in the acacia groves, because the real conditions (2333, 2332) are very favourable for the natural vegetation and at the same time the requirement of the acacia grove is very low. We can say that the new direction of the coordinated development may tend toward this area. The gallery acacia groves are

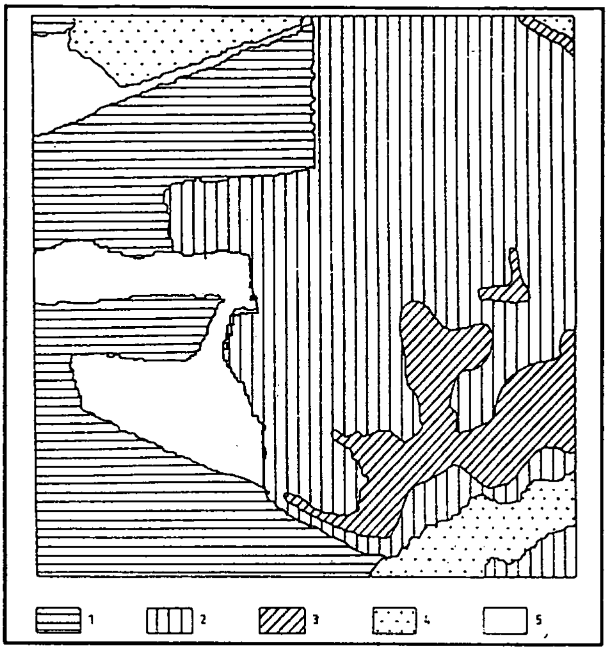

Figure 5 The map of the goeecological conditions of test site No. 2 (Kecske-hill)
1 - 1321-1331; 2 - 2332-2333; 3 - 2223-2211; 4 - 3321-3213; 5 - 1133-1211

especially favoured by these geoecological conditions, but in the closed acacia groves, the soil reaction demand and the true soil pH harmonize while the physical properties and the W factor do not. It is the result of uncontrolled planting.

The meadow and grassland are situated on favourable lands (3321), and their indices of stability are high and the true conditions are in accordance with the ecological requirements. The development is progressive and the association develops from the initial phase (I) to the optimal association (II). This process can be sustainable if human activity decreases. The plants species on the meadows and grasslañds are euryecious plants; therefore, the direction of development is favourable and the index of stability is also high.

It can be claimed that on the test site there can be simultaneous progressive and regressive developments which can be in equilibrium with proper land use in future.

1.5. In our opinion, the investigation of the landscape budget for entire catchment could be very instructive and the identification of the surfaces of energy and the material loss. We can simply map areas with negative, positive and neutral budgets (from a soil scientific and hydrological point of view). We calculated the energy as a function of relief, solar radiation and aspect (Kerényi A. 1977, Mezősi G. 1985). We would like to present one of the possible combinations of conditions in the following section.

2. One of the most important aims of geoecological mapping is the forecasting of natural hazards. Here we present the analysis of those surfaces which are endangered by soil erosion. We completed this calculation for the whole catchment. The method is based on the Universal Soil Loss Equation (USLE) (Wischmeier, W.H. - Smith, D.D. 1978) as well as on the modification of this equation by Schmidt (Schmidt, R.G. 1988). The aim of the modification is to substitute those factors, which can be defined by experimental methods, with measurable values (e.g. K, i.e. soil erodibility factor). Therefore, the more important

components of this method are the soil-type, slope, precipitation during the growing season and land use as well as other modifying factors (e.g. humus content of the soil, vertical and horizontal slope shape etc.).

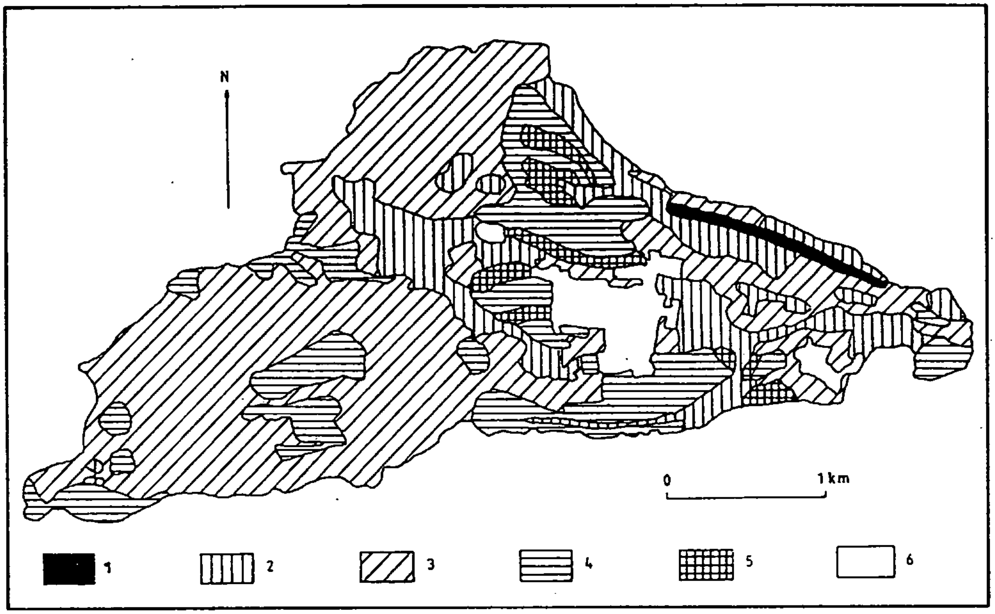

Figure 6 Map of soil erosion on the catchment (t/ha/year)
1 - <1; 2 - 1-5; 3 - 5-10; 4 - 10-15; 5 - 15-30; 6 - settlement

Different tables help us to apply the method (Fig.6). If the plant cover is stable, soil erosion does not reach a value of 10-15 t/ha/y, while on cultivated land soil erosion is always higher (25-30 t/ha/year). The reason for soil erosion on the first test site is the physical and genetic properties of the soils while on the other test site it is the angle of slope.

3. Because of the increasing recreational use of the catchment area, the estimation of the physical carrying capacity is a very important task. This method is based on that fact that the soil can be favourable for characterisation of climate, rocks, relief and vegetation. In the USLE we substitute T for A, the value of the combined cover and erosion-control factors (CP) necessary to maintain the productivity of the soil is: CP=T/RKLS . The P factor approaches 1.0, consequently the P factor was omitted from the equation in its adaptation for outdoor recreation planning (Küss, F.R. - Morgan III, J.M. 1986). Thus the equation becomes: C=T/RKLS. The product is a measure of the erosion potential of each soil, assuming barren soils. According to the empirical data, if the value of C ranges from

80-100%, the physical carrying capacity of the given area is low (60-80 % - medium, below 60 % -high capacity).

On the test sites there are areas with medium and high carrying capacities and their greater part belongs to the group of closed grassy associations. We hardly find natural lands of high physical carrying capacity, but the forests are of medium carrying capacity. The reason for this is that the forests are very sensible associations and forested lands showed high angles of slope.

SUMMARY

From the first results of the geoecological mapping on the given area, we can say that geoecological investigation is suitable for the estimation of the physical carrying capacity of the test site. We are able to estimate the development of the land (ecological processes, changes in plant associations etc.). This method helps to coordinate land use and recreation.

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A study of the physical carrying capacities of natural areas for recreation on the catchment of Katarét stream

Dr. Imre Balogh

Summary

There is no unified, established method for the study of the physical carrying capacities of natural areas for recreation. The present paper undertakes the task of defining the physical carrying capacity of a mountain range of medium height by applying Wischmeier and Smiths Universal Soil Loss Equation (USLE) and vegetation coverage.

Introduction

In the urbanized world of today the recreational potential of natural areas is increasingly appreciated. More and more people decide to spend their leisure time hiking, take week-end and holiday trips outdoors. In some cases, however, this increased interest can produce undesirable consequences. A beautiful landscape, a unique natural phenomenon draws too many visitors to its location, which can be significantly damaged. The exploitation of natural areas by outdoor activities is known in many fields. The assessment of the physical carrying capacity of these areas is a serious problem, since generally there is only a small amount of information available and there is no comprehensive method for study.

While working on the geo-ecological map of the catchment of the Katarét stream, we had the opportunity to examine this area of the Eastern-Mátra from a recreational point of view as well.

Method

The assessment of the utilization and physical carrying capacity of natural areas usually employs general ecological criteria, but these can provide mostly quantitative evaluation only. This hinders a management that focuses on environmental protection, because primarily it requires the quantitative rating of land units into classes according to their carrying capacity. F.R. Kuss and J.M. Morgen III (1986) presented a method to solve this problem by classifying natural areas on the basis of their relative carrying capacities for recreational activities.

The theoretical background of the method is the observation that it is enough for the assessment of the physical carrying capacity to examine the soil and the density of the vegetation. This estimation is possible because the soil may be appropriate for the examination of the impact of climate, age, constituents, configurations of the terrain (slopes, depth of the water table). Also, the type and orographical situation of the soil affects the vegetational order, the biomass-product, the variety of the flora and fauna, and the degree of suitability as a biotope. The capacity of the natural area to avert the effects of recreational activities is largely attributed to these factors. The density of the vegetation is an additional factor significantly influencing the spatial extension and temporal intensity of soil erosion.

Our method is based on the Universal Soil Loss Equation introduced by Wischmeier and Smith that can be expressed as

$$A=R*K*LS*C*P$$

where A is the predicted soil loss in tonnes per hectare, R is the erosion potential of the rainfall, Ls represents the length and steepness of the slope, K is the erodibility of the soil, C is the factor representing the vegetation that covers the soil and P is the factor expressing the of erosion control practice.

A sixth factor affecting the use of the equation is T, a factor established for different soil types expressing the maximum soil loss on 1 hectare that does not impair the productivity of the given area.
If we substitute T for A in the equation, the combined value of the cover and erosion control factors

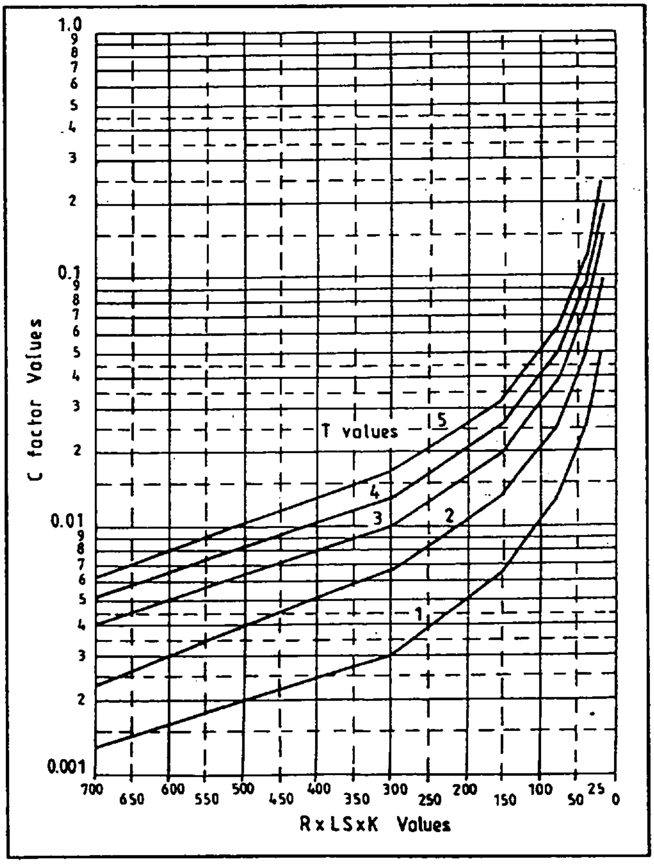

Figure 1 Graph showing the relationships of T values to C factor and Soil Loss Index values

necessary for maintaining the productivity will be $C*P=\frac{T}{R*K*Ls}$

Since in natural circumstances erosion control activities are generally not present, the value of P approaches to 1.0, therefore, when designing recreational activities, we disregard P and arrive at

$$C=\frac{T}{R*K*Ls}$$

Figure 1 serves to help to define the actual values of C.

The alternatives suggested for the estimation of the physical carrying capacity of natural areas regard the percentage values of the vegetation necessary to maintain the productivity of the soil to be the most acceptable basis for assessment. In accordance with this, the defined values of C for soil types, which indicate the impact of vegetation on soil erosion, should be converted into percentage values of vegetation coverage. Figure 2 serves to convert the values for woods and grass-covered areas.

It is necessary for the manageability of the resulting percentage values to assign them into categories. Practical considerations suggest the establishment of three categories. Areas that require 80-100% vegetation cover

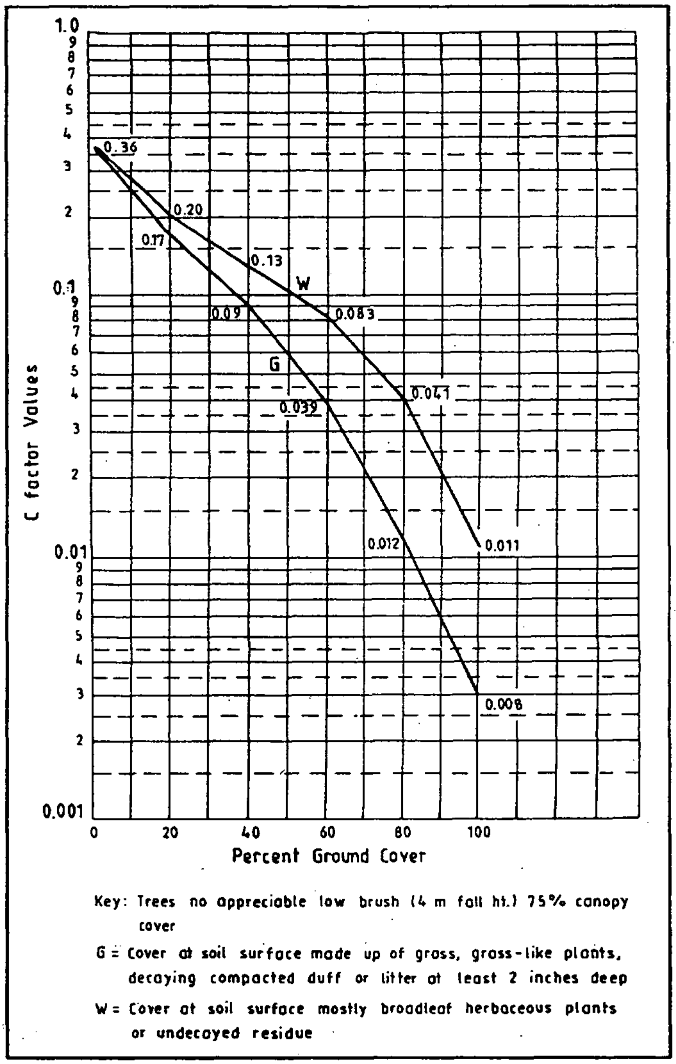

Figure 2 Graph showing the effect of two types of ground cover and variable ground cover percentages on C values

can be classified as low carrying capacity areas, those with 60-80% cover are medium, those requi-ring cover under 60% are high carrying capacity areas.

Results

The geo-ecological mapping of the drainage basin of the Katarét stream resulted in a large amount of reliable data that helped us understand the ecological and geo-ecological conditions of the area and the magnitude of the control on soil erosion processes (Mezősi et al., 1993.) We also regarded it as our important task to examine the carrying capacity of the drainage basin, where the significant proportion of protected areas and the increasing recreational utilization both called for the independent examination of these areas.

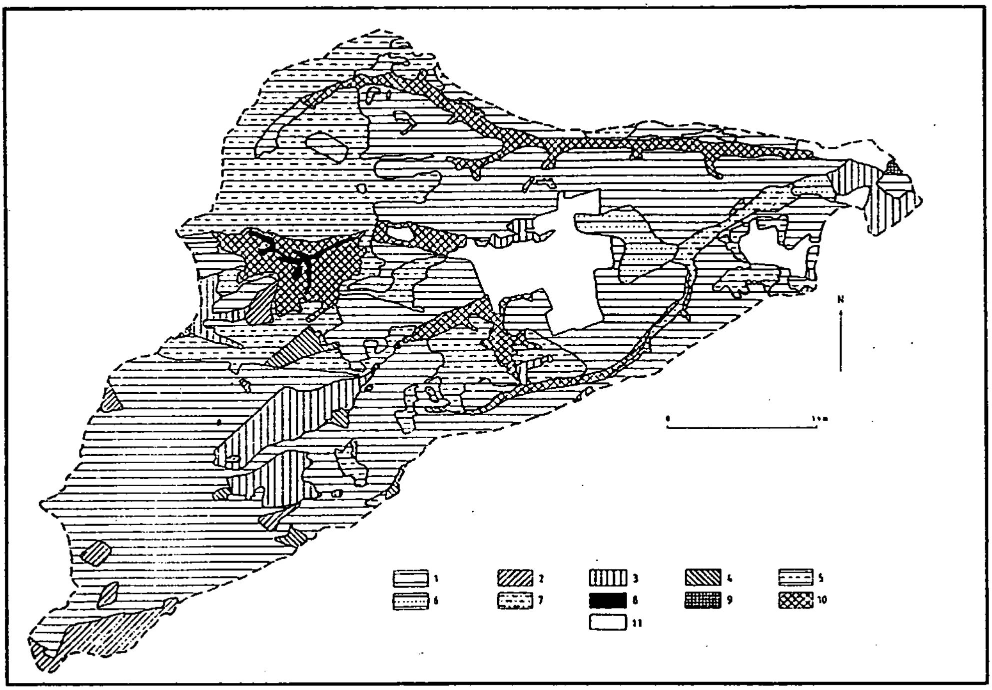

Figure 3 The soil types of the Katarét stream catchment

1 - brown forest soil with clay illuviation 2 - ranker soil
3 - Raman brown forest soil 4 - pseudogley brown forest soil
5 - ferrugineous forest soil 6 - carbonatic humic alluvial soil
7 - non carbonatic humic alluvial soil 8 - meadow soil
9 - non carbonatic stony soil 10 - colluvial soil
11 - settlement, water, mine, spoil

Our area comprised approximately 20 km² best of the NE Mátra mountains. Heights varied between 189 m and 956 m; in the formation of the major soil types the predominant factors were the andesite-rhyolite series that are the main components of the mountains and the regolith, the lacustrian deposit and fluvial formations. There are two major groups of surface forms in the area. The middle and Eastern half of the drainage basin is dominated by gently sloping riverside lines of hills, while the Northern and Western parts are characterized by ridges with steep crests and, in their foreground, similarly steep hills with narrow valleys between them. The lower areas, as well as the gently sloping, wide hillsides are intensively used for agricultural purposes. The situation, the soil types are shown in Figure 3.

We carried out the examination of the carrying capacity of natural woods and meadows on the basis of the soil units defined as part of the mapping of the soil. Thus we were able to define the values of C and the parameters explained above for the test area promptly and this way it was easy to show them in the map. The percentage values of the vegetation coverage necessary for the maintenance of the productivity of the soil are shown in Figure 4 in categorized territorial occurrence.

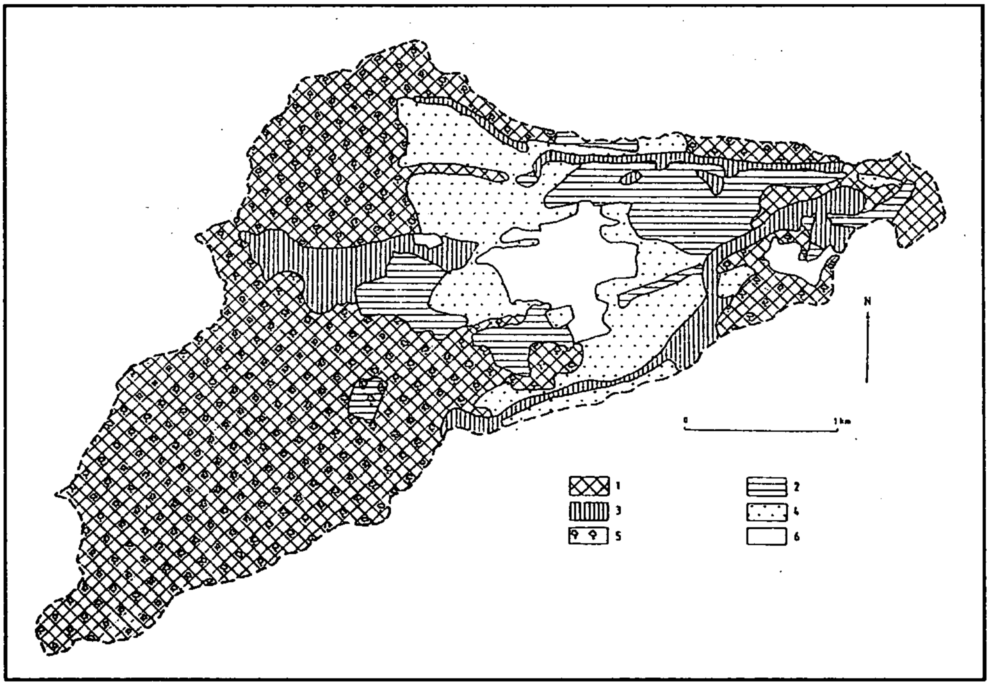

Figure 4 Physical carrying capacity of natural areas in the catchment of the Katarét stream
1 - low; 2 - medium; 3 - high; 4 - cultivated area;
5 - forest; 6 - settlement, water, mine, spoil

It is obvious from Figure 4 that the high capacity areas are located on the hills in the foregrounds of mountains and on those bordering the streams as floodplains. A common characteristic of these areas is coverage by grassy plant communities. Concerning the woods, these are primarily low capacity areas, with the rare occurrence of some medium capacity areas. The main reason for this is that the woods cover areas with the highest relief and that the thin soils formed on the andesite-rhyolite rocks have high K values. We consider it very important to emphasize the high sensitivity of wooden areas because in the privatization process large forest areas became privately owned and in many of these areas intensive logging has already started. And this, in an extreme case, can lead to the complete eradication of the soil.

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Remote sensing methods in soil erosion assessment in the Mátra Mountains, Hungary

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Abstract

In the test site, which is situated in the northern part of Hungary in the Mátra Mountains there are various lithological and morphological conditions together with special land uses. In the test area, the importance of relief, plant cover characteristics and the physical properties of the soil types can be emphasized by examining the degree of soil erosion caused by water. Different field measurements based on soil mapping were performed to assess the erosion intensity of the area. Landsat digital data were used to calculate the C and K factors of the Wischmeier-Smith formula. These results were compared with field measurement data. The factors of USLE were stored and processed using a GIS. The field measurement results and the values of soil erosion estimated by the Wischmeier-Smith formula were compared. An estimate of the intensity of soil erosion by distinctive composition of Landsat TM images was calculated. This was also compared with the USLE values.

The results show that the punctiform measured data can be extracted regionally but that remote sensing methods are not enough for an estimation of soil erosion and must be used in conjunction with field measurements. Surface areas which have to be protected against soil erosion were identified together with potential sites which may be destroyed by this process in the future.

Introduction

About 3O % of the cultivated area of Hungary is affected by soil erosion. The soil erosion lessens soil capability and upsets the dynamic ecological equilibrium of the soil system. Because of the changes in land ownership as a result of privatization, there has been a significant transformation in land use, agricultural technology and the area of farms. The big cooperatives and governmental soil conservation services were defuncted and consequently, new owners are short of information concerning the soil erosion risk.

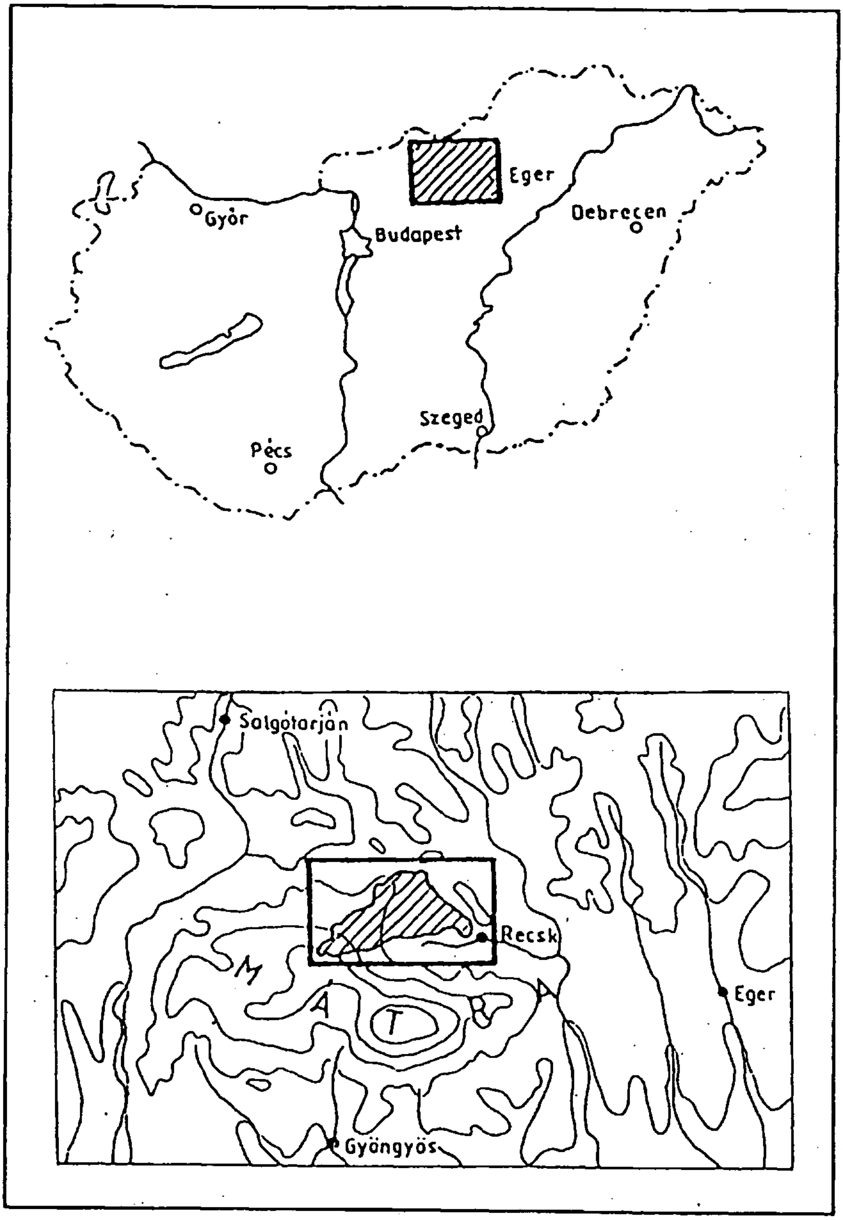

Figure 1 The situation of the catchment area in Hungary

The basic ecological conditions are not modified by the changes in ownership and th erefore a catchment area (Fig. 1) was chosen as the test site unit. Considering this fact, the USLE formula was applied to the catchment area. The main aim of the study was to locate those areas which are endangered by soil erosion independently of the borders of land parcels and to find areas in which the dynamic equilibrium is upset.

METHODS

In the investigation the unified soil loss equation (USLE -Wischmeier, W.H.-Smith, D.D. 1978) was used. The USLE is an erosion model, which assesses the soil loss for a given site as the product of six major factors, whose most likely values at a particular location can be expressed numerically. The soil loss per unit area is (A):

$$A=R*K*Ls*C*P$$

where R - the rainfall and runoff factor (most important part is the rainfall erosion index), K - the soil erodibility factor, Ls - slope length and steepness factor, C - surface covering and management factor, P - support practice factor. The two complicated factors K and C were controlled with the help of remote sensing methods. The K factor was simultaneously experimentally measured in the field using a field-plot rainfall simulator. The K factor depends mainly on soil type and texture, which allows the use of remote sensing methods. There are a lot of formulae to express the NDVI or the biomass value of a surface by measuring the vegetation cover characteristics and from these, the regional differences of the C factor can be assessed. The C value was also calculated from the suggested tables in Wischmeier and Smith (1978). All bands of the Landsat TM image recorded on 7 July, 1987 were used because the rainfall intensity (EI) and the predicted soil erosion give the highest rate in this early summer period. The LS values were measured using field methods. The maps were digitized in AutoCAD and the results were transferred to IDRISI v. 4.O (Eastman, J.R. 1992). In IDRISI the vector database was converted into a raster database, and stored in GIS. The rasterized database was then used to compare field measurement data with the remotely sensed data. The best composite of different TM bands which substitute the slow process of the experimental field measurement data can then be distinguished.

RESULTS

Some factors in the USLE formula can be easily calculated or, owing to the insignificant differences, the factor value can be constant. For example, the P factor is equal to 1 for the entire catchment area because there was no special soil conservation management.

Other factors, such as L and S, were measured at the test site: the value of steepness of land slope ranges from 10 to 12 %, while the length of land slope ranges from 300 to 500 m. The LS values therefore, are more than 3 and less than 5. It may also be deduced that the steepness of the land slope is greater in the western part of the catchment than on the cultivated eastern part.

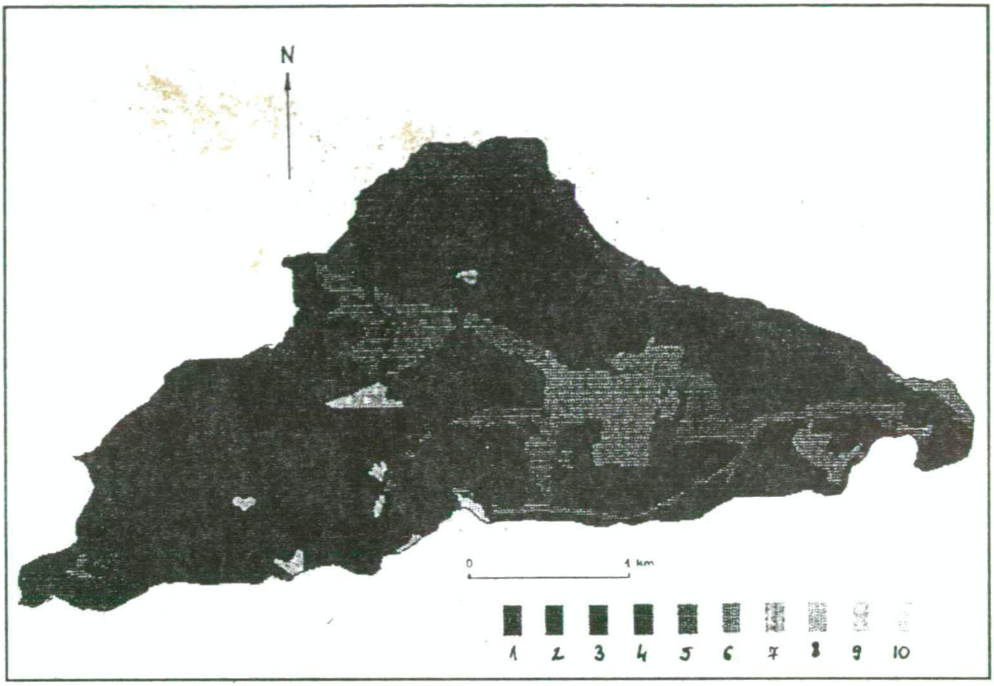

Figure 2 Map of soil erodibility factor (K) on the catchment
1 - 0.11; 2 - 0.18; 3 - 0.25; 4 - 0.26; 5 - 0.28;
6 - 0.29; 7 - 0.3; 8 - 0.32; 9 - 0.35

The soil erodibility factor (K) must be evaluated independently of the effects of the other factors. The K factor in the USLE is a quantitative value which is experimentally determined. The calculation of this factor is difficult and requires measurement, but with the help of the soil erodibility nomograph the approached value can be calculated if the soil's sand content, the amount of organic matter, the structure and permeability are known. A map of K factors for the entire catchment area was constructed. In spite of the fine resolution there are no significant differences between the K value of the patterns, and it ranges between 0.1 and 0.3 in 95 % of the area (Fig. 2). In the transitional zone between the cultivated area (meadow, grassland, pasture, orchard) and the uncultivated area (forest, deciduous forest, acacia grove, hydrophyte association), small patterns occur and it is here that greater differences between the K values are found.

A TM image or image composition, which can represent the same conditions as the map of the K factor, was determined. However, the calculation of the K factor is difficult and it is not the same as soil erosion, therefore there is not a single image which can take the place directly of the original method. On the 742 (RGB) TM composite the important

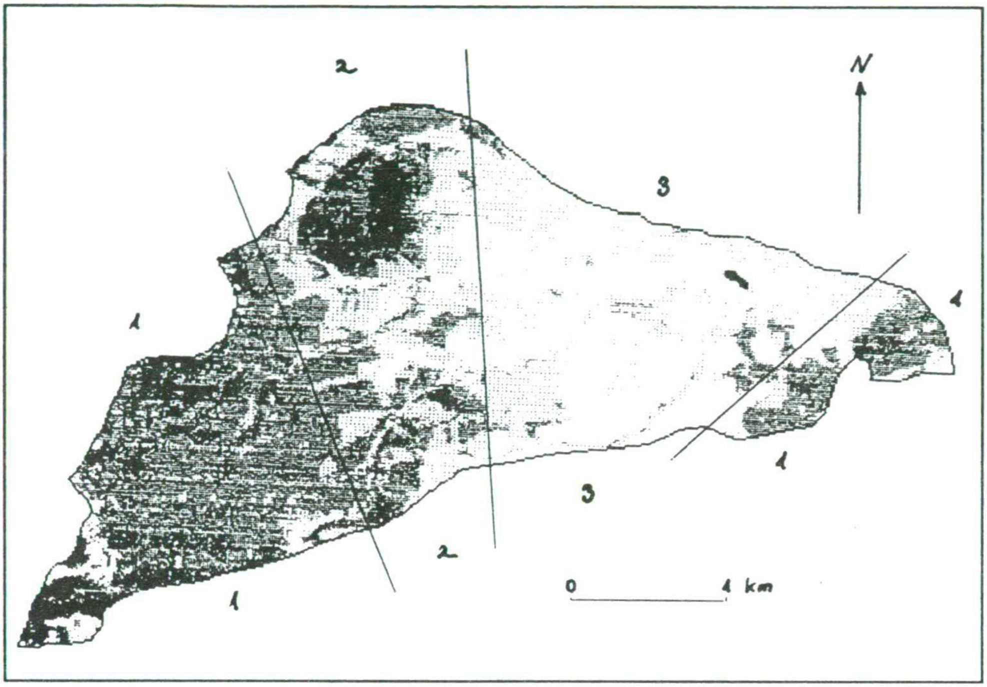

Figure 3 7,4,2 (RGB) Landsat TM color composite of the catchment
(Black & White representation)
1 - forested area
2 - transitional zone
3 - cultivated area

patterns which appear on the map of the K factor may be found. The transitional zone is apparent on the composite but there is a difference between the anticipated and the cultivated area, which is the result of the distinctive reflection of the plants (Fig. 3).

Before calculating the C factor value, the plant cover map of the area together with the map of series of succession of plant associations had to be constructed because the latter is very closely connected with land development and soil erosion. Environmental factors control the rate of development. The development of the succession can be divided into three phases: the initial phase (I), the optimal phase (II) and the degraded phase (III). The development is progressive from phase I to II and regressive from II to III. Since the bulk of the area is under cultivation, the majority of the patterns belong to the degraded phase (Fig.4).

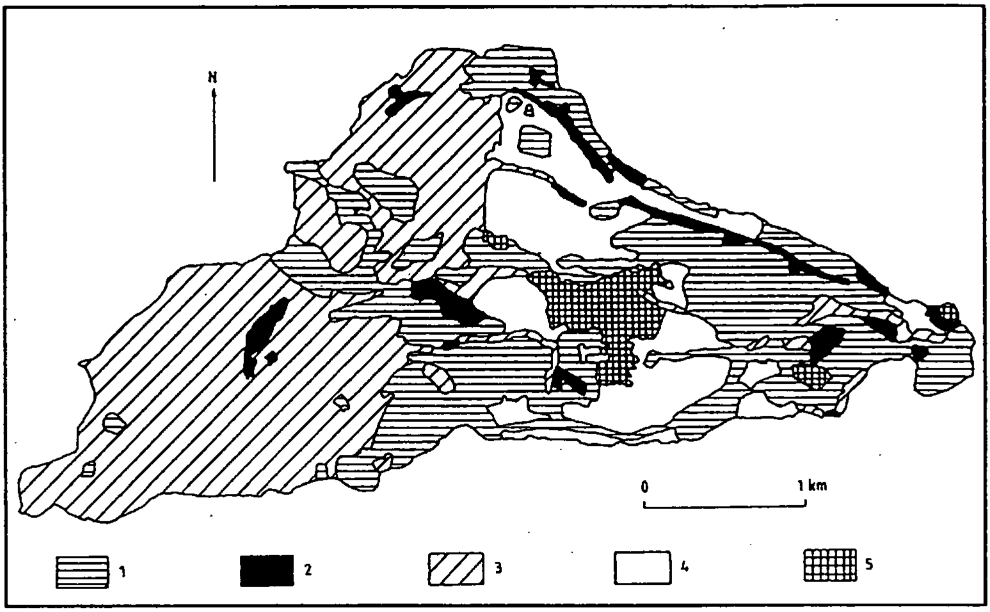

Figure 4 Series of succession of plant assotiations on catchment
1 - degraded; 2 - initial; 3 - optimal; 4 - cultivated area; 5 - settlement

The acacia groves and the mixed deciduous forest with pine are situated between the optimal and the degraded patterns and their development may be either progressive or regressive. The initial plant associations appear as narrow ecological corridors between degraded and optimal associations. At present these areas are in the regressive phase. If human activity decreases in these areas then progressive development will be possible. The optimal association is oak forest with hornbeam as well as submontane beeches situated on higher ground. Alder forest on wet surfaces and grassy associations on slopes as optimal associations were also considered. The pattern of the area shows that the former homogeneous biotopes of plant associations were divided into smaller spots isolated from each other. This process is called "fragmentation" in ecology. Usually, fragmentation is unfavourable for the development of living beings in a given area and the earlier series of succession have less stability than that of the climax phase. However, the stability may be high if successions promote a natural development. Instability is always a consequence of some kind of intervention of natural processes.

The value of the C factor is determined by many factors such as the ratio of plant cover as it changes as a result of plant growth and crop management. Major variables that can be influenced by management decisions include crop canopy, residue mulch, tillage, land use residual, etc. For an evaluation of the C factor six crop stages are distinguished from tillage to harvest. As C is a very complex factor, it was not expected to create a composite of TM bands which reflect the C value correctly. Instead, it was supposed that the most significant factor is the density of vegetation cover (the morphometrical characteristics of the catchment are similar). The NDVI is used for the assessment for crop production. This volume increases as vegetation gains chlorophyll and becomes greener. In this study the density of plant cover is more important and consequently the band4/band3 relationship was used (Fig. 5).

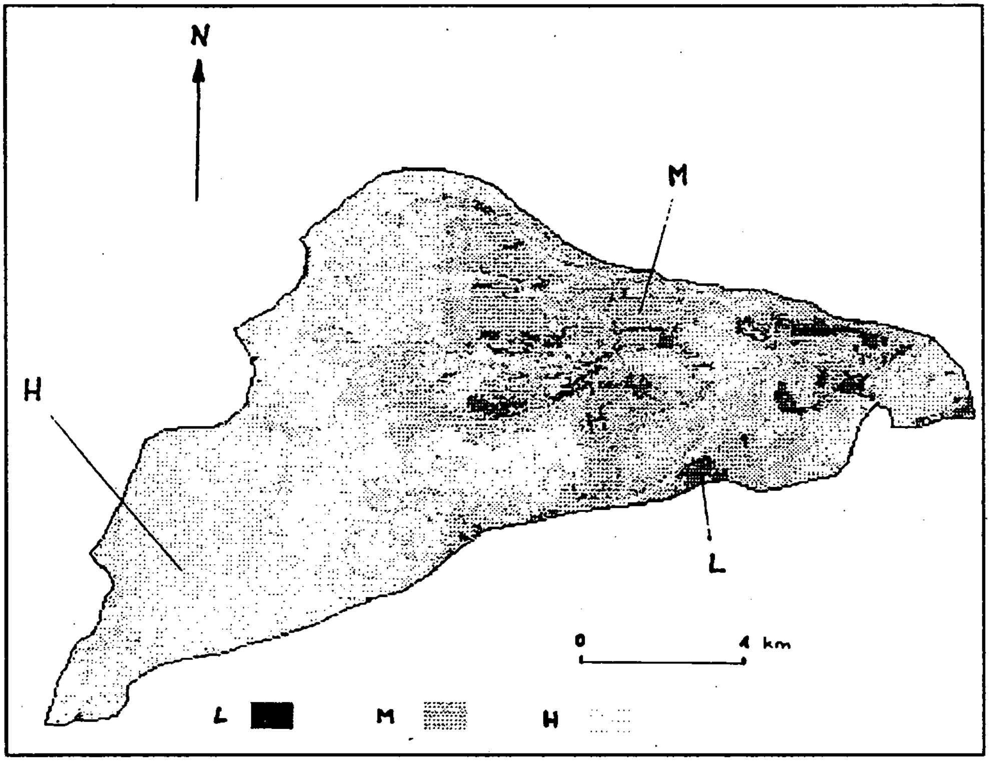

Figure 5 Biomass production on the catchment
(Landsat TM bands 4/3 ratio (B&W repr.)
L - low biomass production
M - medium biomass production
H - high biomass production

Comparing the composite with the map of potential vegetation, it can be deduced that the composite significantly reflects the differences of biomass distribution. In the western part of the catchment the dense homogenous forests are typical, while in the eastern part the different types of arable land show the condition of the surface in connection with the spatial differences in land use i.e. after harvest, in development, growing, the differences in residual mulch, etc. Large areas in which there is a distinctive plant cover may be delimited. For example, arable land, acacia grove - grassland and deciduous forest in the northern part of the test site.

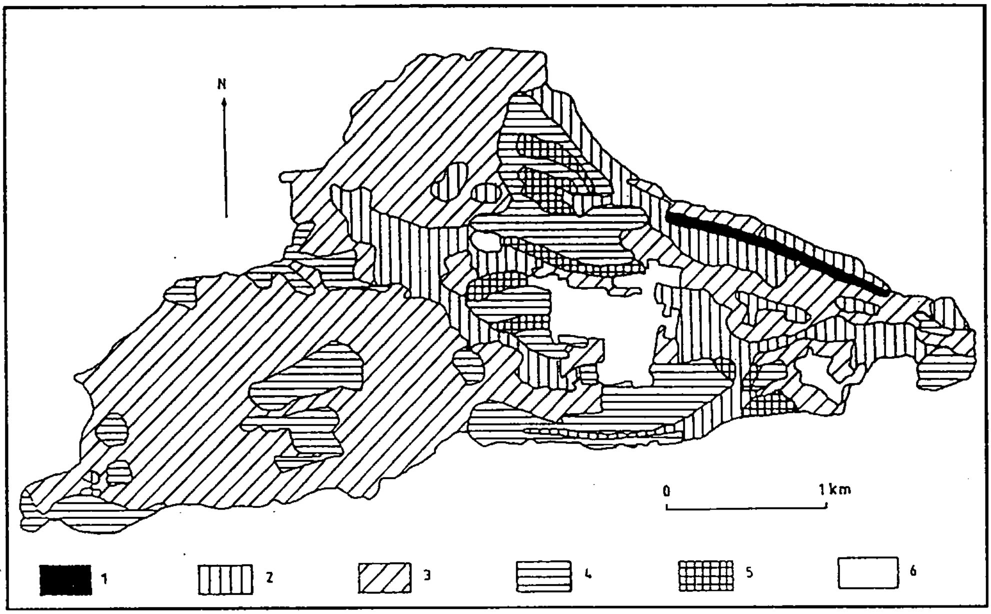

Figure 6 Map of soil erosion on the catchment area (t/ha/year)
1 - <1; 2 - 1-5; 3 - 5-10; 4 - 10-15;
5 - 15-30; 6 - settlement

By multiplying the above mentioned factors the soil loss value may be calculated (Fig. 6). Comparing these results with the plant cover conditions the following rules may be stated. If the plant cover is stable then soil erosion does not reach the value of 10-15 t/ha/y, while on the cultivated land soil erosion is always higher than the above mentioned value (25-30 t/ha/y). The reason for soil erosion on forested lands is the physical and genetic properties of the soils while on the cultivated test site it is the steepness of land slope and plant cover. Owing to the close connection between plant cover, soil and plant moisture and soil erosion, compositions in which these factors can appear have been chosen. It is known (Banninger, C. 1986; Crist, E.P. 1983) that wetness and plant cover densities can be expressed:

Greenness Index: 0.7243(TM4)+0.0840(TM5)-0.1800(TM7)
Soil Wetness Index: 0.3406(TM4)-0.7112(TM5)-0.4572(TM7)

According to the histogram of pixel values the area is divided into three categories: low (L), medium (M) and high (H) plant cover density and low (l), medium (m) and high (h) soil moisture. In considering soil erosion, the following combinations were selected:

low soil erosion : H,l + M,m + M,l
medium soil erosion: H,m + H,h + L,l
high soil erosion: L,m + L,h + M,h

This selection (Fig. 7) proved useful in assessing the degree of soil erosion and in locating those areas potentially affected by soil erosion.

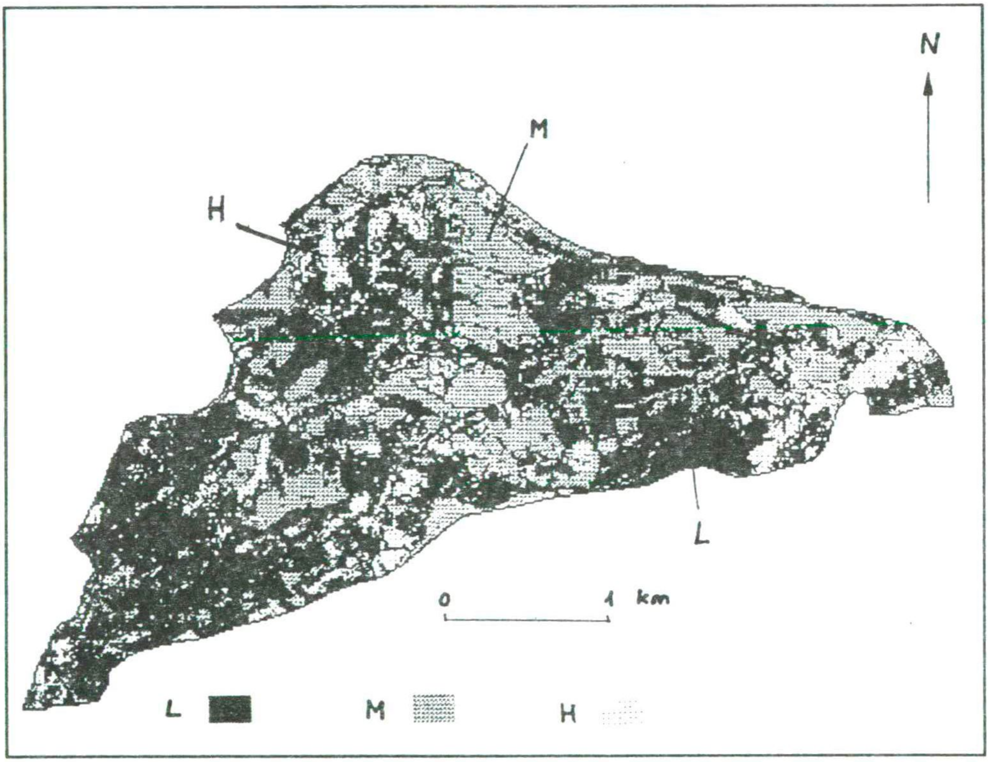

Figure 7 Soil erosion map of the catchment from the Greenness Index and Soil Wetness Index ratio (Black & White repr.)

L - low soil erosion
M - medium soil erosion
H - high soil erosion

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Critical environmental areas in Hungary (a GIS based approach)

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Summary

In Europe and also in Hungary the ecological condition of the environment is extreme rapidly changing. In this paper we try to create a GIS based method to identify the critical environmental areas and to compare these results with the ecological stability/ sensitivity of the given area.

In the project we connect the natural limiting factors and the socio-economic factors of agriculture, industry that cause the greatest environmental impacts. The following natural limiting factors were taken into consideration: karst areas, steep slopes, extreme climate (drought, frost), areas affected by landslides, inland waters, extreme chemical and physical properties of soils, danger of wind erosion. These factors restricted land use and can be exploited only at much higher risks and costs. There are some places where more than one factor limit utilisation. The human activity (intensive agricultural, industrial, transportation use) affects these surfaces having distinctive limiting factors. In this case the sensitivity of the environment increases and its stability decreases, the more environmental risks can be found in the given region.

The limiting natural factors and the parameters of human activity were digitized and stored in a GIS. We use ARC-INFO to overlay the maps and ERDAS/IDRISI for classification by remote sensed data. Overlaying the maps we can identify areas with different natural and economical limitations. We divide critical areas into three categories. Land utilisation in the first class claims prudent management.

Introduction

In Hungary - similar to other European sites - the geoecological condition of environment decreases by the increasing economical impacts. The society is unsusceptible to environment and the level of "environmental consciousness" is also low. The intention and aims can be more or less circumscribed and it is typical that the observance of the existing decrees is not general. Environmental impact statement is rarely part of the planning. In Hungary due to the former economical and social conditions environmental protection was based on the protection of nonusable resources instead of the health and ecological approach. From 0.7 to 1% of GDP was applied to environmental investments between 1980 and 1990 (Report 1992). At the same time according to the most humble estimation the environmental damage reached 3.5 - 4.5 % of GDP. These financial resources were insufficient for the stabilization of the conditions, apart from few exceptions (e.g. Balaton Project).

The short-term severe disasters urge as to do something, because more than 170 havarias were harmful to the lithosphere and 20 of them were particularly. But the long-term effects give us also much trouble, because they cause slow decay. At present both the politics and decision makers are disinterested in evaluating the environmental effects, but we are not able to say, on what kind of level do we have to intervene in the process. Analysis made after the decay (caused by continuous damage) as well as after the environmental damage, are very accurate but all of them contain the following general but correct phrase: " It could have been avoided."

The aim of our study was not to assess the condition of environment in the classical meaning (the assessment of the environmental factors or effects), the harmful materials, perhaps the complete system. We wanted to localize those surfaces in Hungary, where the land became sensible (in environmental sense) due to the intensive social and economic effects. Our aim was not direct human ecological but we analyzed the system of effects in practical point of view (e.g. tolerance of the environmental elements, stability, sustainable renewal etc.).

Definitions of the critical environmental areas

Many explanations of CEA are known (see Stoddard, R.H. 1977). We considered the land as a CEA, where the development of the natural environment is determined or its stability decreases due to the injured real geoecological conditions or the economical effects. It does not mean critical situation, but in our opinion on these sensible areas we have to make continuous and detailed measurements of the condition of the environment. If we adhere to the assuring of the compatible and sustainable development and the prevention of damage than we have to know that the intervtion can be successful only in small regions.

Analyzing environmental havarias occurred in small regions requires specialised methodology.

Method

We used GIS to circumscribe the CEA in the above mentioned concept in Hungary. Two major overlay systems got into the GIS. First group contains 11 limiting (abiogenic) natural factors (National Atlas of Hungary, 1989; Szabolcs, I. et al. 1978):

- landslide
- inland water

- karst area
- sensibility for pollution
- area endangered by wind erosion
- soil erosion
- alkali soils
- acid soils
- marshy, swampy area
- drought-affected land
- land endangered by early spring frosts.

In our opinion the limiting natural factors considerably control the utility, the sensibility, the condition of the biogenic factors, the stability, the possibilities of the development of the given surfaces. It does not mean that the above-mentioned geoecological factors could be the most important structural components, but determine the character of the unit.

In principle all the natural components have an influence on the condition and structure of environment. A factor becomes a limiting factor if it has the above influence. On the other hand it becomes significant and perhaps a limiting factor if it turns into determinant in the use of natural resources and conditions or in the living conditions. Depending on the economic and social conditions the judgement of a limiting factor can be different in the stage of the condition and the change of the environment. The above-mentioned limiting factors make land use hazardous and expensive.

The other large overlay group contains the environmental stresses. We characterized the intensity of human activity by 4 factors density of population over the average (over 100 persons per km^2) as the intensive urban factor, the use of chemical fertilizers (over the average +300 kg per ha) as the intensive agrarian factor the mining and economic activity (over 1 billion Ft) as the industrial technogenic factor as well as the recreation stress (over 10.000 days per km^2). We have added to these factors the areas of National Parks and nature conservation areas (Fig. 1).

The aim of this study is the areal comparison of the limiting natural factors and the factors having the most critical and greatest environmental effects.

We digitized the limiting natural factors and above listed parameters of the human activity under AutoCad, and the data were transformed into Idrisi and later into Erdas. We used GIS modules of these softwares to the analysis. We have chosen Erdas and Idrisi softwares because we tried to correct the localization of the critical and sensible lands by remote sensing data (LANDSAT TM), and the calculation of stability of the landscape units based on remote sensing data.

Results

The logical base of the investigation was to determine those areas where the limiting factors and the social effects are cumulated. We overlaid the limiting natural factors, then compared them with the ecostability of the land. In our opinion if one or more

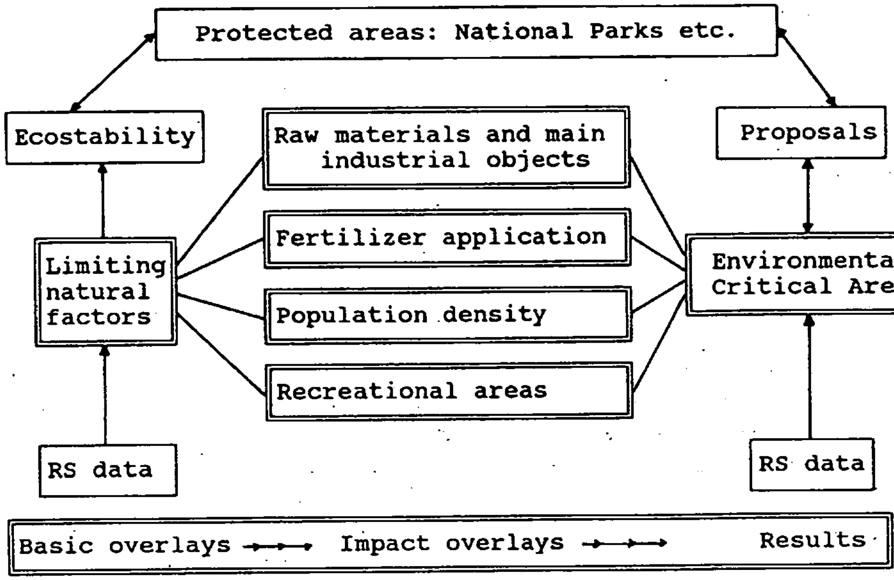

Figure 1 The scheme of the investigation

social/economic activities have influence on the land characterized by more limiting factors (land of small stability) then on these lands the sensibility of the environment increases and at same time the tolerance of the environmental elements and the stability of the natural environment decreases. We had to calculate with great environmental hazard and then with higher costs. On Fig. 2 we present the overlaid map of the limiting natural factors. In many instances the limiting factors can cover each other. We divided whole are into 3 categories according to the following system:

class No.1 ---- 1 - 2 limiting factors
class No.2 ---- 3 - 4 limiting factors
class No.3 ---- 5 - 8 limiting factors.

One of the most critical problem is to weight the limiting factors. Naturally these factors have different weights and they are very variable in time. For instance if we analyze the problem from human ecological point of view then they can have different values. It can be a very interesting task to examine the effects of the limiting factors on land use. Because of the forced and subjective simplification we disregard weighting (we know that the subjectivity of the examination is apparently decreased by this reduction). We mechanically supposed that if there are more limiting factors then the sensibility of areas increases. The most significant limiting effects occur in Great Hungarian Plain and in the Transdanubian Mountains.

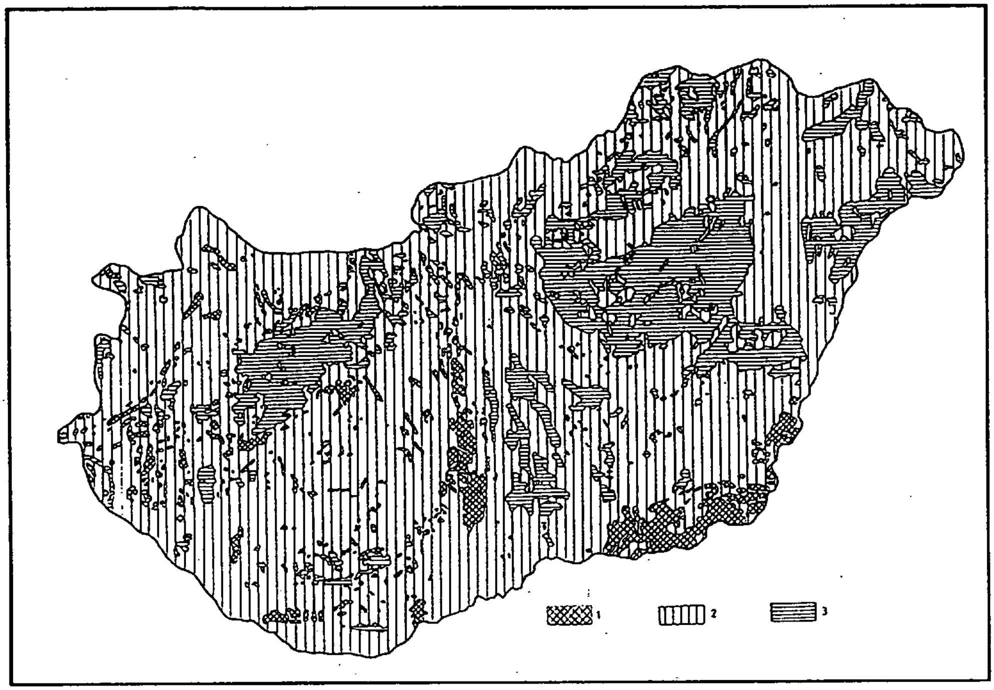

Figure 2 Superimposed map of the limiting natural factors.
1 - 1-2 limiting factors; 2 - 3-4 limiting factors; 3 - 5-8 limiting factors

On the basis of the LANDSAT TM images of Hungary we made the map of land use and by the method of Environmental Atlas of Czechoslovakia we calculated ecostability. According to this simple process we divided the area of "green surfaces" (forest, meadow, grassland, swamp, garden, wineyard) by the summarized area of available land and urban areas. This ratio can be used to express the value of ecostability. On the map presented on Fig. 3 we show these values on level of landscape units (microregions) in Hungary. Low values of ecostability are the results of many unfavourable natural effects in the central part of Great Hungarian Plain and in Transdanubian Mountains. These low values of ecostability combined with many limiting factors can from areas appear under very sensitive conditions.

Using a GIS we could compare the industrial, agrarian, urban and recreation effects with the natural limits as well as with ecostability.

Major energy resources and raw materials, mines as well as industrial factories - as potential industrial stresses - can be compared with the summarized limiting factors and it can be laid down as a fact that the southern part of the Transdanubian Midmountains and the central part of the Great Hungarian Plain are in the most critical condition. In these sites there are many limiting factors and sum of them is in class No.1 (or in 1-2). This fact shows the problem what is in connection with the environmental havarias endangering the lithosphere. We can list environmental havarias appeared in the following places: Héviz,

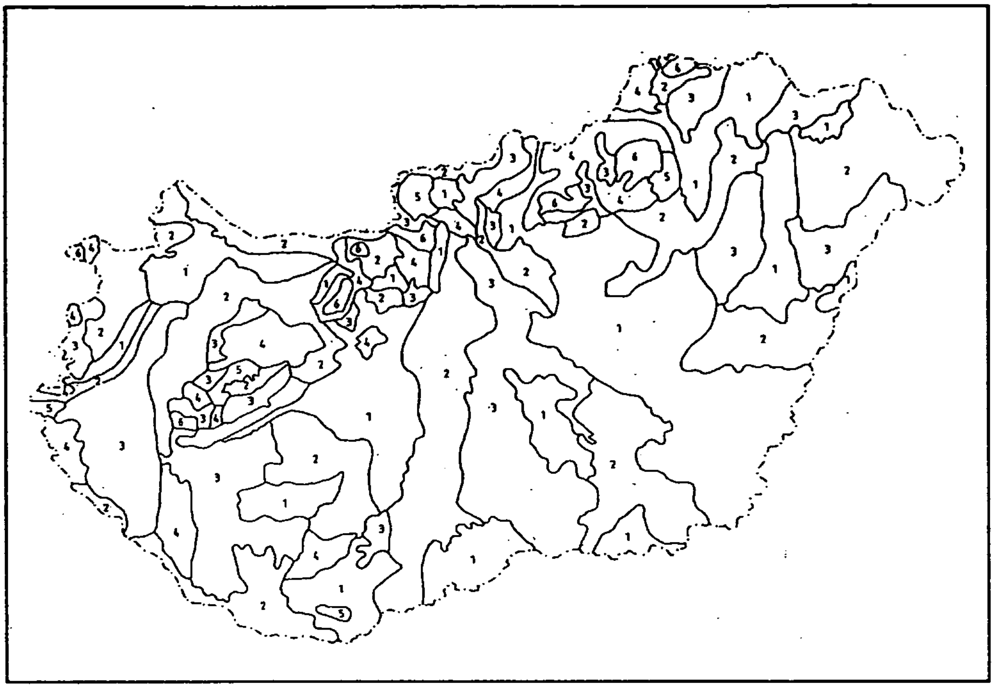

Figure 3 Ecostability of landscape units in Hungary.
1 - 0-0.25, 2 - 0.25-0.5, 3 - 0.5-1.0, 4 - 1.0-3.0, 5 - 3.0-5.0, 6 - under 5.0

Ajka, Veszprém, Biatorbágy, Etyek and Monori erdő, Albertfalva (Bohn, P. 1992). There are fewer and smaller surfaces with not so significant problem in the Northern Hungarian Mountains (pediment of Mátra Mountains, Borsod), in Mecsek Mountains, in the southern part of the Transdanubian Mountains as well as in West Hungary. If we make the comparison with the map of ecostability the same facts can be established, in spite of that the Hungarian Mountains show a higher value of ecostability.
The agrogenic stresses (over 300 kg fertilizers per ha) concentrate from the line of Duna river to west (Mezőföld and western part of region), in Kisalföld and in south-western part of Hungary.

Naturally these surfaces "avoid" the land with more limiting factors, because those are not typical agricultural areas. The use of fertilizers and pesticides is more benefitial lands under conflict on central part of Great Hungarian Plain (Hajdúhát, Körös region, Szolnok loess region). It is very unfavourable that the biggest use of chemical fertilizers concentrates on the lands of smallest ecostability. Intensive decrease of the use of fertilizers due to the change in agricultural devolution of ownership is not disadvantageous from the point of view of environmental protection.

On Fig. 4 we compared strong urban stresses with overlaid limiting natural factors. Potential and real conflicts (as was mentioned in the description of effects of technogen

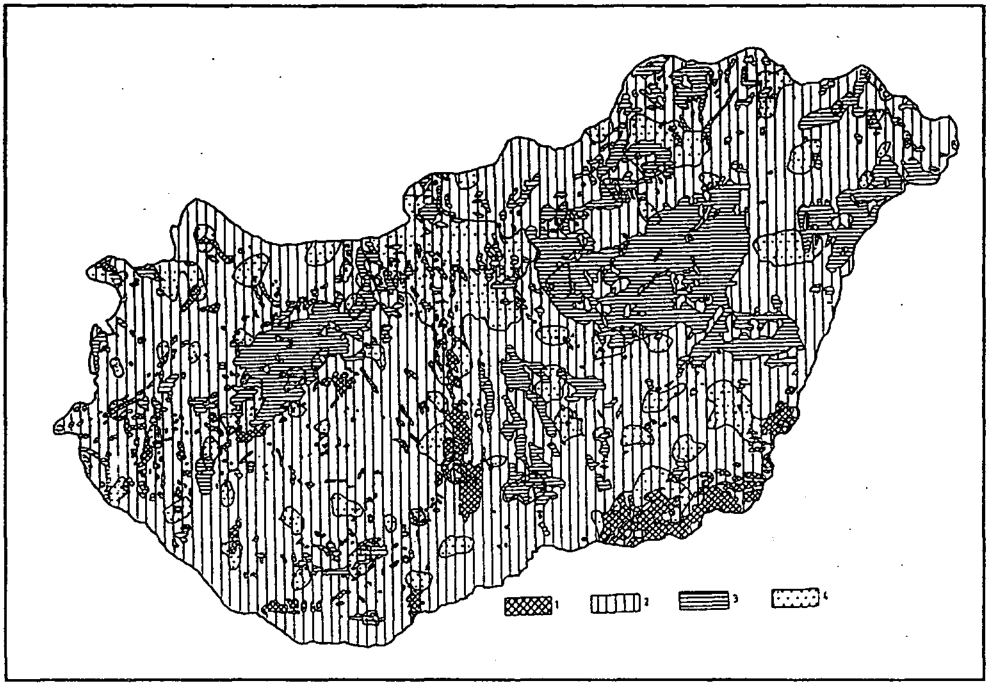

Figure 4 The limiting natural factors overlaid by urban impacts.
1 - 1-2 limiting factors; 2 - 3-4 limiting factors; 3 - 5-8 limiting factors;
4 - regions with population density over 100 person/km^2

stresses) appear on the southern border of Transdanubian Mountains (Várpalota, Veszprém, Ajka, Tatabánya), in borderlands of the agglomeration of capital (Budapest), in North Hungarian Mountains (e.g. Miskolc, Hatvan) as well as in the Great Hungarian Plain (Szolnok, Kiskunhalas).

On Fig. 5 we compared the limiting natural factors with the travel stress (over 10.000 persons per day). Similar to the above-mentioned facts, we are not able to find significant differences between the economic effects, although the following order of intensity of factors obtains: industrial - agrarian - urban (infrastructural) - recreational. The maps of economic effects were overlaid, then were compared to the same map of limiting factors. We could identify such areas where there are different numbers of limiting natural factors and economic-social effects. Depending on the overlay of the two investigated groups of factors we can divide the combinations of factors into categories.

We have chosen those categories, in which most of the limiting natural factors and the intensive economic effects appear together. It indicates about two dozens of areas that are presented on Fig. 6. If we did not investigate the simple "point" effects, then in our opinion these areas are the critical environmental areas (CEA) in Hungary. If we compare the

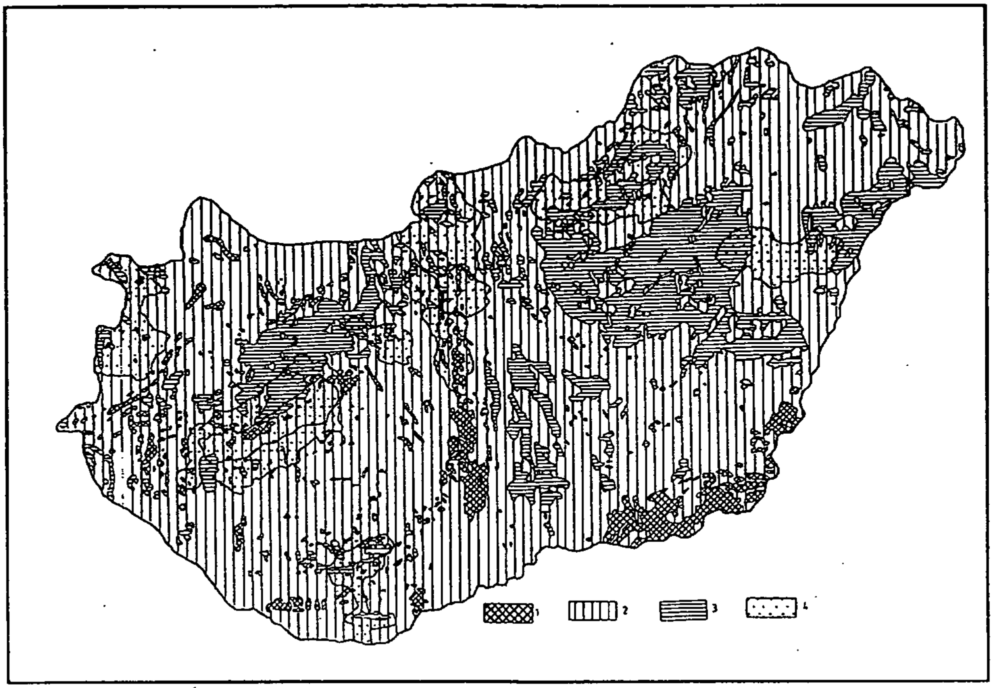

Figure 5 The limiting natural factors and the recreational impact.
1 - 1-2 limiting factors; 2 - 3-4 limiting factors; 3 - 5-8 limiting factors;
4 - recreational impact 10.000 days/km^2 (Balaton - 56.000, Budapest - 115.000 days/km^2)

results to the map of the nature conservation areas it can be assested that one of the CEA is in the Bükk Mountains National Park and another one in the Hortobágy National Park, while three CEA are in nature conservation areas in Transdanubian Mountains. It may prove that one of the conservation methods of critical environmental areas can be to place them under protection. When we compared the protected areas with the map of ecostability then the comparison shows that the protected areas perform conservation function and they are able to increase the ecostability. They cannot, however,re-establish the original natural condition (e.g. re-establishment with expansive direction, as a focus). This method can be used in European scale, as Chadwick et al. (1991) presented in connection with the stability against acid fall-out.

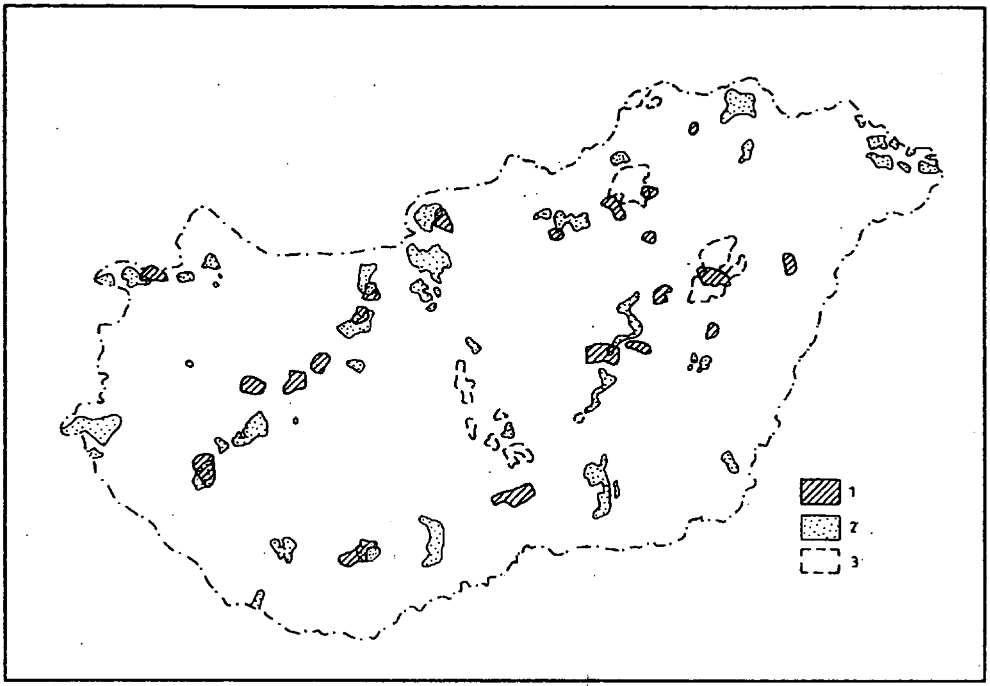

Figure 6 Critical environmental areas in Hungary
1 - critical environmental areas; 2 - landscape protection areas; 3 - natural parks.

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