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INDICATORS OF LANDSCAPE FUNCTIONING, WHICH MARK THE MATERIAL AND ENERGY BUDGETS IN LANDSCAPES

key words: landscape indicators, landscape functioning, landscape planning, landscape management, landscape protection

INTRODUCTION

Most important task of modern landscape ecology is to support landscape planning, landscape management and landscape protection with reliable data and observations that can be used in their practice. These landscape-forming activities mean more or less significant interventions into the functioning of landscapes since social demands to landscapes change perpetually: people want to utilize the biological productivity, water potential, climatic endowments or raw material sources of the landscapes in new ways. New social demands tend to utilize those endowments of landscapes that were considered as not important ones for centuries, like recreational, bioclimatic or nature protection potentials instead of traditional landscape endowments today. Suitability for building in, waste displacement or ecological buffer capacity as well, has a constantly growing landscape value. (Bastian, Schreiber, 1994).

Every type of landuse has an influence on the material and energy fluxes, this way the functioning of the landscapes. The utilization of landscapes for different social purposes usually alters the visual structure; the visible patterns of landscapes change. The question is that, how strong relationships are there between the scenery and functioning of landscapes (Lóczy, 2003; Haines-Young, 2005; Hof, Flather, 2007)? Although, it can be demonstrated in many cases that the scenery is a sensitive indicator of landscape functioning, there are material and energy transport processes that have less visible impacts on landscapes. E.P. Odum (1963) has tried to understand the (ecological) functioning of landscapes via their material and energy transport processes. However, landscape metrics make attempts to prove that visual landscape structure reflects correctly the functioning of landscapes (Blaschke, 2000; Mezősi, Fejes, 2004). Several characteristics of the functioning and temporal changes of landscapes were determined using the landscape metric parameters like patch density, shape indices, area-diameter ratio, closest neighbor indices etc. of the landscape pattern system, what consists of patches, corridors and matrixes. (Haines-Young, Chopping, 1996; Jaeger, 2002; Lóczy, 2002; Wu, Hobbs, 2007). Naturally, there are landscape types, such as Karst-landscapes, where significant elements of forming processes are hidden; they can hardly be seen on the surface. In the industrialized countries, where there are cultural landscapes every-where, mosaic-like landscape structures tell much about the functioning of land-scapes. In the structures of such landscapes built-up areas, agro ecosystems and forest plantations are the dominant elements, where material and energy transport processes are known and controlled mainly by man. There are numerous case studies on the fitomass production, nutrient consumption, water supply of agro ecosystems. However, it is a hard task to complete a landscape level material- and energy budget due to annually changing landuse structures.

MATERIAL - AND ENERGY TRANSPORT EXAMINATIONS ON LANDSCAPE LEVEL

Analysis of visual landscape structures has become a very popular branch of landscape evaluation in the last 10-15 years (Wiens, Moss, 2005; Wu, Hobbs, 2007). Visible landscape patterns are easy to analyze using CORINE satellite images for instance; the FRAGSTATS software has become a widespread landscape evaluation tool within a short period of time (McGarigal, Marks, 1995). Unfortunately, our knowledge on the material- and energy processes, which indicate the real internal functioning of landscapes, has not grown the same way yet. However, in such landscape balance examinations Soviet landscape ecologic schools for instance, have reached outstanding results in the period between 1930-1970 already. The very detailed field measurements of Mihailov V.A., Polunov B.B., Ramenskiy L.G., Sochava V.B., Sukachev V., Miller G.P. and others have provided basic data on the material and energy transport processes of different study areas (Sochava, 1972, 1987; Sukachev, Dilis, 1964; Preobrazhenskiy, 1966). Data of the field measurements had been utilized in the elaboration of complex landscape geographic concepts (Isachenko, 1965; Solntsev, 1968, Gerasimov, 1980; Miller, 1980, etc.). These were real landscape budget exami-nations ("Naturhaushaltslehre") in the classical meaning of the word used by Haeckel.

Similar detailed examinations were carried out in Eastern Germany in the 1960' and in the 1970's by the landscape ecologic schools of E. Neef, G. Haase and H. Richter

(Neef, 1967; Richter, 1968; Haase, 1967, 1991, 1999). H. Leser made attempts to gain a more detailed picture on the ecological-geographical functioning of study areas via the tessera model in Switzerland, while K. Buchwald and W. Engelhardt, later Mosimann, Th. summarized the results reached till that time in West Germany (Leser, 1976; Buchwald, Engelhardt, 1968; Mosimann, 1984). The Slovakian LANDEP landscape evaluation program, which got great inter-national appreciation, took its origin from analytical landscape evaluation (Ruzicka, Miklós, 1982) E. Mazur (1983) completed an outstanding summary as well. The most important representatives of analytical landscape research and evaluation in Poland are Bartkowski T., Richling A., Solon J., Ryskowsky L., among others (Bartkowski, 1984; Richling, 1976; Richling, et al., 1994; Richling, Solon, 1996; Ryskowski, 1992).

Undoubtedly, systematic landscape analysis requires a strong technical, material background and tiring, time consuming work, what was not very attractive for young researchers. Much more spectacular results could be gained from the 1970's via the analysis of satellite images for instance. There could be found hardly any papers dealing with systematic analysis of European landscapes in the literature in the last 20 years, such works have been carried out in Africa, Asia in semiarid or tropical regions usually.

The latest analytic field result in geographic or ecologic analysis of landscapes were published in Hungary in the 1980's as well, since then monitoring systems, regular field measurements and field experiments have become rather rare. Hungarian landscapes are highly endangered by erosion, so it is not surprising that soil and wind erosion field research programs have survived, or even new programs were launched in that area. (Kertész, 2001; Mezősi, Balogh, 1993; Farsang, et al., 2008). Examinations which make possible to carry out measurements of the material – and energy transport processes of close-to-natural ecotops – grasslands forest types, wetlands – have become rare in the last 15 years also.

Researchers of the Geographic Institute of the University of Debrecen carried out a complex landscape geographic research program in a study area of 9 km^2 within the wine growing region of Tokaj between 1973 and 1980. Lithologic, pedologic orographic and biogeographic surveys were parts of the project (Pinczés, et al., 1980, 1984, 1987/a, 1987/b; Kerényi, 1989). There were water output measurements on the two periodic creeks of the half basin and at their sources. Changes of the groundwater table were measured at some selected sites each month for two years. The irradiation map of the study area was compiled with the help of meteorologists (Justyák, Tar, 1975). There were some temporary temperature and precipitation measurement stations, and additional microclimate measurements were carried out. It was a great advantage that the traditional landuse system of the Tokaj wine growing region could be surveyed in the first years of the research. The small vineyards covered almost the whole ecologically optimal medium zone of the slopes of the hills around the half basin in 1974. Higher parts of the slopes were occupied by smaller forest plots and pastures. The foot of the slopes and the central parts of the half basin were occupied by cornfields. The vineyards, what had good crops on the steep slopes were abandoned swiftly and wine cultivation moved to the central part of the half basin from 1974/75. There were widespread attempts to build terraces in order to use the steep slopes again in 1979-81. Small vineyards were losing ground however, so the traditional system of landuse zones was demolished (Csorba, 1993, 1999). The strong changes of the landuse structures were partly a reason and a consequence of the modifications of the demographic structures of the settlement, namely the aging of the village, decreasing employment rate, decaying infrastructure the same time. These problems were traced in the frame of a sociogeographic survey as well (Süli-Zakar, 1978).

Although, a summarizing evaluation of the project was never compiled, on the base of the data gathered during the program it seems that climate – what is a mosaic-like pattern of **meso - and microclimates** formed by the complex relief – has a role which is more emphasized than in other regions in the forming of ecological landscape structure in the foothills of the Tokaj-mountains region. Processes gene-rated by microclimate (former periglacial processes) react on the development of the relief also, as it was proved by lithologic surveys. Microclimate has a remarkable impact on one of the fundamental pedologic factors, the moisture content of the soil forming detritus. Changes of soil moisture content were detected via soil samples taken every week by drilling, during one whole vegetation period (Csorba, et al. 1989; Kerényi, Csorba, 1991). A. Kerényi has calculated material budgets form the data of the soil erosion measurements. He has determined the amount of soil loss due to the accelerated soil erosion caused by changes of landuse (Kerényi, 1985).

Traditional landuse had adapted to the rather mosaic-like pattern of the original pedology and vegetation of the half basin, while the new type of landuse developed after 1979 had a strong homogenizing effect. Microclimate, pedologic endowments, soil erosion and landuse for instance, became rather uniform (Csorba, 1996). Large terraces, built in the 1980's have not lived up to expectations. Although, those terraces were much more suitable for mechanized cultivation, but the hazard of frost increased and the vine did not cropped better. Some of those terraces were abandoned recently and steep slopes abandoned in 1975 were replanted in 2003!

A very detailed material- and energy transport analyses was carried out in the frame of the Síkfőkút project in a *Quercetum petreae-cerris* forest study area of 64 hectares on the Southern foothills of the Bükk Mountains from 1972. Radiation, precipitation temperature measurements are carried out at different levels of the vegetation, in the level of the canopies, inside the foliage of the trees, at the level of the shrubs and on the surface of the soil from the beginning of the project. The way of precipitation was traced from the leaves via the infiltration into the trunks to the deep soil layers (Jakucs, 1985). It was the most detailed ecological research program on material - and energy transport processes in Hungary.

POSSIBLE INDICATORS OF MATERIAL – AND ENERGY TRANSPORT PROCESSES AT LANDSCAPE LEVEL

To understand deeper connections of landscape functions, parameters are required which indicates the amount of material and energy that is produced and transported in; and removed from a given area – e.g. a micro region (=landscape) – in an exact form.

The Cadastre of the Micro regions of Hungary (Marosi, Somogyi, 1990) deals with a part of the indicators of the material and energy transport processes. Geologic, climatic, hydrologic biogeographic, landuse characteristics and landscape type categories of the 230 micro regions of Hungary can be found in that work. According to Hungarian taxonomy of landscape categories, micro regions usually have a spatial extent of 200-800 km^2, which together form 35 meso regions and 7 macro regions. However, there are constant arguments about the actual borders of the individual micro regions, the system seems to be stable, since there were only some significant modifications suggested by researchers during the last 20 years of its existence. Since during the process of the marking the borders of the micro regions every landscape forming factors must be taken into consideration from geologic structure to vegetation, definite borders on the maps are results of compromises of the representtatives of the different fields of research usually. Perfect match is a rather rare phenomenon between the borders of micro regions in lithologic, hydrologic, pedologic or biogeographic maps.

However, there is a database for the Hungarian micro regions, what contains data for material- and energy transport processes at landscape level either. For climatic data the Climate Atlas of Hungary is a useful source. (Mersich, et al. without date). It seems reasonable to divide the possible landscape budget indicators into three groups.

The **three indicator groups** represent the following material- and energy transport aspects:

1. intensity
2. rate and temporal course

3. degree of human impact.

It is clear from the names of the suggested indicator groups that they do not deal with the actual base data of material- and energy transport processes of landscapes. They do not tell us how many tones of soil or biomass, or how many mega joules of energy per square kilometers are transported. Most of these indicators are suitable for the qualitative characterization of the material – and energy budgets of landscapes.

Indicators of intensity of material- and energy transport processes

- Intensity of solar radiation, that is the primary energy input from **global irradiance** measured in MJ/m^2 usually. 13 automatic instruments carry out global irradiance measurements in Hungry. Measured values are between 3800-5200 MJ/m^2; their cartographic presentation makes possible to gain appropriate data on meso region – and naturally, with lower accuracy – micro region level. Maxima within Hungary occur in the Southeastern part of the Great Hungarian Plain, while minima are measured north of Budapest in Nógrád-County. Averages for the micro regions are simply to calculate, and there are significant distances between the individual micro regions presumably.
- **Number of sunny hours** is another data, what is simply to gain with an adequate accuracy on micro region level. Averages are between 1750 and 2050 hours annually with maxima in the southern part of the country around Pécs and in the territory between the river Danube and Tisza. Measurements are carried out in areas with high sky view factor at every weather station, so there are not any data available for the shading effect of relief. However, there are some hilly micro regions, where for this reason, some data correction is needed to gain a reliable number of sunny hours.
- Intensity of material transport in a given area is determined by the water supply to a high degree, what can be derived from the data of **water budget**. Water budget is positive in the major part of Hungary, while in the minor part it is negative. The National Atlas of Hungary represents the spatial pattern of the water budget in a scale of 1: 1 000 000. The map is highly detailed enough to determine average water budget values with an accuracy of 50 mm. There are maps with higher resolution as well, so this parameter can be calculated for the micro regions. There is a so called aridity index in the Cadastral of the Micro regions of Hungary, what is worth taking into consideration as well.
- Amount of **fitomass** should be considered as an indicator of intensity of material- and energy transport as well. That value represents the amount of material mass in natural and agro ecosystems, but in the case of the latter one

it is not added to the material content of a given micro region, if products are transported from there. Therefore, very inaccurate estimations can be made on the green mass of agricultural products only, even if there are data on their use locally or in other places. More established calculations can be made in the case of grass, shrub and forest vegetation types, although the same is true for forestry; the mass of wood steps into the mass transport processes of other micro regions. There are not such data in the Cadastre of Hungarian Micro regions, but they are available from other sources.

We believe that an indicator what contains the four before mentioned data related to material- and energy transport would provide reliable information on landscape budgets on a micro regional level. Due to errors of data and measurements 3-5 relative categories could be established today only. Material- and energy transport processes in micro regions could be categorized as

- strong
- moderate
- weak

ones for instance. For this reason, some micro regions situated in plains and in hilly regions could fall into the same category, so the result map would not show highly differentiated pattern.

The second indicator of material – and energy transport would describe the rate and temporal course of material – and energy transport processes. This indicator consists of different elements as well

- There are close relationships between relief and material transport in an area. Therefore, **relief energy** is a data what is available in a resolution suitable for analyses on micro regional level. There are not very great differences in the relief in Hungary, although the maximal vertical differences per a square km reach 850 meters, the average for the whole country is around 100 m per a square kilometer. Widely known and used relief energy maps have a resolution that makes possible to gain data for the micro regions. These average values can be found in the Cadastre of the Micro regions of Hungary also.
- Other important element of the rate of material transport processes is **mean air temperature**. Material- and energy transport processes (the growth of vegetation e.g.) are much slower in periods, when air temperatures are below zero, therefore it is reasonable to consider this factor in the indicator of material- and energy transport somehow. There are slight, but detectable differences in mean air temperatures between neighboring micro regions. Phenological maps represent the dates of the start of the growth of vegetation, which is the

beginning of the material- and energy transport processes. Hungary is not a big country in area, but the difference in date of the beginning of the apple blooming, what is used for description of Phenological situation, can reach one month, anyway.

- Natural material transport processes are bind to the soil to a high degree. Activity of microorganisms in the soil is determined by the **temperatures in the upper layers of the soil**. Borders of landscapes are borders between soil types as well very often. Soil temperature data can be used for analyses on micro regional level as well.
- Seasonal differences in **water supply** have a decisive effect on material transport in our climate zone. There are great differences in the rate of material transport between sandy soils which lose water rapidly and very frequently, sloping areas and soils covered with water. Therefore it would be a bit more complex index, what contains relief, climatic, hydrologic and pedologic elements.
- Naturally there are not very strong **seasonal differences** in the continuous, periodic or episodic nature of water supply of micro regions within small countries. In the case of micro regions that lay along rivers and are strongly affected by floods and inland inundations this aspect has to be taken into account also.

On the base of summarization of the before mentioned indicators relative categories can be established again, what describe the rate of the material- and energy transport processes of a given area. On this base the following categories can be established:

- rapid, continuous
- moderate, periodic, and
- slow, episodic landscape budget rate.

Human activiteis have drastically altered the material – and energy transport processes of some landscapes already. Natural material transport processes play minor role only in the material – and energy transport processes of the landscapes in some micro regions, for instance: in areas occupied by cities, built-up recreation areas and intensive orchards. Some indicators are suitable for the determination of the strength of anthropogenic impacts on landscape functioning:

- **Hemeroby** categories have been established specifically for the determination of the strength of anthropogenic impacts on landscapes. Hemeroby (or synanthropy) categories suggested by the Finnish researcher, Jalas J. in 1955 were completed by German researchers later. The classical -/oligo- /mezo-/ eu-/ poly-/ and metahemerob scale consists of 7 levels with the addition of the alfa- and beta-euhemerob levels (Bornkamm, 1980; Bastian, Schreiber, 1994; Grabherr, et al., 1998). Classification of the micro regions of Hungary has been completed partly yet, so it is a current task of Hungarian landscape research.

- There is no doubt that ecological processes are strongly affected by the density of settlements and the spatial pattern of linear infrastructure (roads, railway lines) within a region. We have published some studies on the **landscape fragmentation** ecologic effect – what hinder not only the migration of animals but material transport processes – of the before mentioned landscape elements (Csorba, 2008). These data are available for all the 230 micro regions of Hungary.
- There is a national survey on the amount of material transported in connection with outcrop **mining activities**, what makes possible to gain data for that factor on micro regional level.

For the summarization of the anthropogenic impacts it is reasonable to use the levels of the hemeroby categories:

- low degree
- medium degree
- high degree of anthropogenic impacts
- landscapes affected by human impacts dominantly.

SUMMARIZATION OF THE SUGGESTED INDICATORS

Average most of the 11 indicators listed above have to be calculated on a micro regional level. Sources give from-to intervals in many cases (e.g.: relief energy, soil temperatures or hemeroby levels). Naturally, it cannot be expected that values of the indicators be valid for each parts of a given micro region. There can be significant spatial differences in the values of the indicators within a micro region.

Different units of the indicators makes impossible to unite them. The before mentioned relative categories can be used only, therefore it can be stated that "it is a landscape with moderate intensity, rapid, continuous effects, what is under strong anthropogenic impacts".

Beside the before mentioned indicators other parameters can be taken into consideration as well. However, data for the 11 indicators listed above are available in Hungary and it is probable that they are available in the industrialized countries, in Europe, North America and Australia also. The method presented here is a **first approach** to learn the most important factors of the functioning of landscapes, the **material – and energy transport processes** yet. The author believes that this kind of classification means steps towards that distant aim.

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REFERENCES

Bastian O., Schreiber K-F., 1994: Analyse und ökologische Bewertung der Landschaft. Gustav Fischer Verlag, 502 p.

Bartkowski T., 1984: Landscape or Geocomplex – substratum of the Ecosystem – as viewed in the light of the notion of geosystem. Ekológia CSSR, 3.2. pp. 159-170.

Blaschke T., 2000: Landscape Metrics: Konzepte eines jungen Ansatzes der Landschaftsökologie und Anwendungen in Naturschutz und Landschaftsforschung. Archiv für Naturschutz und Landschaftsforschung, 39. pp. 267-299.

Bornkamm R., 1980: Hemerobie und Landschaftsplanung. Landschaft+Stadt, 12. Jg. H. 2. pp. 49-55.

Buchwald K., Engelhardt W. (Hrsg.), 1968: Handbuch für Planung Gestaltung udn Schutz der Umwelt. BLV Verlagsgesellschaft, München-Bern-Wien.

Csorba P., 1993: The role of landforms in ecological landscape structure. Zeitschrift für Geomorphologie, Supplement Bd, 87. pp. 19-25.

Csorba P., 1996: Landscape-ecological change of the land use pattern on the East Foothill Area of the Tokaj Mountains (Hungary). Ekológia (Bratislava), Vol. 15. No 1. pp. 115-127.

Csorba P., 2008: Landscape ecological fragmentation of the small landscape units (Microregions) of Hungary based on the settlement network and traffic infrastructure. Ekológia (Bratislava) Vol. 27, No. 1. pp. 99-116.

Csorba P., Kerényi A., Marton-Erdős K., 1989: Untersuchung der Ökologischen Gegebenheiten an Hängen von Unterschiedlicher Exposition. Acta Geographia Debrecina, Tom. 24-25. pp. 33-56.

Csorba P., Zsadányi E., 2003: Veränderungen des Characteristikums der Naturnahen Vegetation in den Letzten 30 Jahren in dem Halbbecken von Bodrogkeresztúr. ACTA Geographica Debrecina, Tom. XXXVI. pp. 121-140.

Farsang A., Kitka G., Barta K., 2008: Modelling of the material transport in sustainable agriculture [in:] Csorba, P. Fazekas I. (eds.) Landscape Research Landscape Ecology. Debrecen, (in press).

Geraszimov I.P., 1980: Konsztruktívnaja geografija. Nauka, Moszkva.

Grabherr G., Koch, G., Kirchmeier H., Reiter K., 1998: Hemerobie österreichischer Wald-Ökosysteme. Veröffentlichtungen des Österreichischen MaB-Programms, Bd. 17. Universitätsverlag Wagner, Innsbruck, 493 p.

Haase G., 1967: Zur Methodik grossmasstäblicher landschaftsokologischer und naturräumlicher Erkundung. Wiss. Abh. Ges. De DDR, 5.

Haase G (Hrsg.), 1991: Naturraumerkundung und Landnutzung. Beiträge zur Geographie, Berlin, 34. pp. 315-331.

Haase G., 1999: Beiträge zur Landschaftsanalyse und Landschaftsdiagnose. Abhandlungen der Säschische Akademie der Wissenschaft zu Leipzig, Bd. 59. Heft 1. 203 p.

Haines-Young R., Chopping M., 1996: Quantifying landscape structure: a review of landscape indices and their application to forested landscapes. Progress in Physical Geography, 20. pp. 418-445.

Haines-Young R., 2005: Landscape pattern context and process. In: Wiens J., Moss M. (eds.): Issues and Perspectives in Landscape Ecology. Cambridge Studies in Landscape Ecology, Cambridge Univ. Press, pp. 103-111.

Hof, J., Flather C., 2007: Optimmization of landscape pattern [in:] Wu J., Hobbs R.J. (eds.) 2007: Key Topics in Landscape Ecology. Cambridge Studies in Landscape Ecology, Cambridge University Press, pp. 143-172.

Iszacsenko A.G., 1965: Die Grundlagen der Landschaftskunde und die physisch-geographische Gliederung. Moskau.

Jaeger J., 2002: Landschaftszerschneidung. Ulmer Verlag, Stuttgart, 447 p.

Jakucs P., 1985: Ecology of an oak forest in Hungary. Results of "Sikfőkút Project". MTA

Justyák J., Tar K., 1975: Investigations on the Ratio of Direct and Global radiation Amounts, Part II. Acta Geographica Debrecina, Tomus XIII. pp. 125-137.

Kerényi A., 1985: Surface Evolution and Soil Erosion as reflected by Measured Data. [in:] Pécsi M. (ed.): Environmental and Dynamic Geomorphology, Akadémiai Kiadó, Budapest, pp. 79-84.

Kerényi A. 1989: Die Beziehung zwischen den Bodenkundlichen und Reliefgegebenheiten im Halbbecken von Bodrogkeresztúr. Carpatho-Balcan Geomorphological Commission, Debrecen, pp. 53-64.

Kerényi A., Csorba P., 1991: Assessment of the sensitivity of the landscape in a sample area in Hungary for climatic variability. Earth Surface Procesess and Land-forms, Vol. 16. pp. 663-673.

Kertész Á. 2001: Land degradation in Hungary. In: Bridges E.M., Hannam, I.D., Oldeman L.R., Penning de Vries, F.W.T., Scherr S.J., Sombatpanit S. (eds.): Response to Land Degradation. Oxford & IBH Publishing Co. New Delhi. Calcutta. pp. 140-148.

Leser H., 1976: Landschaftsökolgie. Ulmer Verlag, Stuttgart, 432 p.

Lóczy D., 2002: Lndscape evaluation, soil evaluation (in Hungarian). Dialog Campus, Budapest-Pécs, 307 p.

Lóczy D., 2003: Possibilities for the Evaluation of Microstructures in Agricultural Landscape Patterns (in Hungarian). Tájökológiai Lapok, 1.1. pp. 33-43.

Marosi S., Somogyi S. (szerk.), 1990: Cadaster of the Hungarian Microlandscapes (in Hungarian) MTA Földrajztudományi Kutató Intézet, 1023 p.

Mazur E., 1983: Landscape Syntheis – Objectives and Tasks. GeoJournal, 7.2. pp. 101-106.

McGarigal K., Marks B.J., 1995: FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure. - General Technical Report PNW-GTR-351, US Dept. Of Agriculture, Forest Service Pacific NW Research Station, Portland, Oregon, 141 p.

Mersich I., Práger T., Ambrózy P., Hunkár M., Dunkel Z. (szerk.). Climatic Atlas of Hungary (in Hungarian) Országos Meteorológiai Szolgálat, Budapest, 107 p.

Mezősi G., Balogh I., 1993: GIS method for identification of environmentally critical region in Hungary. In: Widacki W (ed.) GIS for environment: conference on geographical information systems in environmental studies. Krakow: GIS Labo-ratory - Institute of Geography - Jagiellonian University, pp. 153-163.

Mezősi G., Fejes Cs., 2004: Landscape metrics (in Hungarian) [in:] Táj és Környezet, MTA, FKI pp. 229-242.

Miller G. P. 1980: Landscape Research in Mountain and Pediment Areas. (in Hungarian) Szovjet Földrajz, MTA,FKI, 185 p.

Mosimann Th. 1984: Landschaftsökologische Komplexanalyse. Steiner Verlag, 115 p.

Neef E. 1967: Die theorethischen Grundlagen der Landschafts-Lehre. Gotha, Leipzig, 152 p.

Odum E.P. 1963: Fundamentals of Ecology. Saunders, Philadelphia 574 p.

Pinczés Z., Kerényi A., Erdős-Marton K., Csorba P., 1980: Judgement of the danger of erosion through the evaluation regional conditions [in:] Morgan, R.C.P. (ed.): Soil Conservation, Problems and Prospects, John Wiley and Sons, Silsoe, Bedford, UK. pp. 89-103.

Pinczés Z., Kerényi A., Marton-Erdős K., Csorba P., 1984: Reconstruction of a vineyard area based on the analysis of the geoecological factors. IALE Proceedings, Roskilde University, Denmark, Vol. IV. pp. 89-98.

Pinczés Z., Kerényi A., Marton-Erdős K., Csorba P., 1987/a: Bodenvernichtung infolge einer unrichtigen Terrainregulierung. Acta Geographica Debrecina (1984), Tom. 23. pp. 125-144.

Pinczés Z., Kerényi A., Marton-Erdős K., Csorba P., 1987/b: Geoecological research methods and utilization of the results on the basis of investigations in Tokaj Mountains. Ekológia (CSSR), Vol. 6. No. 4. pp. 403-416.

Preobrazsenszkíj V.S. 1966: Landsaftnyije isszledovanije. Moskva, Nauka, 191 p.

Richling A., 1976: Analiza struktury srodowiska geograficznego i nowa metoda regionalizacji fizycznogeograficznej. Rozprawy Un. Warszawskiego, no. 104, 108 p.

Richling A., Malinowska E., Lechnio J. (eds.) 1994: Landscape Research and its Applications in Environmental Management. IALE Polisch Association, Warsaw, 289p.

Richling A., Solon J., 1996: Ekologia krajobrazu. PWN, Warszawa, 230 p.

Richter H., 1968: Naturräumliche Strukturmodelle. Petermanns Geographische Mitteilungen, 112. pp. 9-14.

Ruzicka M., Miklós L., 1982: Landscape–ecological Planning (LANDEP) in the Process of Territorial Planning. Ekológia (CSSR), 1. 3. pp. 297-312.

Ryszkowski L., 1992: Energy and Material Flows across a Central European hedgrows ecotone [in:] Hansen, A.J. – di Castri, F (eds.): Landscape Boundaries. Eco-logical Studies 92, Springer Verlag, 344 p.

Süli-Zakar I., 1978: Mapping of the Land use near Bodrogkeresztúr (Tokaj vineyard area) (in Hungarian) Földrajzi Közlemények, 26. (102). pp. 280-296.

Szolncev N.A., 1968: K tyeorii prirodnüh komplexov. Vesztnyik MGU, Szerija Geografii, 3. pp. 14-27.

Szocsava V.B., 1972: Geographie und Ökologie. Petermanns Geographische Mitteilungen, 116. pp. 89-98.
Szocsava V.B., 1978: Vegyenyije v ucsenyie o geoszisztémov. Novoszibirszk, Nauka, 310 p.
Szukacsev V., Dilisz N., 1964: Osznovü lesznoj biogeocönologii. Nauka, Moszkva, 574 p.
Wiens J., Moss M., (Eds.) 2005: Issues and Perspectives in Landscape Ecology. Cambridge Studies in Landscape Ecology, Cambridge University Press, 382 p.
Wu J., Hobbs R.J. (eds.), 2007: Key Topics in Landscape Ecology. Cambridge Studies in Landscape Ecology, Cambridge University Press, 297 p.

SUMMARY

We have limited knowledge on the material- and energy processes, which indicate the real internal functioning of landscapes. To understand deeper connections of landscape functions, parameters are required which indicates the amount of material and energy that is produced and transported in; and removed from a given area – e.g. a micro region (=landscape) – in an exact form.

We suggest three indicator groups to characterise the material- and energy transport of the landscapes:

1. Indicators of intensity of material- and energy; the global irradiance, the number of sunny hours, the water budget, and the amount of fitomass.
2. Rate and temporal course of material- and energy transport processes; the relief energy, the mean air temperature, the temperatures in the upper layers of the soil, the water supply and the seasonal differences of the water supply.
3. The degree of human impact; the hemeroby, the landscape fragmentation and the mining activity.