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Les espaces naturels protégés sont-ils nécessaires ?

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photo 7: Temporary creek on the surface of the forest road during a heavy rainfall, 2015 (photo by Gábor Varga).

Geohazards of the natural protected areas in Southern Transdanubia (Hungary)

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Résumé/Abstract/Összefoglaló

Many nature reserves and protected areas are found in the Southern Transdanubian Region (SW Hungary) and they partly belong to the operational area of the Duna-Dráva National Park (DDNP). In the current paper we review the potential geohazards that may affect the area. Our results indicate that the predominant geohazards include large riverine floods on the alluvial plains, while a high-degree of vulnerability is generated owing to the high relief. High relief may trigger intense runoff following intense rainfall events and downpours, where consequences, such as flash floods, mass movements and soil erosion may result in various disasters and catastrophes. Nonetheless, since the definition of catastrophes is human-oriented, the direct consequences of disasters may act as positive and beneficial processes in uninhabited natural environments.

Risques géomorphologiques dans les aires naturelles protégées de Transdanubie méridionale (Hongrie)

Beaucoup de réserves naturelles et de zones protégées sont répertoriées dans la région de Transdanubie méridionale (sud-ouest de la Hongrie), dont une partie appartient au Parc National Duna-Dráva (DDNP). Cet article présente une étude des risques géomorphologiques potentiels pouvant affecter cette région. Les résultats montrent que les grandes crues fluviales dans les plaines alluviales représentent les principaux risques impactant la Transdanubie méridionale, risques aggravés par un haut degré de vulnérabilité généré par d'importants reliefs et de fortes pentes. Ces forts ruissellements, faisant suite à des événements météorologiques intenses, provoquent les inondations brutales et soudaines, des mouvements de masse et l'érosion du sol pouvant entraîner de nombreuses catastrophes. Néanmoins, bien que la notion de catastrophe soit liée à la vulnérabilité des sociétés humaines, les conséquences directes de ces événements revêtent un caractère bénéfique au fonctionnement des milieux naturels de cette région de Hongrie, faiblement peuplés voire inhabités.

Védett területek természeti veszélyei a Dél-Dunántúlon (Magyarország)

A Dél-Dunántúlon változatot természeti környezetben számos védett terület található, amelyek egyrészt a DDNP igazgatóságához tartoznak, másrészt egyéb védettséget élveznek. Cikkünkben áttekintettük a védett területeket érintő természeti veszélyeket és megállapítottuk, hogy ezek közül a sík területeken futó folyóink áradásai okozzák a legnagyobb károkat. A hegységi és dombosági felszíneken a nagy relatív relief és az ebből következő hirtelen lefolyás (hirtelen áradás), a csuszamlások, valamint a talajerzió a sérülékenység fő okai. A természeti veszélyforrásokat a védett területeken természeti folyamatként értelmezhetjük, amely az élővilág megújulását is elősegítheti.

Mots clés/Key-words/Kulcsszavak

Natural hazards, vulnerability, landscape evolution, risk assessment, Duna-Dráva National Park, Hungary.

Risques d'origine naturelle, évolution des paysages, évaluation des risques, Parc National Duna-Dráva, Hongrie.

Természeti veszélyek, sérülékenység, tájfejlődés, veszély értékelés, Duna-Dráva, Nemzeti Park, Magyarország.

Preface

One of the six main landscape units of Hungary is the Transdanubian Hills with the Mecsek Mountains. The Duna-Dráva National Park (hereafter DDNP) was established in 1996 along the human modified

floodplain of Danube and Dráva rivers that borders the Transdanubian Hills from East and South, respectively. DDNP manage and control all protected areas in different levels within this region. In spite of the massive preventions and precautions, the magnitude of damages, generated by natural disasters, does

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not diminish even in developed countries, and, simultaneously, decreasing return periods have been observed since the 1950s.

The interpretation of natural-, environmental- or geohazards is out of the scope of this study. Geohazards are considered as harmful event for humans, however, ultimately, they may act as positive phenomena in the area of the DDNP.

Introduction

Natural hazards were interpreted as 'Acts of God' till the 1930s, but anthropogenic effects play also important role in the triggering of these processes (Smith K., 2004). The meaning of hazard was always interpreted as the socioeconomic and anthropocentric consequences of a possible disaster. Related parameters (e.g. loss or death) also measured from the human side or perspective. Sometimes, especially in relation to the environmental contamination natural damage was mentioned (cyanide poisoning of Tisza River). Even though disasters are considered as undesired phenomena from the viewpoint of humans, they also affect nature and uninhabited areas in either a negative, but occasionally in a beneficial way. Vulnerability of the nature and natural protected areas was occasionally studied in earth sciences (e.g. Wilkerson F.D. & Schmidt G.L., 2003; Dragičević S. et al., 2013).

Natural disasters, that either endanger human life or hazardous for economy, rarely occur in Hungary today. Nonetheless, due to the red sludge dam failure in Kolontár, Hungary made it to the breaking news on CNN in 2010. Among the most common geohazards in Hungary (Szabó J. et al., 2007) floods, mass movements, windstorm and soil erosion are considered the most frequently recurring and adverse phenomena within the operational area of DDNP.

The aim of this study is to review and evaluate geohazard-affected natural protected areas of South Transdanubia within the operational area of DDNP.

Study area description

The idea of the establishment of the DDNP first emerged in the early 1990s as a joint effort between the former Yugoslavia and Hungary. However, due to

the subsequent geopolitical changes, the park was solely founded by Hungary. The protected areas are scattered across the Southern Transdanubian region bordered by the Danube on the East and the River Drava on the south. The protected areas are almost contiguous along the floodplains of the Rivers Drava and the Danube south of the confluence of the Sió Canal. Besides the floodplain areas, protected areas are also found in the Mecsek Hills and in the rolling hills of Tolna County and intermittently in the west and northwest (Somogy County). Within the park three protection levels are identified in decreasing order of protection rank: (a) national park, (b) nature reserves and (c) landscape protection areas. The total combined area of the protected land covers an area of 993 km², of which 540 km² is national park, 430 km² landscape protection area and 25 km² is assigned as nature reserve. There are 30 major districts within the entire national park, of which six is protected at national park level (highest protection level), five districts belong to landscape protection areas and 19 falls into the nature reserve category. The classification of the individual areas were based on the natural and cultural values determined by the operative measures.

All protected areas are located in the southern Transdanubian (Dél-Dunántúl) region, specifically on the rolling hills of the Transdanubian region, the Mecsek Hills and plains along the Rivers Drava and Danube. The hilly region of southern Transdanubia is characterized by extremely varied landscapes, which is covered by plains in one third, while the remaining two third is characterized by rolling hills and low mountains (Marosi S., 2002). The rolling hills, like the Marcali Hát (Boronka Region) were predominantly formed on the loose, unconsolidated clayey and sandy sediments that were deposited during the transgression periods of the late Miocene. These latter areas are less rugged than the dissected, tectonically reshaped and loess-covered regions of NE Somogy County, Tolna Hills and the Zselic (Lehmann A., 1979). The hilly areas are interrupted by two low-mountain regions, the Mecsek Mountains and the Villány Hills, built up of dominantly Mesozoic, and to a lower degree, Paleozoic rocks. The two ranges are connected by the southern foothills of the Mecsek, built up of late Miocene unconsolidated sediments and covered by Pleistocene loess deposits (Fábián S.Á. et al., 2005; Kovács I.P., 2015). At many locations, the rolling hills are bordered by alluvial plains covered by wind-blown sands (Lóki J., 1981; Kiss T. et

figure 1: Map of the operational area of DDNP within South Transdanubia (ed. by Edina Józsa). Protected areas are referred with their respective numbers in the text and tables.

al., 2012). The finest example of the latter is found in SE Somogy County (Marosi S., 1970). The Transdanubian Hills are bordered by the alluvial floodplain of the River Drava in the south. The subsided basin of the River Drava consists of a series of Lower Miocene

subbasins subsequently filled up with Late Miocene marine and lacustrine sediments (Kőrössi L., 1989). Later, these sediments were topped by gravelly and sandy sediments deposited by the River Drava. The area along the Drava is a low elevation floodplain,

photo 1: Panoramic perspective of the Dunaszekcső Loess profile (16) from the underlying peninsula (photo by Tamás Varga).

ID	Area (km ²)	Mean elevation (m a.s.l.)	relative relief (m/km ²)	Natural values	Description
1	187	87	2	Hungary's largest red deer (<i>Cervus elaphus</i>) herd, wetlands	one of the largest continuous floodplains in Europe, fok (cape) culture
2	96	85	4	wetlands, specific bird fauna, flora	fok (cape) culture
3	212	111	7	flora, wetlands, bird fauna	dead channels, gallery forests
4	93	377	157	invertebrate fauna	catchment of Balaton, reservoirs along the Boronka Creek
5	103	341	141	loess formations, drift areas, fauna, flora	riverbed of the ancient Sárvíz
6	83	205	77	bird fauna, flora	deep valleys, rocky canyons, varied microclimate
7	84	136	8	geological values, fauna, flora	Jakab Hill, Abaliget Cave, Zsongor Rock
8	77	133	7	red deer herd, fauna, flora	forests, Zselic Dark Sky Reserve
9	0.13	117	18	Europe's largest continuous daffodil field	Cemeteries and churches from the 14-15 century
10	1	160	1	bird fauna, forest reserves	creeks, wetlands, lakes and marsh lands
11	1.1	96	31	preserved Pleistocene Iris species	loess valleys
12	4.5	97	3	fauna	oak, ash and elm forests
13	4.3	133	7	fauna, flora	small forests, fields and pastures
14	0.5	151	10	bird fauna	oxbow lake
15	0.7	85	0	invertebrate fauna, bird fauna, flora	wetlands, dry sandy meadow
16	0.07	125	69	fauna, flora	loess high bluff
17	3.3	92	8	bird fauna, amphibians, flora	oxbow lake covered by reed and willow
18	1	261	177	flora	downy oak (<i>Quercus pubescens</i>) forest
19	1.5	90	5	bird fauna, flora	marshes, wetlands and groves
20	0.08	90	1	-	Mohács Memorial Site
21	0.9	305	77	exceptional flora	small dry forests and wetland forests
22	5	105	49	bird fauna	waterlands, small forests and marshes
23	0.6	122	5	bird fauna, woody flora	forests and marshes
24	0.01	183	66	flora	small pasture
25	2.5	102	2	flora, fauna	karstic forms, springs
26	2.3	252	260	flora, bird fauna	oak, ash, elm gallery woods, hornbeam and oak forests
27	0.1	137	78	geological values	ammonite and vertebrate fossils

table 1: List of the protected areas with the main morphometric parameters. Numbers in the ID column refer to figure 1.

occasionally spotted with wind-blown sand mounds (Lovász G., 1977). In the valleys of the connected tributary streams low-terrace plains and alluvial fans are also visible. Since the beginning of the Pleistocene, the area has been reshaped to a flat terrain of 90 to 200 m a.s.l. by the River Drava and its tributaries.

The Mecsek foothills and the Tolna and Szekszárd Hills to the north, are directly bordered by subsided alluvial basins, filled with Late Pleistocene and Holocene deposits that predetermined the north-south flow direction of the Danube. Due to the lateral erosion of the Danube, at the edge of the loess plateau with a mean thickness of 40 to 60 meters, high bluffs developed (Pécsi M., 1994). The rolling hills are separated from the Danube's floodplain with steep slopes that trigger active surface movements even today (Kovács I.P. et al., 2015). East of the Tolna Hills, in the area of the southern part of the Mezőföld, the ground surface is covered by wind-blown sand and loess deposits, and drops to the Sárvíz area and II/a terrace of the Danube on the east. The narrow, about 20-km wide alluvial floodplain of the Danube follows the river in a north-south direction.

Geohazards within the operational area of DDNP

Mass movements in the South Transdanubia

Among the most common geohazards in Hungary floods, mass movements, windstorm and soil erosion are considered the most frequently recurring and adverse phenomena within the operational area of DDNP.

One of the most common natural disasters in the study area belongs to the group of mass movements. They origin is rather complex while their magnitude is extremely varied within the administrative area of the DDNP. The most impacted areas include the steep

slopes and undermined areas of the Eastern and Western Mecsek Hills, the high bluffs of the Danube and the steep shoreline of the River Drava.

The most impacted area in the Western Mecsek Hills include the valley of the Orfű Stream. The sandy and clayey sediments of Miocene age (Chikán G. & Budai T., 2005) lean against the adjacent, carbonate-rich karst area, therefore the primary reason for the landslides here is the continuous water supply from the karst area. The landslides primarily appear as a carpet-like movement while the anthropogenic activities have transformed the foothills to a gently rolling surface (Lovász G., 1980).

A second typical location of landslides is found in the Eastern Mecsek (figure 1), where due to the intense uplift, slopes have become steeper and increasingly dissected by the gullies and valleys. Intense linear erosion destabilizes the slopes, therefore landslides frequently occur on the loose, Miocene, gravelly sediments (Szászvár formation, Görcs N.L., 2013). The mining of the Lower Jurassic coal seams began in the northern ranges of the Eastern Mecsek Hills. By the end of 19th century, mining was done with advanced methods, while surface open pit mines were commonly deepened (Zsámboki L., 1995). After the abandonment of the mines and the exploitation of the productive seams, shafts collapsed, filling rocks were compacted, and, as a consequence, intense subsidence of the ground surface was observed. With increasing distance from the undermined sites, cover layers are compressed, therefore, due to the shear stresses, significant movements and landslides occurred (Erdősi F., 1987). Several sinkholes of this type and associated landslides have been developed in the Eastern Mecsek over the past decades. In the light of projected restart of coal mining, additional and large number of newly developed mass movement phenomena is expected in the region (Görcs N.L., 2013).

Besides the low-mountain and hilly parts of SW Hungary, the floodplains of larger rivers are also impacted by various types of mass movement phenomena. The water regime (Kiss T. & Andrási G., 2011) and the stream bed morphology (Fluvius 2007) of the River Drava has been profoundly affected by the dams, jointly constructed with the adjacent countries. Due to the broadening of the river meanders, high bluffs are frequently eroded by landslides and collapses.

Due to the lateral meandering and erosion on the north-south directed part of the Danube, multiple high bluff banks have been formed (Karácsonyi S. & Scheuer G., 1972). These vertical walls often reach a height of 40 to 50 meters, and commonly consist of Miocene clay-rich layers, Pliocene red clay and buried soil layers of 10s of meters (Pécsi M. & Schweitzer F., 1995). The widely studied high bluffs of the Vár and Szent János Hills in Dunaszekcső are one of the most actively moving bank sections along the Danube (Bugya T. et al., 2011). The dissected, relocated sediment layers, formed over the past centuries, are found at several elevations between the current Danube bed and the high bluffs. Dunaszekcső entered to the media when a sediment block of about 1 million m³ was dissected from the high bluffs sinking a vertical distance of about 8 to 9 meters (Újvári G. et al., 2009). The landslide generated a new peninsula with a width of about 20 meters. The moving mechanism was identified earlier as rotational land slide, based on the monitored data, while lately they have been interpreted as complex land slide (lateral spreading). South of the 2008 disintegration profile, a formerly stable part of the high bluffs have been moving since 2011. The triggering

factors are complex, as the water level of the Danube, temperature fluctuations, precipitation, infiltration and oscillation of the groundwater table may influence the movement rates magnitude.

Riverine floods - source of the natural diversity, constant risk for inhabitants

The unique natural habitats along the Drava and Danube rivers are under national park and Natura 2000 protection. The diversity of flora and fauna in these ecological core zones could not exist without the annual floods covering large areas along the rivers. The extensive and coherent floodplain forests are maintained by keeping the balance between the natural process of flooding and the interests of the inhabitants.

As the second largest river of Europe the Danube gathers the water of 15 large water courses before reaching Southern Transdanubia. The topographic and climatic conditions over the watershed of these tributaries have a significant influence on the occurrence and duration of the floods. After the snowmelt in the alpine regions, early in the spring, comes the first flood. A dangerous variant of these floods happen when the melting already starts on the upper part of the watershed, directly causing flooding and the ice, still covering the downstream sections, builds-up and blocks the river (e.g. 1838, 1956). Normally the largest water levels are reached by the summer floods in the period of May-June, caused by the snowmelt in the highest mountain regions and heavy rains. A moderate flood occurs as a

photo 2: Head of the landslide on the top of the Loess Profile in Dunaszekcső (photo by Tamás Varga).

photo 3: Bird's eye view of the Dunaszekcső Castle Hill with recently sliding blocks (from the archive of DDNP).

result of the water transport from the tributaries at the Mediterranean region during the autumn (Lóczy D., 2010; Mészáros E. & Schweitzer F., 2002).

The duration of the floods on the Danube is relatively short, lasting for a week or two. In cases when the floods come in more waves, they amplify each other and cause catastrophic events.

During the flooding the width of the river can grow from the normal 500–600 meters to 4.5 kilometres under the confluence of the Sió, at the Gemenc forest. The nearly 9 meters of difference between the annual lowest and highest water level also confirms the significance of the floods in this region of the country (Pécsi M., 1968).

Below Paks (Central Hungary) the bed of the river moves away from the hills, forming the most uniform landscape in the region, the so-called Sárköz. The floodplain narrows at Bács, but widens up again near Mohács where the other floodplain forest, the Béda-Karapancsa region is located (Láng S., 1957; Leél-Óssy S., 1953).

For centuries the inhabitants of this region were able to benefit from these floods and the forests, living together with the river. They used the natural side-arms and backwater channels to fish and the floods were providing nutrient-rich sludge every year. This was the so-called 'fok' (cape) system (Andrásfalvy B., 1973). Due to the economic changes in the 19th century regulation works started on the river to extend the agricultural fields and reduce the flooded area. A long levee system is responsible to protect the area from the effects of floods, but due to the floodplain sediments and former channels inland water is still occurring in extensive regions of the Sárköz (Pataki J., 1954).

The Drava is the fourth largest and longest Danube tributary, gathering the water from the southern slopes of the Alps. On this river the spring flood also appears after the melting starts in the mountains. The summer flood is showing the same characteristics as in case of the Danube. The third flood in the autumn is more evident as the river is crossing Mediterranean areas (Lóczy D., 2010; Mészáros E. & Schweitzer F., 2002). Due to the more than 20 dams for the hydropower stations along the river in Austria, Slovenia and Croatia it has a daily water level change as well. Early in the morning and in the afternoon the water level rises, and lowers back during the day and night. This has an adverse effect on the ecology (Iványi I. & Lehmann A., 2002).

The floods of the river also cover a large portion of the Drava-plain. The highest risks of floods occur near Barcs, where the river is significantly meandering¹. The settlement network of the region is in connection with the floods – the villages are small and built upon the slightly elevated surfaces of the floodplain (Gyenizse P. & Ronczyk L., 2011).

Just like the Danube, Drava has been considerably regulated in the previous centuries. This was partly to protect the built environment and also for managing

the water for the hydropower stations. Recently the flood protection and nature conservation interventions on the rivers are improving. River restoration and rehabilitation started on both rivers, in the frame of international projects. This process is beneficial for preventing the ecological diversity of the floodplain forests and still reduces the uncontrolled flood events².

Flash floods

In Hungary, weather phenomena often cause disasters (hail storms, floods and mudflows) that subsequently generate considerable economic loss and may jeopardize human life. The most severe natural hazards in the country are associated with atmospheric convections and storms (Horváth Á., 2005). Intense upward convection triggers various weather phenomena ranging from small cumulus clouds to devastating supercells. Their devastation is further exacerbated by prediction challenges, as their magnitude and exact locality varies considerably in space (Gaume E. et al., 2009; Klug H. & Kmoch A., 2015). Convective processes develop rapidly and, with their associated features and consequences, may create tremendous damage and disastrous corollaries. Typical observed phenomena related to convective storms in hilly and mountainous regions are flash floods (Horváth E., 1999).

Flash floods represent a unique subtype of floods, where times of concentration are less than 6 hours. Flash floods typically last for a few hours, but in extreme cases even up to a day. Due to the topographical settings of SW Hungary and the DDNP, especially in the Mecsek Hills, flash floods are relatively frequent phenomena and have been reported several times over the past decades. However, their prediction is rather challenging, due to localized characteristics of torrential rainstorms both in time and space. Rainfall heterogeneity is further exacerbated by the mixed pattern of topography, land use, and soil types.

Rainfall is considered to be the primary triggering factor for flash floods, but certain environmental temporally-variable boundary conditions are also considered to be crucial. These environmental factors include canopy cover (land use) and antecedent soil moisture content (Cassardo C. et al., 2002; Smith J.A. et al., 2002; Le Lay M. & Saulnier G.M., 2007; Jessup S.M. & DeGaetano A.T., 2008). Spotty clear cuts in steep slopes in the vicinity of DDNP may also contribute to the increased partitioning of rainfall to surface runoff and the reduced infiltration and subsurface storage.

According to the data of the National Disaster Hazard Estimation Committee, the annual frequency of +50 mm daily precipitation totals reach 0.5 day in and around the Mecsek Hills, being a core area of DDNP with the highest flash flood risk potential (figure 2). Rainfall totals exceeding 100 mm per day have a return period of 100 days. Furthermore, due to the global climate change, annual rainfall totals decreased moderately, while the number rainy days per year diminished more significantly over the past century. Although, as a consequence of the

1. Nagy valószínűségű árvízveszély Magyarországon, térkép, 2014. https://www.vizugy.hu/uploads/csatolmanyok/96/mapa1_arviz_high.pdf

2. ICPDR Drava Declaration, 2008. <https://www.icpdr.org/main/publications/new-drava-declaration-signed>

photos 4: A. Levee near the Keselyűs Oxbow Lake, B. Information board near Nagypartos (Mohács), C. A rescued red deer calf, D. Road 55 and Railway 154 on the active floodplain near Baja. All pictures were taken during the flood of the Danube in June, 2013 (from archive of DDNP).

subsequent droughts of the 1970s and 1980s, the long term annual precipitation totals indicate a decreasing trend, annual rainfall totals increased by 16 to 25% since 1990, simultaneously with an increased annual variability.

Between 1900 and 1950, one fifth of the annual precipitation was provided by the top 1% of the most intense rainfall events, this ratio was doubled over the past 30 years. Formerly, large daily precipitations, exceeding 30 mm per day dominated the period of late spring and early summer. By today this period grew significantly longer, and rainfalls of over 30 mm in a day may occur throughout the year.

The majority of flash floods in SW Hungary occur between March and mid-October. Several flash flood-related catastrophes have been reported in the operational area of the DDNP and the adjacent areas over the past decades. Events of disastrous consequences were reported for example on June 27, 1987, several houses and part of the railroad were washed away in the Bükkösd Valley (Mecsek Mountains) when 71 to 88 mm rain fell during a 6-hour period (Gyenzse P. & Vass P., 1998). In the latter case, the largest economic losses were reported from Hetvehely, a village that is located just upstream from the confluence of the Bükkösd-víz and the

Sás Streams. The three aforementioned environmental factors trigger very rapidly increasing flood levels and extremely asymmetrical flow time series in the Mecsek Hills: for instance, in 1996, the rising limb of the hydrograph taken in Hetvehely lasted for a mere 6 minutes (!), while the falling limb lasted for 3–3.5 h (Vass P., 1997).

These environmental factors affect the time of concentration, and indirectly the prediction time lead. Prediction time lead, in turn, strongly influences

figure 2: Flood risk potential levels (1 is the lowest, 5 is the highest) in the operational area of the DDNP in the Mecsek Hills and its immediate vicinity (ed. by Szabolcs Czigány & Ervin Pirkhoffer).

photo 5: The gas station of Sásd flooded by the Baranya Canal during the heavy rains of the Zsófia Cyclone in mid-May, 2010 (photo by Szabolcs Czígány).

the general character of the flood mitigation efforts. To overcome the challenging prediction issues in unexplored and (quasi-) ungauged small watersheds, numeric rainfall-runoff models, physical geomodels and flumes may play a crucial role in predicting flash flood events with sufficient lead time for prevention (Georgakakos K.P., 1986; Ogden F.L. & Julien P.Y., 2002; Georgakakos K.P., 2002; Javier J.R.N. et al., 2007).

Nonetheless, we shall emphasize, that the coincidence of the above mentioned factors should contribute the generation of flash floods, while precautions preventions and appropriate communication to stakeholders are the most important tools to lessen flood-triggered losses in the park area.

Soil erosion in hilly landscape

Soil erosion is characteristic on sloped terrain, where no vegetation cover is found, therefore rainfall reaching the ground surface flows downhill unhindered (areal or sheet erosion), or flow is concentrated into distinct channels and moves in a linear manner, forming gullies (linear erosion). The latter is a typical process in intensively cultivated, tilled farmlands and vineyards. The process is further enhanced in places, where the soil forming parent material is loess, like in the Zselic, Eastern Somogy, Marcal Hills, Tolna Hills, Geresd Hills and the South Baranya Hills. Erosional processes are not only influenced by parent material, but also by soil texture and structure. The operational area of the DDNP is located on the wettest, south-western part of the Carpathian Basin and Hungary, with a mean

annual rainfall totals of 700 to 800 mm. In SW Hungary, annual rainfall pattern is characterized by late spring and early summer precipitation, with a pronounced secondary maximum in fall due to the Mediterranean low pressure systems. The first wet period temporally coincides with the non-vegetated, sparsely crop covered periods on farmlands, leaving the soil surface unprotected against erosion. With subsequent rainfall events and erosion processes, the pre-existing gullies are further deepened, excavating groundwater aquifers, forming tortuous gully systems with a depth of several meters. The uphill elongation of the gullies may also reach and impact non-tilled or protected lands. However, the newly excavated profiles shed light on the geological, geomorphological evolutions of the area. Erosional processes in the area are most characteristic in the Tolna Hills (Ádám L. 1964, 1967, 1969; Hervai A. et al., 2008). Surface runoff may trigger catastrophic flash floods in the downstream part of the watershed. Such events of disastrous consequences has been observed with an increasing frequency lately (Pécs, Szekszárd, Szekszárd-Sötétvölgy and Nagykónyi) (Czígány S. et al., 2010, 2011; Fábíán S.Á. et al., 2009).

In some places, due to wind erosion, drought may also trigger erosional processes in the study area. In places, where non-vegetated surface dries out due to the lack of soil moisture, and due to high wind velocities and wind storms, soil particles are carried away, typically in South Mezőföld, Western Somogy and on the alluvial plain of the Drava. Wind also erodes the surface in vegetated, grassland covered and protected areas, like the nature preserve in the South

Mezőföld, Paks Gopher Field, and the juniper (*Juniperus communis*) forest in Barcs. Often, the consequences of wind erosion are exacerbated by anthropogenic practices, while natural processes play only a secondary role, however, fortunately, the impact of wind erosion is usually localized and do not extend to extensive areas. Erosion is also archetypal in the steep slopes of the Mecsek Mountains and the Villány Hills. Even though the two protected areas in the Mecsek are entirely covered by forests, erosion is still a dominant process there as the area has a topography of strong relief. Here, in the track of the hiking trails, following high intensity rainfall events, gully erosion is a prevailing process. Since in forestry clear cutting is still dominant, steep slopes remain unprotected against erosion, and fertile topsoils are easily washed away after heavy precipitation.

	Floods		Surface movements		Erosion	
	Riverine floods	Flash floods	Landslides, rock falls	Landforms caused by mining	Water	Wind
<i>Gemenc</i>	X					
<i>Béda-Karapancsa</i>	X					
<i>Drava Plain</i>	X	X	X			
<i>Eastern Mecsek</i>		X	X	X	X	
<i>Western Mecsek</i>		X	X	X	X	
<i>Zselic</i>		X	X		X	
<i>Boronka area</i>					X	X
<i>Southern Mezőföld</i>		X	X		X	X
<i>Basa Garden of Babócsa</i>		X			X	
<i>Lake Baláta</i>						X
<i>Bölcske Iris Field</i>			X		X	
<i>Bükkhát Forest Reserve</i>						
<i>Wooded pasture of Csokonyavisonta</i>						
<i>Csombárd Meadow</i>						X
<i>Dávod Földvár Lake</i>	X					
<i>Dunaszekeső Loess Profile</i>	X		X		X	
<i>Dunaszentgyörgy Marsh-forest</i>	X					
<i>Fekete Hill</i>			X		X	
<i>Lake Kapszeg</i>	X					
<i>Mohács Historical Monument</i>						
<i>Nagy-field, Arany-hill</i>		X	X		X	
<i>Pacsmag Lakes</i>	X					
<i>Rinyaszentkirály Woods</i>		X				
<i>Szakadát Pasture</i>					X	
<i>Szentegát woods</i>		X				
<i>Szársomlyó</i>			X			
<i>Villány Templom Hill</i>			X			

table 2: Hazard matrix of the DDNP protected areas. Gray background indicates missing significant hazard.

Conclusion

In the current paper we verified the presence, reappearance and impact of geohazards in the DDNP. In accordance with the conclusions of Lóczy D. (2013), the majority of the geohazards are caused by large riverine floods, flash floods, mass movements and soil erosion in the study area. Similarly to other large national parks, predominantly located in floodplains and low elevation river terraces, water is the most dominant factor in the DDNP. The preliminary causative of vulnerability in the DDNP is its rugged topography, and the existence of both alluvial floodplains and areas of high relief. Therefore, owing to the extreme weather of the past few years, large floods are not only expected along the large rivers of the area, but also in small catchments, commonly in foothill positions and the bottom hill slopes. In parallel with the increasing amount of daily rainfall totals (in terms of rainy days per year) an increasing soil erosion risk is expected in the near future. According to the results of the Universal Soil Loss Equation (USLE) calculations, annual soil loss may reach 25 to 30 per hectare in the hilly parts of the DDNP.

In certain areas, where relief exceeds 100 m/km² soil loss rate may reach as much as 50 t/ha/year (**table 2**). From the viewpoint of natural protection, the studied natural hazards are considered natural geoprocesses rather than harmful events, and reflected as positive and beneficial phenomena for the preserved areas in long time scales.

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photo 6: Gully erosion near Boronka Region after a heavy rainfall in March, 2004 (photo by Gábor Varga).

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