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Gully erosion in Hungary, review and case study

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Abstract

Soil erosion is one of the most significant land degradation processes on agricultural areas in Hungary. 25% of the total area of Hungary (more than one-third of agricultural land) is affected by water erosion, 16% by wind erosion. The role of gully erosion has been recognized only lately.

The hilly countries of Hungary are mainly covered by unconsolidated sediments, mainly by loess. Loess covered areas are prone to erosion and mass movements. The paper provides an analysis of environmental conditions of gully development in Hungary.

The role of gully erosion in total soil loss at catchment scale is shown on the example of the Tetves catchment (120 km^2, subcatchment of Lake Balaton catchment). A completely filled up sediment reservoir can be found at the catchment outlet. An attempt is made to determine the share of the material removed by gully erosion, based on the analysis of the sediment accumulated in the reservoir. If there is more topsoil in the reservoir then the role of sheet erosion is more important in the catchment, while more subsoil in the reservoir points to considerable gully erosion activity. Humus content and Caesium-137 activity were used as indicators of the topsoil. Gully erosion activity was investigated in the whole catchment in 1968, 1984 and 2004 using maps, air photos and field survey. The results show that approximately half of the deposited sediments came from the "subsoil" layer pointing to the important role of gully erosion.

The main conclusion is that the Caesium-137 method proved to be very well applicable to identify sediments originating for gully erosion activity. For policy makers it is suggested that land use planning should ensure a minimum risk of gully erosion with special emphasis on afforestation.

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Keywords: Gully erosion, Loess, Caesium-137, Sediment reservoir

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1. Introduction

Soil is one of the most significant natural resources in Hungary, its protection and conservation is of primary importance. Soil degradation processes including water and wind erosion, extreme soil reaction (acidification and salinization/alkalization), physical degradation (compaction, destruction of the soil surface and soil sealing), other chemical, physical and biological degradation processes [1, 2] and even desertification processes endanger high quality soils of the country. Although land degradation processes are induced both by natural and human factors, the role of human impact is definitively more important. This applies especially to those countries of the world where agriculture makes a considerable

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contribution to the national economy and Hungary is one of them. Agricultural area in Hungary and in Europe diminishes (see Table 1) and the percentage of population working in agriculture is decreasing continuously. If the productive area diminishes agriculture has to be more intensive and this intensification process automatically increases land degradation risk accompanied by the risk of pollution. As Table 1 shows fertilizer consumption is decreasing in Europe while it is growing in Hungary.

Table 1 Agriculture in Hungary, in Europe and in the World [3].

	Agricultural land (% of land area)		Fertilizer consumption (100 g/ha of arable land)		Agricultural employment (% of total employment)	
	1992	2005	1992	2005	1992	2005
Hungary	70,7	65,4	796	993	11,3	6,0
Europe (EMU*)	49,7	47,5	2 332	2 059	7,3	4,9
World	37,7	38,3	925	1020	41,8	—

* EMU – European Monetary Union

Agriculture has been extending to areas covered by natural vegetation, mainly by forest before. The importance of deforestation from the aspect of gully erosion will be shown in the paper.

As a conclusion of the above statements land degradation and especially soil erosion research is also of practical importance. Research activities of the last few decades focused mainly on sheet erosion. The role of gully erosion has been recognized only lately. The presence and dynamics of various gully types (permanent, ephemeral and bank gullies) can be observed and their development can be followed under different climatic conditions and various land use types and sheet and rill erosion measurements on runoff plots are not realistic indicators of total catchment erosion [4]. Another weakness of plot measurements of sheet erosion is that they do not give information about the redistribution of eroded soil within a field [4]. Gully erosion plays a decisive role in the redistribution of eroded soil on a slope and in delivering it to watercourses [5]. All these statements point to the need of intensive research on gully erosion.

The objective of the present paper is to give an overview on the conditions and development of gully erosion in Hungary and to present a case study on the importance of gully erosion in the sediment budget of a medium size catchment.

2. Gully erosion in Hungary

In Hungary more than one-third of agricultural land is affected by water erosion [6] (see Table 2). Soil erosion is one of the most significant land degradation processes on agricultural areas.

25% of the total area of Hungary (more than one-third of agricultural land) is affected by water erosion (on agricultural land 13.2% slightly, 13.6% moderately and 8.5% severely eroded) and 16% by wind erosion [6] (see Table 2).

The first soil erosion map of the country was created by Stefanovits and Duck [7] covering, however, only improved farmland (excluding non agricultural uses, e.g. forests, urban and industrial areas, roads, etc.). The mapping was based upon the analysis of soil profiles. As a consequence of the applied method only areas effected by sheet erosion are identified on the map and the areas of gully erosion are not shown on it. Soil erosion research concentrated mainly on sheet erosion and the assessments were restricted to smaller areas, plots, hillslopes and sometimes to small catchments.

Bergsma [8] defines gullies as 20-30 cm to 20 m deep linear landforms. The Hungarian classification uses the term linear erosion as for the processes leading to the formation of micro-rills, rills (Fig. 1) and gullies (Fig. 2).

Poesen et al. [3] define gully erosion “as the erosion process whereby runoff water accumulates and often recurs in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths”. Foster [9] introduced the term of ephemeral gully erosion, i.e. these gullies can still be removed by cultivation, while permanent gullies are too deep to ameliorate with tillage machines [10]. Ephemeral gullies occur in Hungary very frequently.

Table 2. Soil erosion in Hungary

	Thousand hectares	% of the total area	% of the agricultural land	% of the eroded land
Area of the country	9 303	100	-	-
Area of agricultural land	6 484	69.7	100	-
Arable land	4 713	50.7	73.0	-
Total eroded land	2 297	24.7	35.3	100
strongly	554	6.0	8.5	24.1
moderately	885	9.5	13.6	38.5
weakly	852	9.2	13.2	37.4

Fig. 1 Rills on arable land in the Tetves catchment

Environmental conditions of gully erosion are given in most of the hilly countries of Hungary. Stefanovits–Várallyay [6] investigated the effect of *relief* on water erosion (including both sheet and gully erosion) in Hungary according to slope gradient categories. On slopes <5% erosion hazard is negligible. As slopes > 25% are generally forested they do not imply a big erosion risk. The 17-25% slopes are either under forest or were deforested in the recent past. Most of the 5-17% slopes are used for agriculture and deteriorated by soil erosion to a certain extent [11]. There are no studies carried out on the threshold value of slope gradient for gully initiation.

Roughly 65 percent of the total area of Hungary are covered by loose sediments, mainly by loess and loess like deposits, susceptible to soil erosion and mass movement processes in the hilly regions of the country. Soil erosion is the greatest environmental hazard on hillslopes under cultivation. The thickness of slope loess varies between 5 and 25 m. The best conditions for gully erosion are provided in the areas of thick loess cover. Other loose sediments like Pannonian sands are also susceptible to gully erosion.

The initiation and development of gullies is in some cases promoted by subsurface erosion, i.e. by piping (called also suffusion in Hungarian literature) [12]. Physical and chemical properties of loess and loess-like sediments offer favourable conditions for the development of pipes. Collapsibility is first of all connected with calcium carbonate content (including lime concretions in older loess deposits), with the very high porosity (volume of pores is 40-60 %). The most important processes on collapsible/dispersive rocks and soils include sheet erosion, rill erosion, gully erosion, piping (tunnel erosion, suberosion), wind erosion and mass movements.

According to Poesen et al. [13] gully erosion is more frequent under arid conditions and less frequent under humid climatic conditions. Recent research concentrates on the occurrence of erosive rainfall events. Evidently the amplitude and frequency of rainfall events are the most important rainfall characteristics.

From the point of view of sheet and gully erosion, „erosion-sensitive days" characterized by >30 mm daily rainfall are of crucial importance [6], which may occur 4-12-times per year in Hungary. Concerning rainfall characteristics the most informative value is the rainfall threshold leading to the development of gullies in various environments. According to Poesen et al. [4] there is not much difference in threshold rains of rills and gullies. There are no data available on threshold rains in Hungary.

Global climate change will increase gully erosion risk. Extreme events will be more frequent. In summer long periods of draught will alternate with storms (high intensity rainfalls). In winter freezing, melting and intensive rainfalls will alternate.

Fig. 2 Deep gully in the Tetves catchment

The role of land use is crucial in the development of land degradation processes. Recent studies indicate that (1) gully erosion represents an important sediment source in a range of environments and (2) gullies are effective links for transferring runoff and sediment from uplands to valley bottoms and permanent channels where they aggravate off site effects of water erosion. In other words, once gullies develop, they increase the connectivity in the landscape. Many cases of damage (sediment and chemical) to watercourses and properties by runoff from agricultural land relate to (ephemeral) gullying. There is a huge number of studies on the effect of land use on gully development. Gábris et al. [14] reported on a very intensive gully erosion activity in the nineteenth century when large areas deforested. Deforestation and starting agricultural activity on former forested areas increases gully erosion risk also in Hungary.

3. Case study

As already mentioned the role of gully erosion in the sediment budget of a catchment has been underestimated, sometimes even overlooked. The case study presented below will demonstrate the importance of gully erosion convincingly.

The estimation and measurement of soil erosion happens mostly by recording the amount of deposited sediments. Usually the largest part of soil loss is deposited at the bottom of the slopes and only a few percent leave the catchment. According to Fitzpatrick [15] soil loss delivered by sheet erosion can take small distances, while the sediment delivered by gully erosion often reaches the streams. In many cases gullies are not the sources of soil loss but as channels they can transport the sediment out of the catchment [16]. The ratio between gully and sheet erosion in a catchment can vary in wide ranges. The USLE [17] absolutely neglects gully erosion. According to De Vente - Poesen [18] sediment sinks are of less importance in basins dominated by bank erosion, i.e. gullies can increase the volume of sediment yield remarkably [19, 20, 21]. During heavy rainstorms the majority of the sediment leaving the catchment originates from gully erosion, but the ratio can vary with time [22]. Climatic conditions usually determine the ratio between gully and sheet erosion [23].

4. Methods

The study area is the Tetves catchment (120 $km^{2)}$, a subcatchment of Lake Balaton, Hungary (Fig. 3). Previous soil erosion studies [12, 24, 25, 26] and landscape ecological research [27] provide a good basis for gully erosion investigations. A detailed description of the study site is given in Madarász et al. [28] and in Jakab [29].

The present study uses the data of a sediment reservoir located at the lowermost part of the catchment, near the outlet of the stream. It was constructed in 1970 with an area of 13 ha and a capacity of 95 300 m^3. Although by 2000 the reservoir was completely filled up the stream is still flowing through. Beside the reservoir some fishponds can be found gaining water also from the stream just above the reservoir. Filling the ponds is possible only at high or mediate water levels of the stream. The sediment reservoir as well as the fishpond contains the deposited soil loss of the catchment.

The case study is based on 30 years sediment yield at the outlet of the catchment, to determine the volume of soil erosion in the basin and to distinguish between sediment from the surface (the uppermost 20 cm) and sediments from lower horizons.

The soil surface can be destroyed both by linear and sheet erosion, but the erosion of subsurface parts of the soil profile is always related to gully erosion [15]. The main task is to find a method for making a difference between sediments of surface and subsurface origin. The best method is to use the Caesium-137 isotope as a tracer of the surface soil. Panin et al. [30] have used this method to investigate the soil loss related to gully and sheet erosion. The Caesium-137 procedure demonstrates the dimension and spatial distribution of erosion and sedimentation processes [31], although it is less accurate than the conventional methods [32]. Conventional methods are based either on organic matter content or on particle size distribution of the samples.

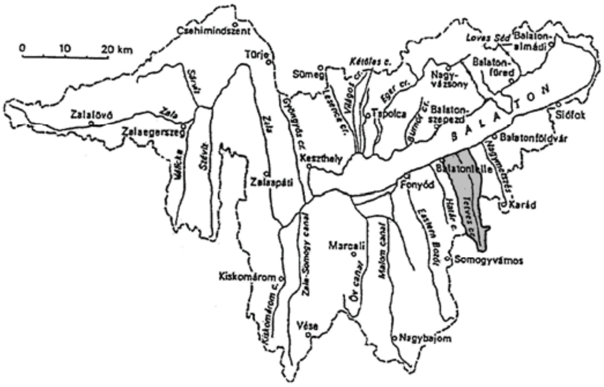

Fig. 3 Location of the study area: The Tetves catchment in Lake Balaton catchment

The isotope is of artificial origin and its presence in the environment is due to nuclear weapon tests and accidents. The direct source of soil contamination is fallout. As the Cs-137 isotope reaches the surface it makes very strong complexes with clay minerals and with organic matter [33]. Since Cs-137 is an alkali metal cation, its behaviour is quite similar to phosphorus, although phosphorus has remarkably shorter radius [34]. As a consequence of this the isotope cannot be leached. The contamination under average Hungarian conditions and in undisturbed soil profiles does not exceed 25-30 cm depth [35]. The migration in the profile is possible only by the help of the clay minerals [36]. In an undisturbed profile the total activity of the isotope decreases exponentially downwards from the surface [37]. If there is no activity concentration at the top of the soil profile, the profile is eroded. The presence of Cs-137 activity in deeper horizons refers to deposition of topsoil on the top of the original profile [38, 39, 40].

The volume of the fallout was determined by applying the reference profiles of Szerbin et al. [35] and Csepinszky [41]. Along the axis of the reservoir six sampling points were established representing the whole deposited mass. At each point samples were taken as a collection of 7 borings. Each profile was divided into horizons and altogether 32 samples were investigated [42]. In addition to this the fishpond was also sampled

Gully Erosion Activity has been investigated in the whole catchment during three years (1968, 1984, and 2004) using maps, air photos and field survey [26].

5. Results

During the field survey in 2004 altogether 140 gullies were identified and mapped. Within this group of gullies only 85 were present in 1968 and 115 in 1984. Changes in total length of these gullies in time can be seen in Table 3. Before 1984 the increase in gully length was relatively slow while after 1984 gully length grows very quickly (Fig. 4). During the period of 34 years the total length of the gullies increased by almost 60%. Before 1984 the increase of the shortest (<50 m) gullies was typical, after 1984 gullies longer than 450 m increased mostly. The reason for this is probably the change in plot sizes of arable fields.

Table 3 Changes in gully length in time.

	1970	1984*	2004
Total lenght (m)	29 942	36 688	47 064
Total lenght (%)	64	78	100
Average increase (m $year^{-1}$)	-	173	519

*Air photos of 1984 do not cover the whole catchment area, there is a lack of data on 15 gullies. For these gullies data of the year 2004 were applied.

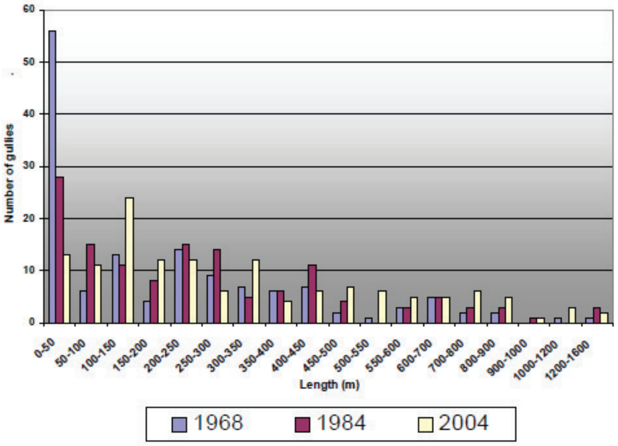

Fig. 4 Gully distribution according to their length in 1968, 1984, and 2004

During the lifetime of the reservoir (1970-2000) the volume of the filling-up was 95 300m^3. The filtering effect was more effective because of the high biomass production. In case of this wetland the annual production is about 2 kg m^{-2} [43], with a bulk density of 1.0g cm^{-1}. These riparian ecosystems have an important influence on the physical and chemical properties of sediments [44, 45]. 7800m^3 organic matter was accumulated during 30 years. The remaining 87 500 m^3 sediment was delivered from the catchment. The average bulk density of the undisturbed sediments in the reservoir is 1.3 g cm^{-1}, net soil loss was 113 750 t during 30 years. The specific annual erosion rate is 0.8 t ha^{-1}. This is a very rough estimation, but it may demonstrate the order of magnitude. It is very important to note that this sediment volume left the catchment.

The samples taken form the reservoir consists of layers. These layers are due to subsequent sedimentation events. The layers are characterized by different organic matter content and particle size distribution corresponding to the erosion/sedimentation event in question. It can be assumed that below a threshold value of precipitation amount and/or intensity gullies deliver only sediments originating from sheet erosion. Above this threshold value gullies become sediment sources as well and transport a big amount of gully parent material into the sediment reservoir. These events are indicated by layers without organic matter (parent material, mainly loess) in the reservoir profiles.

In the fishpond the thickness of the contaminated sediment layer is less than 20 cm referring to the maximum deposition value from the catchment during the last 50 years. Because of the regular distribution of activity values in the sample profiles (Table 4) there is no mixing or redistribution in the sediment layers. The pond is older than 100 years, the thickness of the contaminated layer is less than 20 cm and so the pond has a very limited sediment input from the catchment, although the activity of the contaminated layer is more than three times higher than the fallout. The sampling points in the reservoir have more or less the same order of activity as the fishpond has. The important difference is in the thickness of the contaminated layer. In the reservoir activity was detected also at a depth of 110 cm.

It can be assumed that the whole contaminated layer in the fishpond comes from the catchment. The area of the pond is approximately the same as the area of the reservoir. The sediment volume in the pond is roughly 130 cm m^{-2}. The sediments of the pond and of the reservoir belongs together (Table 5). The fishpond and the reservoir were constructed before the fallout so that they received Caesium loads themselves. As a consequence of this the volume of the fallout (7 900 Bq kg^{-1}) has to be substracted form the measured activity values.

Originally the Caesium-137 contamination did not get below a soil depth of 20 cm. According to our calculations, if the whole sediment was of topsoil origin, the total activity value of the 130 cm is 6.5 times higher than that of the fallout (51 350 Bq m^{-2}). Smaller volumes mean that the sediment contains subsoil without Cs-137 activity, as a consequence of gully erosion (Table 5).

Using the Cs-137 technique it can be concluded that minimum 50% of the sediment at the outlet of the catchment originates from layers below 20 cm of the soil profiles of the catchment. The lower parts of an in situ profile are eroded by gully erosion, which refers to an important role of linear erosion in this case.

Table 4 Cs-137 activity at the sampling points

Sampling point	Depth (cm)	Activity (Bq kg^{-1})	St. dev	Activity (Bq m^{-2})
Fish pond	0-5	159.4	2.9	10361.48
	5-10	152.98	3.4	9944.25
	10-15	82.49	5.6	5362.36
	15-20	5.57	7.1	362.07
	20-60	0.2		
	peat	0.2		
	total			26030.16
S1	0-20	25.0	0.5	
	20-40	46.4	0.7	
	40-60	9.2	0.3	
	60-80	3.8	0.2	
	80-100	2.8	0.2	
	total			11674
S2	0-20	23.5	0.5	
	20-40	30.9	0.5	
	40-60	34.4	0.5	
	60-80	12.4	0.3	
	80-100	7.3	0.3	
	total			12615
S3	0-10	26.6	0.6	
	10-20	103.0	0.7	
	20-30	24.7	0.4	
	30-40	11.1	0.3	
	40-50	7.7	0.2	
	50-60	3.8	0.1	
	total			15773
S4	0-20	46.8	2	
	20-40	14	0.5	
	40-60	9.2	0.4	
	total			16492
S5	0-25	30.2	1.6	
	25-50	3.3	0.2	
	50-80	0.48	0.11	
	80-110	0.07	0.06	
	total			10756
S6	0-12	53.2	1.8	
	12-24	1.35	0.1	
	24-36	17.9	0.4	
	total			8412

Table 5 Measured and modelled activities at the sampling points. Activity corrected = Measured value - fallout on the reservoir (~6000Bq); Activity Corrected 2 = Activity Corrected + value of the fishpond; Topsoil = The uppermost 20 cm of the profile.

Sampling	Fallout	Activity	Activity	Activity	Model	Topsoil
	Bq m^{-2} 20 cm^{-1}	Bq m^{-2} 110 cm^{-1}		Bq m^{-2} 130 cm^{-1}		%
S1	7 900	11 674	5 674	23 774	51 350	0.46
S2	7 900	12 615	6 615	24 715	51 350	0.48
S3	7 900	15 773	9 773	27 873	51 350	0.54
S4	7 900	16 492	10 492	28 592	51 350	0.56
S5	7 900	10 756	4 756	22 856	51 350	0.45
S6	7 900	8 412	2 412	20 512	15 800	1.30

According to former investigations [12] 1 198 268 m^3 material was moved in the Tetves catchment d to gully erosion. This amount was eroded since the formation of the investigated gullies. Assuming direct relationship between the increase of gully length and soil loss the conclusion is that during t investigated period of 34 years 435 086 m^3 soil was eroded by gully erosion. One part of the sediment w deposited on the gully fan another part was sedimented on the valley bottom and the rest reached t stream and was deposited in the sediment reservoir.

Comparing the sediment volume in the reservoir with soil loss volume coming from the gullies it can be concluded that about 10% of the soil eroded by gullies reached the sediment reservoir, i.e. the outlet of the catchment. Assuming uniform soil erosion and sediment transport this means 1287 m^3 $year^{-1}$ from a catchment of 120 km^2 which is a potential danger for Lake Balaton. This amount is only the result of gully erosion and the same amount was eroded by sheet erosion.

6. Conclusions

Conditions of gully erosion and development are given in most of the hilly countries of Hungary. Two third of the area of Hungary are covered by loose sediments susceptible to soil erosion. The areas with thick loess cover provide excellent conditions for gully erosion. Land use and land use change play a decisive role in gully initiation and development.

Results of the case study show that the majority of soil loss in the Tetves catchment is eroded by sheet erosion, however, in most cases the eroded soil remains in the catchment itself and doesn't leave it. Those sediments which leave the basin contain more subsoil, approximately 50% in this case. This fact underlines the role of gully erosion is sediment source and not only as transport channel in the catchment. In addition to this the results show that the activity of gully erosion has a yearly fluctuation on one hand and a 5-10 years periodicity on the other. In general early spring low volume topsoil sediments will be deposited in the reservoir and during the periods of thunderstorms in late summer a large amount of subsoil is eroded and delivered out of the basin. This periodicity can be seen in the stripped profile of the sediments in the reservoir. The most active period of subsoil sediment transportation happened between 1984-1995.

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References

[1] Várallyay Gy, Leszták M. Susceptibility of soil to physical degradation in Hungary. Soil Technology 1990; 3 (3): 289-98.
[2] Kertész Á. (2001). Land degradation in Hungary. In: Response to Land Degradation, eds. Bridges E.M., Hannam I.D., Oldeman L.R., Penning de Vries F.W.T., Scherr S.J., Sombatpanit S. New Delhi, Calcutta: Oxford & IBH Publishing Co; 2001, p. 140-8
[3] The World Bank. Agricultural inputs. In: World Development Indicators 2007. USA, Washington: World Bank; 2007, p. 130-3.
[4] Poesen J, Nachtergaelea J, Verstraetena G, Valentin C. Gully erosion and environmental change: importance and research needs. CATENA 2003; 50 (2-4): 91-133.
[5] Evans R. On assessing accelerated erosion of arable land by water. Soils and Fertilizers 1993; 56 (11): 1285-93.
[6] Stefanovits P, Várallyay Gy. (1992). State and management of soil erosion in Hungary. In: Proceedings of the Soil Erosion and Remediation Workshop, US – Central and Eastern European Agro-Environmental Program. April 27 – May 1 1992, Budapest; 1992, p. 79-95.
[7] Stefanovits P, Duck T. Talajpusztulás Magyarországon (Soil Erosion in Hungary), Budapest: OMMI; 1964.
[8] Bergsma E, Charman P, Gibbons F, Hurni H, Moldenhauer W. C. and Panichapong S. 1996: Terminology for soil erosion and conservation. Wageningen, The Netherlands: International Society of Soil Science. 314 pp.
[9] Foster G. R. Understanding ephemeral gully erosion. Soil Conservation, vol. 2. Washington DC: National Academy of Science Press; 1986, p. 90-125.
[10] Soil Science Society of America. Glossary of Soil Science Terms. Madison, WI: Soil Science Society of America; 2001, http://www.soils.org/sssagloss/.
[11] Krisztián J. Talajvédelem (Soil conservation). Gyöngyös: GATE Mezőgazdasági Főiskolai Kar; 1998.
[12] Jakab G, Kertész Á, Papp S. Gully erosion in the Tetves catchment, Hungary ((in Hungarian with English abstract)) Geographical Bulletin 2005; 54 (1-2): 149-65.
[13] Poesen J, Vandaele K, van Wesemael B. Contribution of gully erosion to sediment production in cultivated lands and rangelands. IAHS Publications 236; 1996. p. 251– 66.
[14] Gábris Gy, Kertész Á, Zámbó L. Land use change and gully formation over the last 200 years in a hilly catchment. CATENA 2003; 50 (2): 151-64.
[15] Fitzpatrick E. A. An introduction to soil science, Second Edition. UK: Longman Scientific & Technical Harlow; 1986.
[16] Wischmeier W. H. (1977). Soil erodibility by rainfall and runoff. In: Terminology for soil erosion and conservation, ed. Bergsma E, Charman P, Gibbons F, Hurni H, Moldenhauer W.C. Panichapong S. Wageningen: Grafisch Service Centrum; 1977, p. 25.

[17] Wischmeier W.H., Smith D.D. Predicting rainfall erosion losses: A guide to conservation planning. - USDA Agricultural Handbook 537. Washington, D.C.: US Government Printing Office; 1978, p. 58.

[18] De Vente J, Poesen J. Predicting soil erosion and sediment yield at the basin scale: Scale issues and semi-quantitative models. Earth-Science Reviews 2005; 71 (1-2): 95-125.

[19] Kertész Á. The role of deep-cut tracks in linear erosion. In: Geographical Essays in Hungary, eds. Enyedi Gy., Pécsi M. Budapest: MTA FKI; 1984, p. 47-56.

[20] Kertész Á. Soil erosion and mass movement processes on the loess covered areas of Hungary (in Hungarian with English abstract). Hungarian Geographical Bulletin 2004a; 53 (1–2): 13–20.

[21] Kertész Á. The role of donga (gully) erosion in surface formation in South Africa (in Hungarian with English abstract). Hungarian Geographical Bulletin 2004b; 53 (3-4): 213-8.

[22] Chaplot V, Coadou le Brozec E, Silvera N, Valentin C. Spatial and temporal assessment of linear erosion in catchments under sloping lands of northen Laos. CATENA 2005; 63 (2-3): 167-84.

[23] Kertész Á. he role of climatic conditions in rill and gully erosion (in Hungarian with English abstract). Hungarian Geographical Bulletin 2006; 130 (3-4): 115-22.

[24] Kertész Á, Tóth A, Jakab G., Szalai Z. Soil erosion measurements in the Tetves Catchment, Hungary. In: Multidisciplinary Approaches to Soil Conservation Strategies, ed. Helming K. Proceedings, International Symposium, ESSC, DBG, ZALF, 11–13 May 2001, Müncheberg, Germany; 2001, ZALF-BERICHT Nr. 47: p. 47-52.

[25] Kertész Á, Jakab G, Tóth A. Water erosion in Hungary – a Case Study on Soil Erodibility. In: Aspects of the Erosion by Water in Austria, Hungary and Slovakia. eds. Nestroy O., Jambor P. Bratislava: Soil Science and Conservation Research Institute; 2003, p. 85-92.

[26] Jakab G, Kertész Á, Dezső Z, Madarász B, Szalai Z. The role of gully erosion in total soil loss at catchment scale. 14th International Poster Day. Transport of Water, Chemicals and Energy in the Soil-Crop Canopy-Atmosphere System Bratislava, 9.11.2006 Proceedings CD; 2006.

[27] Tóth A, Szalai Z. Landscape ecological and typological research in the catchment area of Tetves stream (in Hungarian with English abstract). Hungarian Journal of Landscape Ecology 2007; 5 (1): 131-42

[28] Madarász B, Kertész Á, Jakab G, Tóth A. Movement of solutes and their relationship with erosion in a small watershed. In: Aspects of the Erosion by Water in Austria, Hungary and Slovakia. eds. Nestroy O., Jambor P. (eds.) Bratislava: Soil Science and Conservation Research Institute; 2003. p. 99-110.

[29] Jakab G. Testing a new classification system of gullies within a catchment area (in Hungarian with English abstract). Hungarian Geographical Bulletin 2008a; 57 (1-2), 169-84.

[30] Panin A.V., Walling D.E., Golosov V.N. The role of soil erosion and fluvial processes in the post-fallout redistribution of Chernobyl derived 137Cs: a case study of the Lapki catchment, Central Russia. Geomorphology 2001; 40 (3-4): 185-204.

[31] Bouhlassa S, Azenfar A, Machrouh A. Caesium fallout as a tracer of erosionsedimentation in big catchment. Appl. Radiat. Isot. 1995; 46 (6-7): 659-60.

[32] Wicherek S.P, Bernard C. Assesment of soil movements in a watershed from Cs-137 data and conventional measurements (example: the Parisian Basin) CATENA 1995; 25 (1-4): 141-51.

[33] Mabit L, Bernard C. Relationship between soil 137Cs inventories and chemical properties in a small intensively cropped watershed. Earth & Planetary Sciences 1998; 327 (8): 527-32.

[34] Killham K. (2001). Soil ecology. Cambridge University Press; 2001, p. 175-6.

[35] Szerbin P, Koblinger-Bokori E, Végvári I, Ugron Á. Caesium-137 migration in Hungarian soils. The Science of the Total Environment 1999; 227 (2-3): 215-27.

[36] Chappell A, Warren A, Oliver M. A., Charlton M. The utility of 137Cs for measuring soil redistribution rates in sothwest Niger. Geoderma 1998; 81 (3-4): 313-37.

[37] Porto P, Walling D.E., Ferro V. Validating the use of caesium-137 measurements to estimate soil erosion rates in a small drainage basin in Calabria, Southern Italy. Journal of Hydrology 2001; 248 (1-4): 93-108.

[38] Govers G, Quine T.A., Desmet P.J.J., Walling D.E. The relative contribution of soil tillage and overland flow erosion to soil redistribution on agricultural land. Earth Surface Processes and Landforms 1996; 21 (10), 929-46.

[39] Lu X.X., Higgitt D.L. Estimating erosion rates on sloping agricultural land in the Yangtze Three Gorges, China, from caesium-137 measurements. CATENA 2000; 39 (1): 33-51.

[40] Lu X.X., Higgitt D.L. Sediment delivery to the Three Gorges 2: Local response. Geomorphology 2001; 41 (2): 157–69.

[41] Csepinszky B. (ed.). Testing the applicability of a new method of soil erosion estimation based on radioactive tracers in Lake Balaton catchment (in Hungarian). Research Report, Ministry of Agriculture of Hungary, No. KF- 289/1, 2003.

[42] Jakab G. On- and offsite effects of soil erosion at catchment scale. Final COST 634 International Conference on- and offsite environmental impacts of runoff and erosion” 30 June – 4 July Aveiro, Portugal Abstract book; 2008b, p. 95.

[43] Begon M, Harper J.L., Townsend C.R. Ecology. Third Edition. USA, Malden: Blackwell Science; 1996.

[44] Szalai Z. Spatial and temporal pattern of soil ph and eh and their impact on solute iron content in a wetland (Transdanubia, Hungary) *AGD Landscape & Environment* 2008; **2** (1), 34-45.

[45] Szalai Z, Németh T. Influence of elementary land mosaics on chemical parameters of soils (in Hungarian with English abstract). *Hungarian Geographical Bulletin* 2008; **57** (1-2): 135-46.