NATURAL HAZARDS

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A basic condition of human life is coexistence with the physical environment, which serves the meeting of human demands. Therefore, nature – together with its changes – represents a value for mankind. However, if the changes cross a certain threshold, this may be observed as a danger. Due to the diversity of natural phenomena, the related hazards are also multifaceted. Table 1 informs about natural hazards grouped according to the geosphere of their origin.

Some of the natural hazards – e.g. volcanism, seismicity inducing tsunamis or tropical cyclones – fortunately do not occur in the Carpathian Basin, while others – e.g. tornadoes – are very rare. There are also, however, hazards – e.g. floods, droughts, erosional processes –, which are of utmost importance. In addition, we have to reckon with numerous hazards which are not frequent everyday threats or of smaller scale but may cause significant damage, such as earthquakes, mass movements, extreme weather phenomena and others. This chapter in the Atlas provides an overview of the major types of hazard affecting Hungary on the basis of the most comprehensive database collected in a whole range of disciplines.

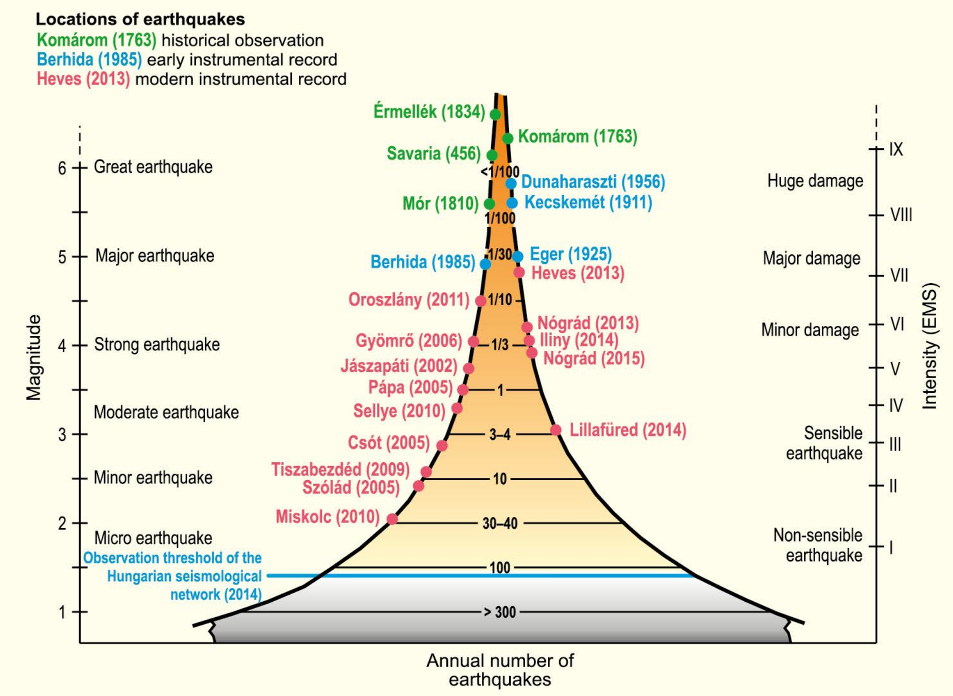
To an increasing extent and frequency, it is human activities which are responsible for natural disasters. Disasters can be either induced by natural processes and accelerated by human impact or induced by human action and then driven by natural laws. A common characteristic is that humans often generate catastrophes involuntarily but, in most of the cases, they are unable to stop breakaway processes. The operation of human society also involves other kinds of dangerous events (such as fires, explosions, radioactive emissions, etc.) which often lead to disasters. An overview of them is found in the chapter of the Atlas on *Economy*.

1 AN OVERVIEW OF THE SYSTEM OF NATURAL HAZARDS AND DISASTERS

By place of origin	By driving factor		Major types
Lithosphere	Endogenous forces	Direct	**Earthquake**
			Volcanic eruption
		Indirect (through water)	Seismic sea wave (tsunami)
	Exogenous forces		**Rockfall**
			Landslide
			Rock and debris avalanche
			Debris and mudflow
			Ground subsidence
			Soil compaction
Atmosphere	*Direct* impact of air		Tropical cyclone
			Tornado
			Wind erosion (deflation, dust storm, sandblasting)
			Soil erosion
			Thunderbolt
			Wildfire
	Indirect impact of air (through water)		**Cloudburst**
			Snow storm
			Hail
			Sea level rise
Hydrosphere	*Direct* impact (on the surface, due to the mass of water)		***Flood, excess water***
			Soil erosion
			Snow avalanche
			Coastal ice
			Iceberg
	Indirect impact through air		***Drought***
			Wave action
Biosphere	*Direct* surface impact of biota		***Spreading of invasive species***
	Indirect surface impact of biota		***Pollen allergy***

The absence or presence and significance of disaster types in Hungary is indicated by the typeface of letters: normal letters = no hazard in Hungary, **bold letters** = occurring in Hungary, ***bold italic letters*** = hazard type of outstanding importance in Hungary

2 NUMBER OF EARTHQUAKES ANNUALLY OCCURRING IN HUNGARY AND MAJOR EARTHQUAKES IN HISTORY



Natural hazards associated with the lithosphere

The Earth's surface is permanently changing. The reasons of alterations taking place at different rates in space and time are, in large part, the processes of the Earth's interior, collectively called the endogenous forces. The most destructive among them are earthquakes, seismic sea waves (partly induced by them) and volcanic eruptions.

Earthquakes

In Hungary, earthquakes represent the most significant danger among natural hazards 1 caused by internal forces. The causes of earthquakes are described in detail in the *Geophysics* chapter of the Atlas. A large part of the earthquakes on the Earth surface explodes along plate boundaries, which are not lines, but often deformation zones with hundreds of miles of width. The structure and tectonic deformation of the Carpathian Basin and the southern part of Europe is governed by the collision of the African and Eurasian plates 1.

Overall, seismicity in the Carpathian Basin is moderate, where smaller earthquakes occur regularly, but fortunately, large earthquakes that cause really great damage are rare. The location of earthquake zones and the frequency of the quakes occurred there are shown on map 8 in the section on *Geophysics* of our Atlas. Over the past one and a half millennia, we know about thirty thousand earthquakes in the area, many of them are identified from historical records. The first known earthquake occurred on 7 September 456 in Savaria, near today's Szombathely. Based on the descriptions, the magnitude of the earthquake was approximately 6.1 (the explanation of magnitude and intensity is also found in the geophysical chapter of our atlas). Not all historical earthquakes can be accurately located, but there are some areas inside the basin where several major earthquakes have occurred. During the 6.3-magnitude Komárom earthquake of 28 June 1763, a third of the city was destroyed, 63 were killed, and more than 120 were wounded. Probably, this was one of the largest earthquakes in today's Hungary. In the nineteenth century, the Mór (1810) 1, the Érmellék (1834) and the Jászberény (1868) earthquakes were notable. In the 20th century, five major earthquakes were recorded in the territory of today's Hungary, which caused significant damage: Kecskemét (1908 and 1911), Eger (1925), Dunaharaszti (1956) and Berhida (1985) 2.

Examining Hungary's earthquake hazard, it must first be stated that earthquake prediction is not possible. It cannot be predicted with correct precision when a fracture will occur in the inhomogeneous Earth's crust, due to the slow (a few or a few tens of mm/year) stress accumulation for several decades. However, it is possible to calculate the probability of expected shaking in a given area over a given period of time. Thus, the damage and loss caused by future earthquakes can be reduced by preliminary preparation. As the most important task of the preparation, it is necessary to design and build structures in earthquake prone areas so that they can withstand earthquakes without major damage.

100–120 smaller magnitude earthquakes are detected every year in Hungary by the sensitive seismograph network, but most of these earthquakes do not reach the limit of perceptibility. On average, there are four to five 2.5–3 magnitude earthquakes, which can be felt well around the epicentre, but which do not cause any damage. Larger magnitude earthquakes of 6.0–6.5 are also possible, but not common 2. In the whole of the Pannonian Basin, major damage is caused in every 15–20 years, while strong, devastating earthquakes occur in every 40–50 years.

The effects and damage caused by earthquakes can be expressed by earthquake intensity. The European Macroseismic Scale (EMS) 7 describes earthquake effects by a 12-grade scale 3. Seismic hazard represents the future earthquakes in a given area. The value of the expected hazard can be defined in a seismic zone map either by earthquake intensity or by ground acceleration generated by earthquakes expressed as a fraction of gravity acceleration (*g*) 4. The value of the hazard depends to a great extent on the chosen probability of exceeding or the annual frequency.

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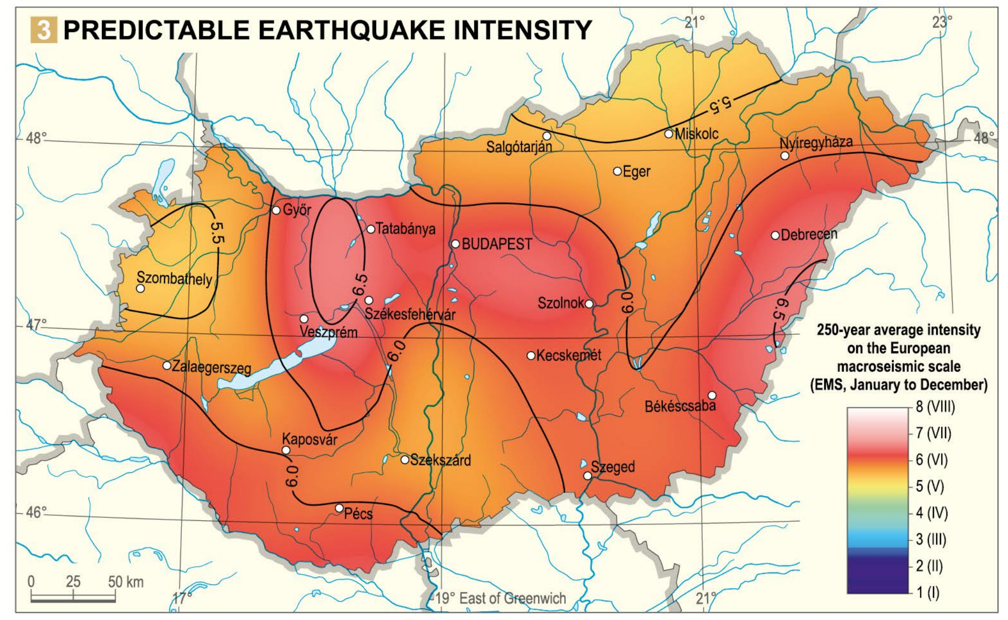
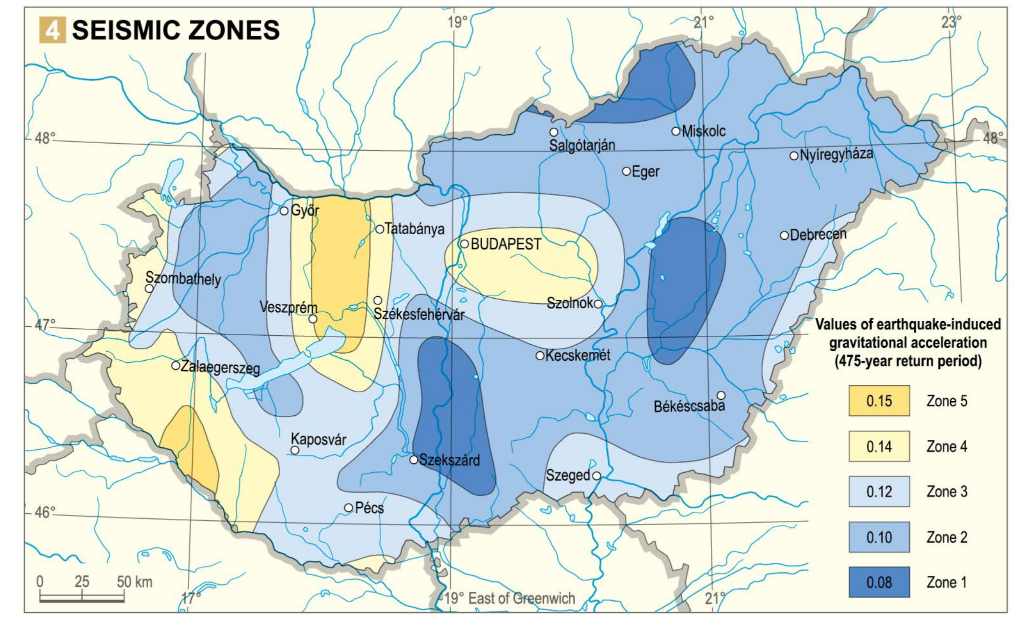
3 PREDICTABLE EARTHQUAKE INTENSITY



4 SEISMIC ZONES



Mass movements

Displacements of masses on the surface directly driven by gravity (without a medium of transport) are called mass movements. A necessary condition to their generation is a sloping surface. Therefore, the majority of mass movements occur in hills and mountains.

Mass movements come about if shear stress in the slope material exceeds shear strength. Mass movements are diverse in nature, have different mechanisms and, consequently, cause disasters in a variety of ways. Among the types of hazard the most rapid are *collapses*, which develop on steep slopes of rigid rocks and involve the vertical downward movement of large rock masses (by free fall along such sections). During *landslides* in a broad sense part of the slope material is detached along a well-expressed slip plane and glides or slides downslope. If water content in the slope material highly increases, part of the mass loses its stability and flows downslope *(rock and debris avalanches, debris and mudflows)*. In Hungary all the three types can be observed. They are often so intertwined that it is difficult to identify the main mechanism of the movement. Mass movements are rather interrupted than continuous processes in space and time. Although their possible places of occurrence are relatively easy to delineate 6, the particular sites and dates of movement cannot be predicted precisely.

Among mass movements, landslides are the most common and most destructive in Hungary. An overview of landslides and their types associated with the individual geographical landscapes is found in Table 5. Concentrated in relatively small areas, the largest landslides, dependent on numerous topographic, geological and climatic conditions, primarily occur in the zone of steep rock walls and escarpments as well as on high bluffs along rivers and lakes (along the Danube 1, Hernád 7 2, Rába, Dráva Rivers and next to Lakes Balaton 3 and Fertő).

5 MASS MOVEMENT (CHIEFLY LANDSLIDE) HAZARDS IN HUNGARY

Landscape type	Regions where landslides are typical			Landslides				
	geology (rock and structure)		locality	slip plane		morphological position	landform	activity (degree of hazard)
				typical material	position			
Hills	Oligocene Kiscell Clay, Buda Marl, usually covered with loess or travertine		around Budapest	Kiscell Clay, Buda Marl	Of highly variable depth	Terrace edges, quarry walls	Slump, layered slide (also flow)	Mostly to human impact
	Lower to Middle Miocene schlier (occasionally with volcanic cover)		Medves–Vajdavár Region, Mecsekhát	Clay layers in schlier, locally sand	At depth, but above base level	Valley slope, tectonic line	Layered slide with large heap	Low, declining (human-induced)
	Pannonian clay, sand	Covered with loess	Tolna Hills, Zselic, Outer Somogy	Surfaces of Pannonian layers, loam horizons in loess	At depth, close to base level	Landscape margins, valley slopes	Layered slide with large heap, carpet-like slide, creep	Low, moderate, many fossil features, recent fields with higher activity
		Covered with loam	Vasi-Hegyhát	In loam, below the root zone	Close to surface, above base level	Valley slopes		
		Loess-free	Cserehát, Sajó–Bódva Midland	Surface of Pannonian layers and sequence				
High bluffs	Pannonian clay, sand	Covered with thick loess	Along the Danube 1	Pannonian surface, loam zone in loess	At depth, often close to base level	Along riverbank edges	Sliced slide	Many are recent and active
		Variable cover	Lake Balaton 3	Surface of Pannonian layers			Sliced layer slide and layer slide with large heap	Major activity and hazard
		Pliocene–Pleistocene gravelly-sandy cover	Along the Rába River				Layered slide with large heap	Recent, few are active
		Covered with thin loess, uncovered	Lake Fertő, Hernád River 7 2	Pannonian layers	At depth, variable		Layered slide with large heap, many collapses	Locally outstanding activity
Mountains of volcanic origin	Badenian and Sarmatian acidic and neutral volcanites	Typical stratovolcanic structure	Visegrád, Börzsöny, Cserhát, Mátra, Tokaj (Zemplén) Mountains	Mostly loose layers below volcanites or weathered tuff horizons	Deep, close to base	Mountain and caldera margins, tectonic lines, valley slopes	Mountain slide and slides with large blocks	Overwhelmingly fossil, few are recent, exceptionally active
	Upper Pannonian basalts		Tapolca Basin, Medves			Mountain margins		

1 *Recent landslides on the high bluff of the Danube at Dunaszekcső*

2 *Recent roadcut slide in the Hernád Valley, near Gibárt (2013)*

3 *High bluff at Balatonföldvár*

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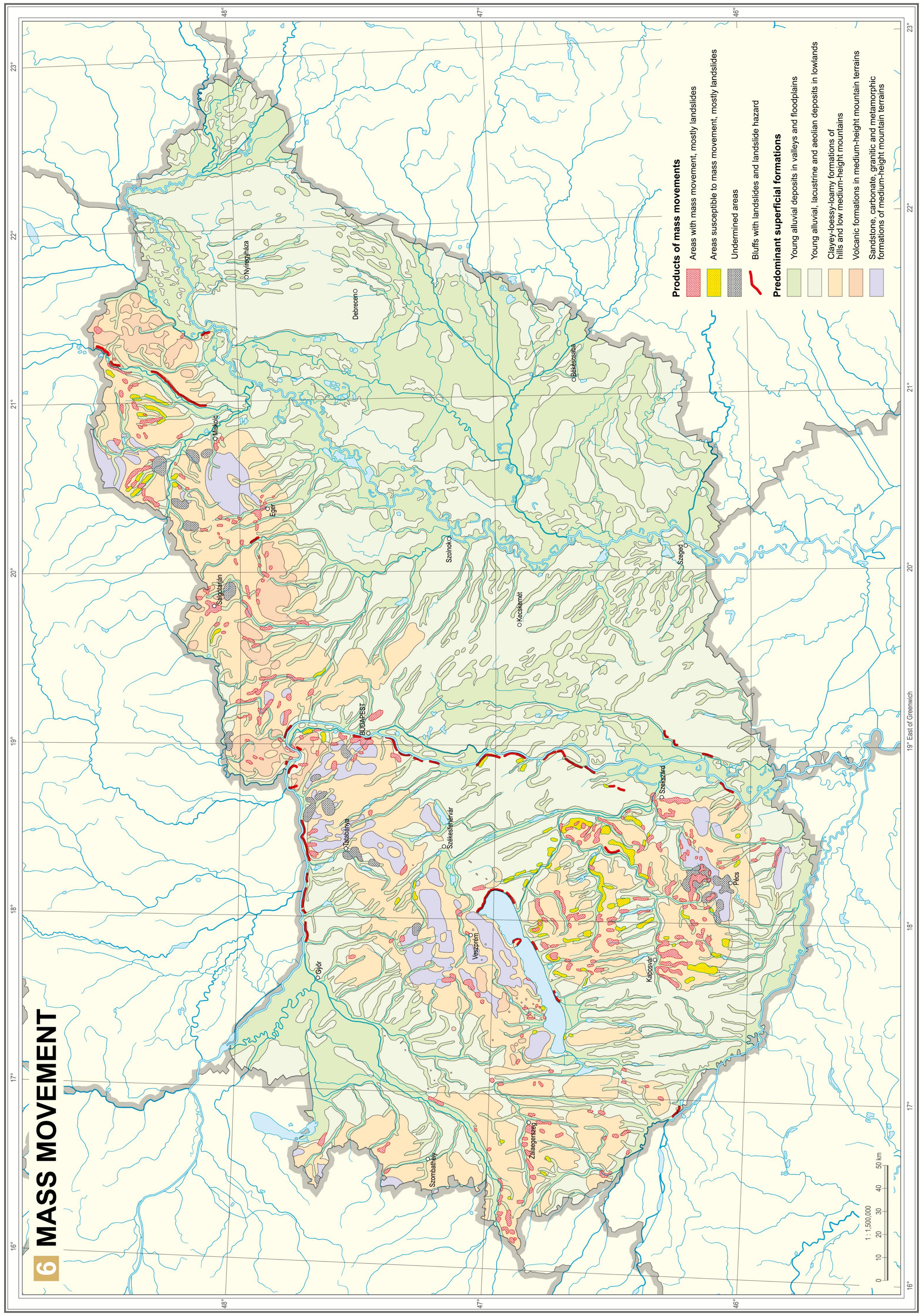
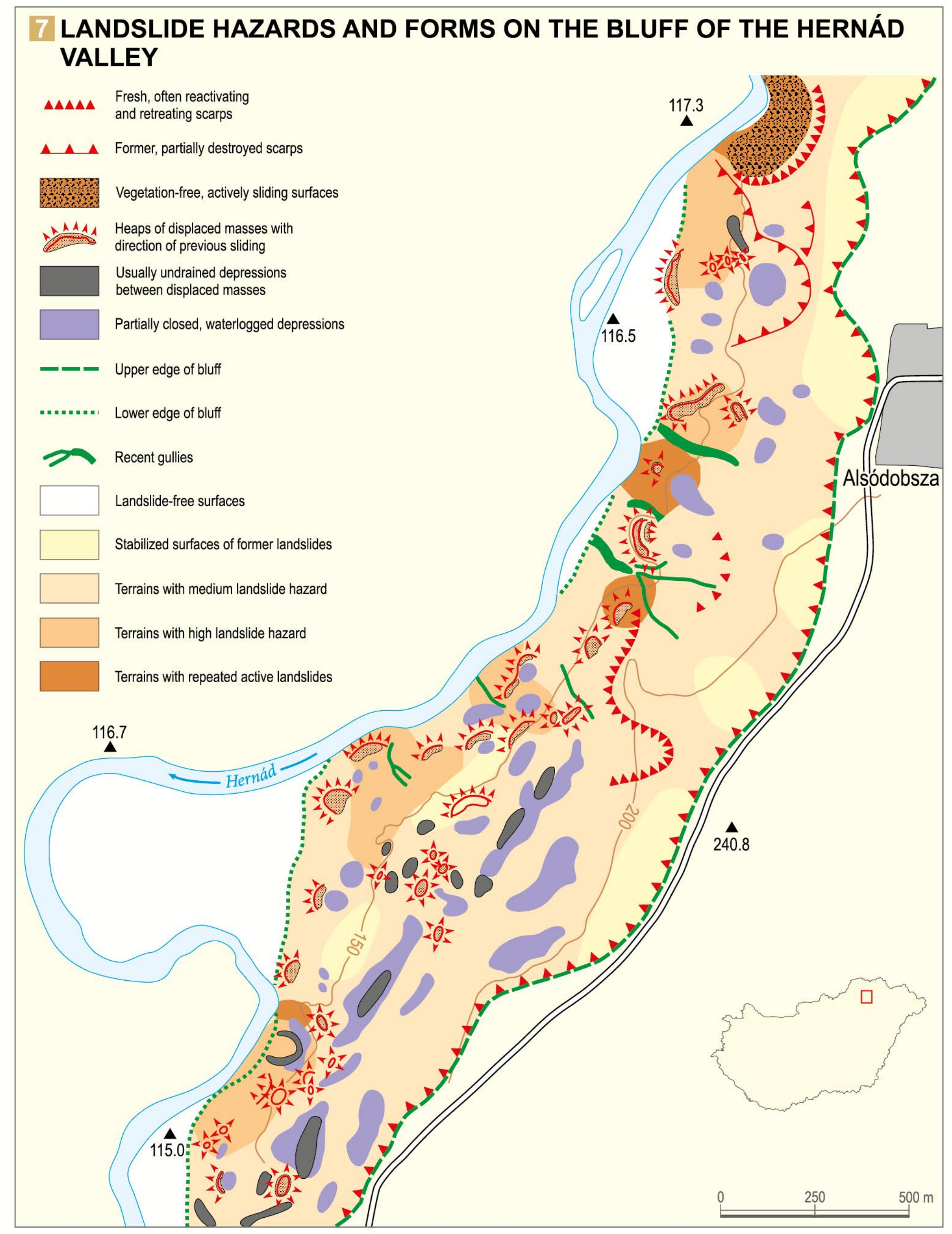
6 MASS MOVEMENT



7 LANDSLIDE HAZARDS AND FORMS ON THE BLUFF OF THE HERNÁD VALLEY



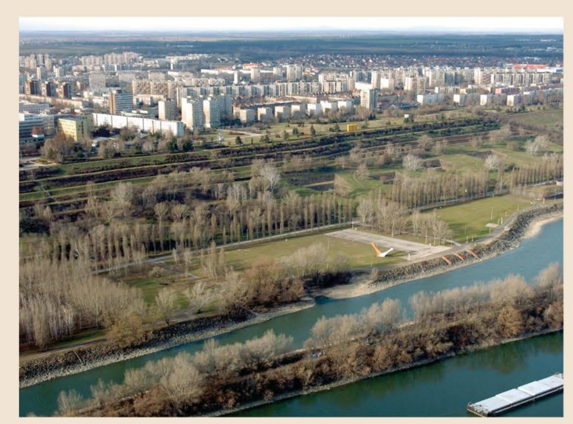
Danubian high bluffs with landslide hazard between Érd and Mohács

South of Budapest, above the western edge of the Danube floodplain, rises a bluff, 20–50 m high and, with interruptions, 180–200 km long, where collapses and landslides are common. During the Holocene the lateral erosion of the Danube has repeatedly undercut and destroyed the eastern margin of the Mezőföld and Baranya loess areas.

Along the high bluffs of the Danube near-surface movements have occurred since millennia. Conclusions on landslides can also be drawn from fossil landforms and from the extension of historical settlements. Thus, most of the numerous small islands attached to the foot of bluffs are remnants of large-scale landslides destroyed by the erosion of the Danube. On the other hand, only a smaller portion of the Roman camps – about one half of the castrum of Intercisa – can still be seen, the rest has fallen victim to landslides. Judging from the groundplan, the edges of camps of the Roman period retreat at rates of 5–7 m per hundred years towards the west.

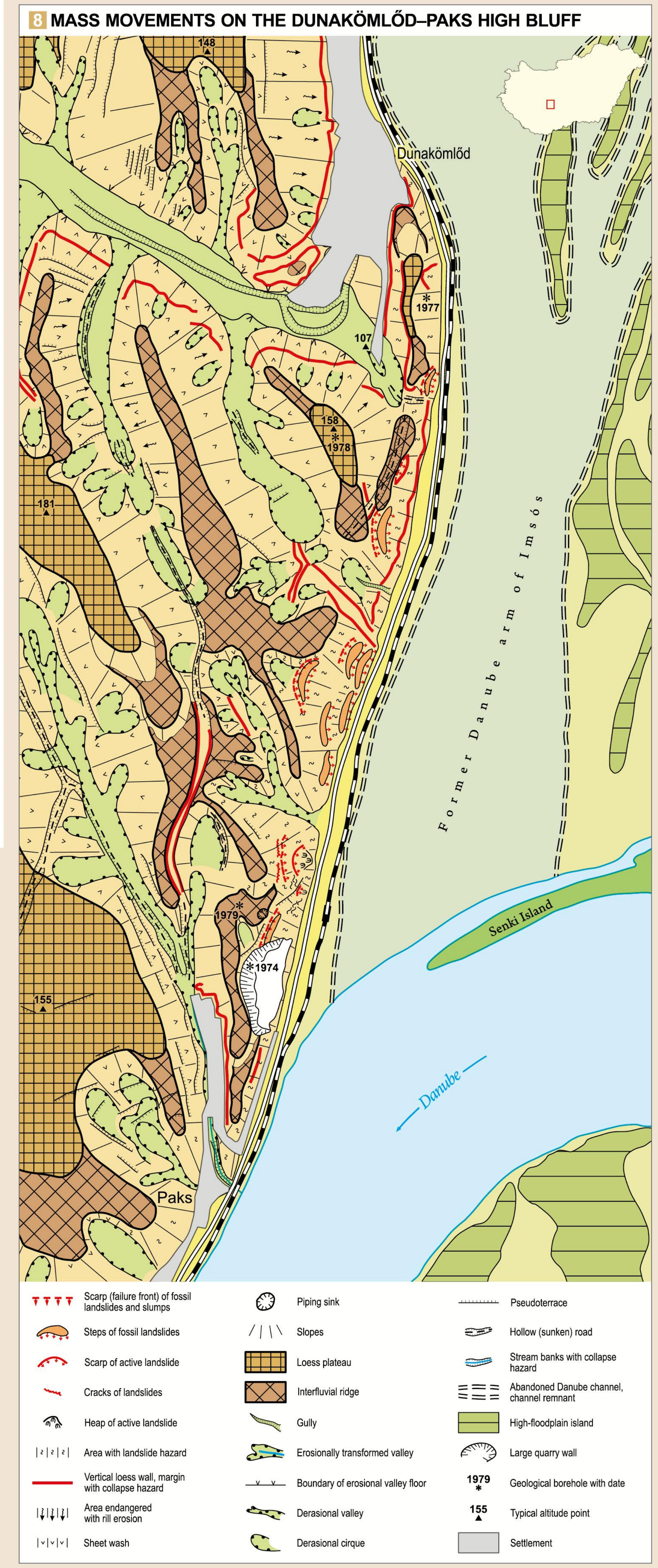
Landslides are influenced by both geological-geomorphological and hydrogeological conditions. The cyclical recurrence of landsliding is caused by the lateral erosion of the Danube and the 8–10 m fluctuation of its water level. The geological-petrological build-up promotes the formation of excellent slip planes in the 30–50-m-thick Quaternary terrestrial sediment sequence – mostly loess – overlying Pannonian clays and clayey sands deposited in an inland sea. The loess series is wetted by infiltrating waters and partly loses its stability.

On the right bank of the Danube, from Érd to Bár, six distinct bluff sections with landslide hazard can be identified. In recent decades, the most destructive landslides affected the 20–25-km-long Kulcs–Dunaújváros bluff section. The edge of the bluff rises at about 200–300 m distance from the Danube channel, while the zone in between is occupied by slide heaps. The town of Rácalmás itself, where movements frequently damage buildings seriously, is built on a slid mass, which is temporarily settled. At Dunaújváros, along the urban bank section, after a landslide which caused huge damage in 1964–1965, so successful bank protection was implemented along 5 km length 4 that no bank movement has been observed ever since. Another highly active bluff rises between Dunaföldvár and Bölcske, where the lateral erosion of the Danube attacks an island detached from the Mezőföld. In 1970–1972 an extensive sliced landslide occurred here at 200–300 m length, heavily transformed the Danube channel, too, and created an island. As a consequence, navigation had to be restricted. Also endangered is the Paks–Dunakömlőd section of the high bluff, where the bend of the river was diverted into an artificial channel in 1854, but along the subvertical, 30–50 m high bank landslides still occur 8. In the foreground of the bluff the heaps of old landslides, partly destroyed by the Danube, can be detected.



4 *Terraced revetments along the Dunaújváros bluff of the Danube*

8 MASS MOVEMENTS ON THE DUNAKÖMLŐD–PAKS HIGH BLUFF



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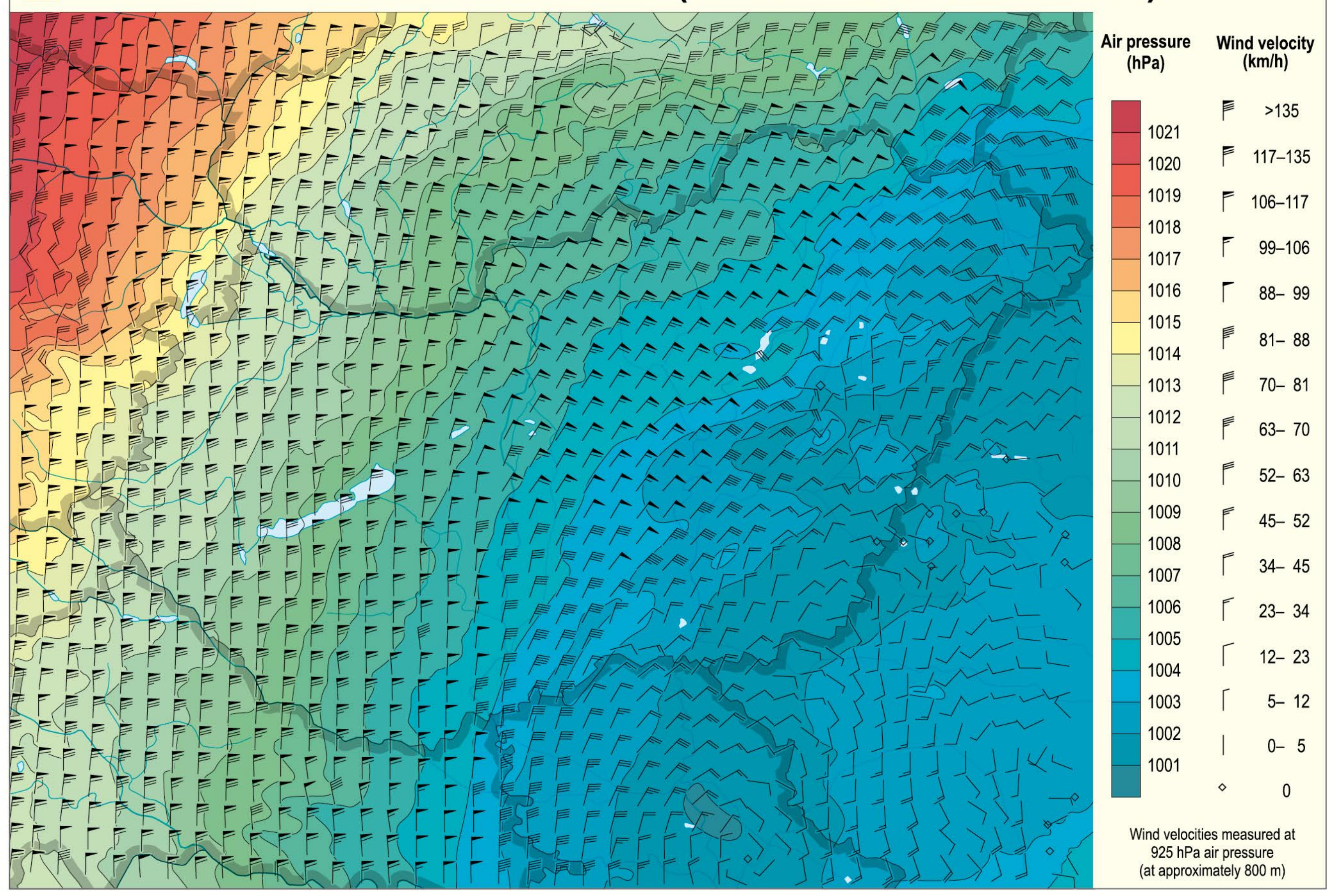
9 AIR PRESSURE AND WIND FIELD (AT 19:00 ON 15 MAY 2014)



5 *Supercell above Lake Balaton*

Atmospheric natural hazards

The atmosphere of the Earth is changing continuously and sometimes very fast. Because of a sudden, rapid change in the physical state of the atmosphere (e.g. alteration in the temperature, air pressure or water vapour content), the movement of the air masses can fasten, and though devastating tropical–subtropical vortices like hurricanes and typhoons do not affect Hungary, movement of cyclones, meeting of air masses with different temperature, rapid condensation of water vapour all can produce extreme weather situations occurring as a natural hazard. In general, weather hazards occur suddenly, pass off relatively fast, affect small areas and destroy in limited extent in most cases, fortunately. At the same time, heavy rainfalls or persistent lack of precipitation can create dangerous situations, even if wildfires are associated to them.

Extreme weather events

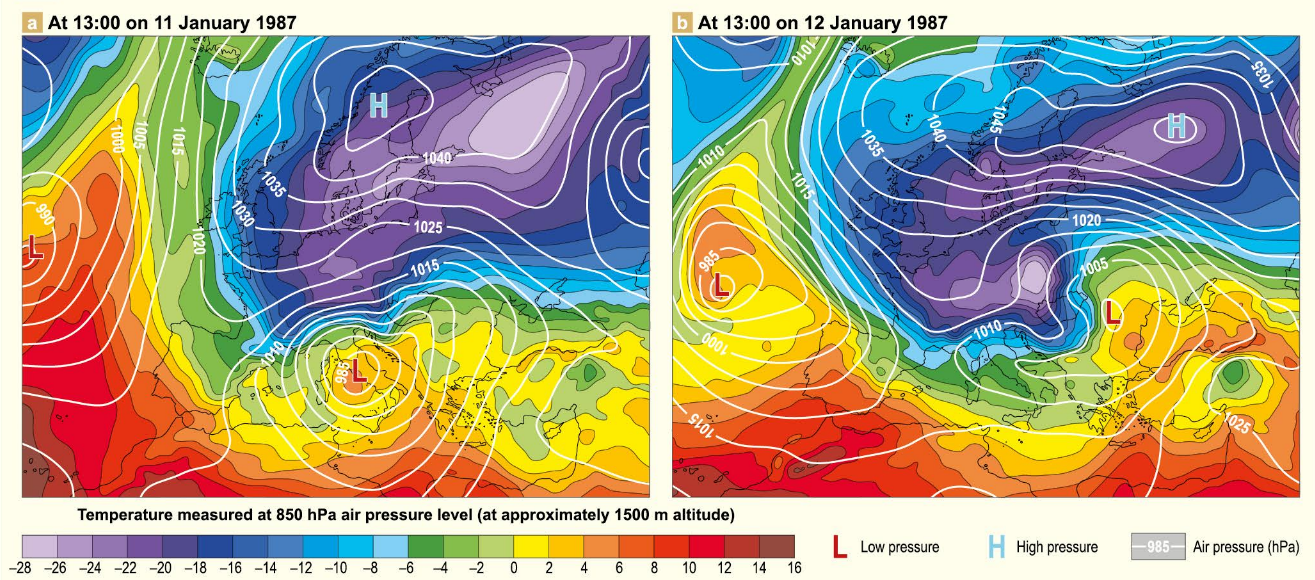
In Hungary, well-known extreme weather events are the sudden windstorms pouncing on Lake Balaton. Generally two weather phenomena can cause these storms: northerly winds formed on the rear side of a cyclone drifting above the region or much smaller thunderstorms. The current system of these cyclones can cause wind gusts with 100–120 km/h speed for hours, mainly on the southern shore of Lake Balaton resulting in high waves and water level rise. Such a storm rampaged on 15 May 2014, when even 130 km/h wind gusts were observed at the lake caused by a large air pressure difference 9 created above Transdanubia.

Thunderstorms, which are much smaller than cyclones, can cause intense storms also, mainly if they appear in a well-ordered way as squall lines. The speed of fast moving cells of the most dangerous squall lines – added to the speed of the runway gust – often exceeds 100 km/h. In certain atmospheric conditions the thunderstorm cells start to rotate causing very intense inner updrafts. Sometimes even a tornado can be associated with the very intense, rotating thunderstorms called supercells 5.

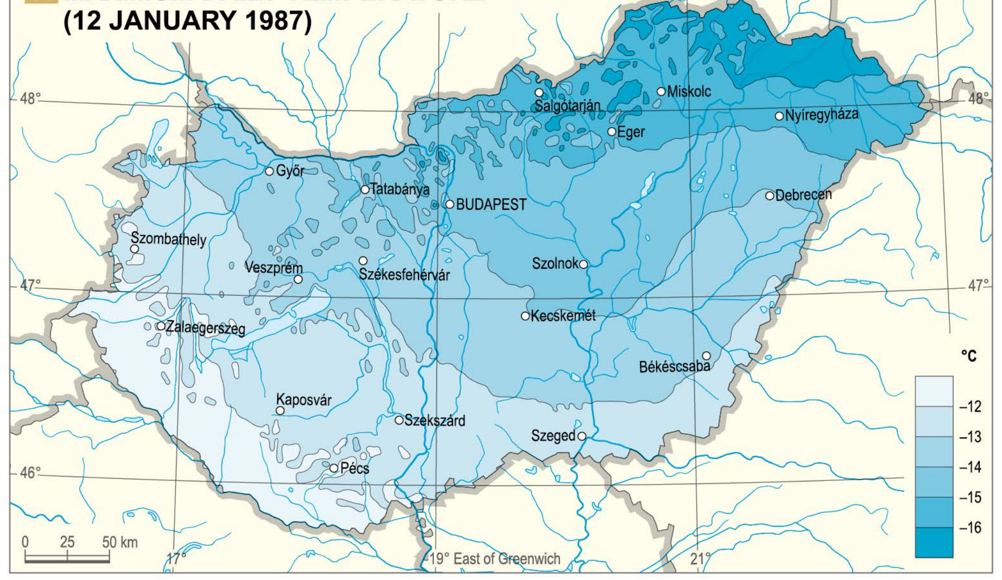
Extreme cold and warm periods are equally dangerous for the society and people. An extreme cold winter weather situation emerged on 10 January 1987, when a strong Mediterranean cyclone 10 reached our region from southwest. After a continuous, two-day-long snowing, extremely cold air masses accompanied by stormy north–northwesterly winds poured into the Carpathian Basin in the morning of the 12th of January. The daily maximum temperature stayed below −10 °C 11. Due to the big amount of snow 12, strong snowdrifts and cold temperature records, this was the most severe winter weather event in the 20th century in Hungary.

Extreme rainfalls can cause floods (floods are examined in detail in the next section). For example, due to the large amount of precipitation fallen between the 30 May and 3 June 2013 in the Alps, a record setting water level appeared on the whole Hungarian section of the Danube. On 10 June 2013, the water level peaked at 891 cm at Budapest, which was 31 cm higher than the former record 6. This extraordinary precipitation 13 was caused by a cyclone moving from south to north, in which the distribution of the moisture and the flow conditions near the ground were in the best conjunction above the Alps 14 to form persistent rainfalls with large amount of precipitation. The direction of the flow and the backward bending of the warm, wet air was meridional to the mountain ridge, thus strengthening its precipitation growing effect.

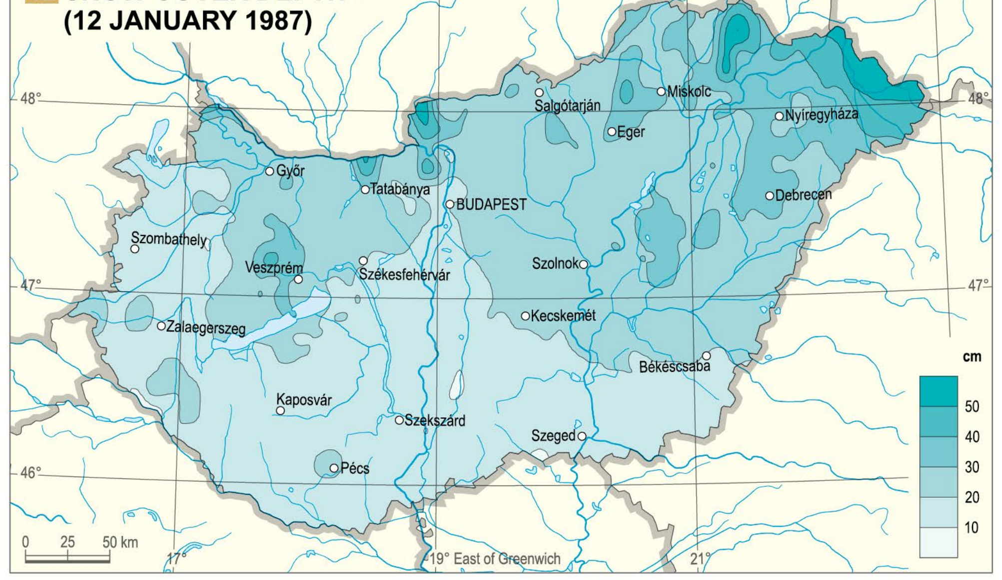
10 AIR PRESSURE AT SEA LEVEL AND TEMPERATURE



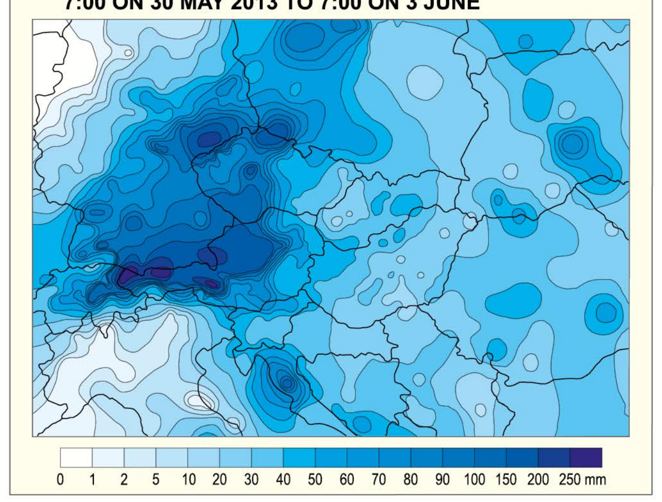
11 MAXIMUM DAILY TEMPERATURE (12 JANUARY 1987)



12 SNOW COVER DEPTH (12 JANUARY 1987)

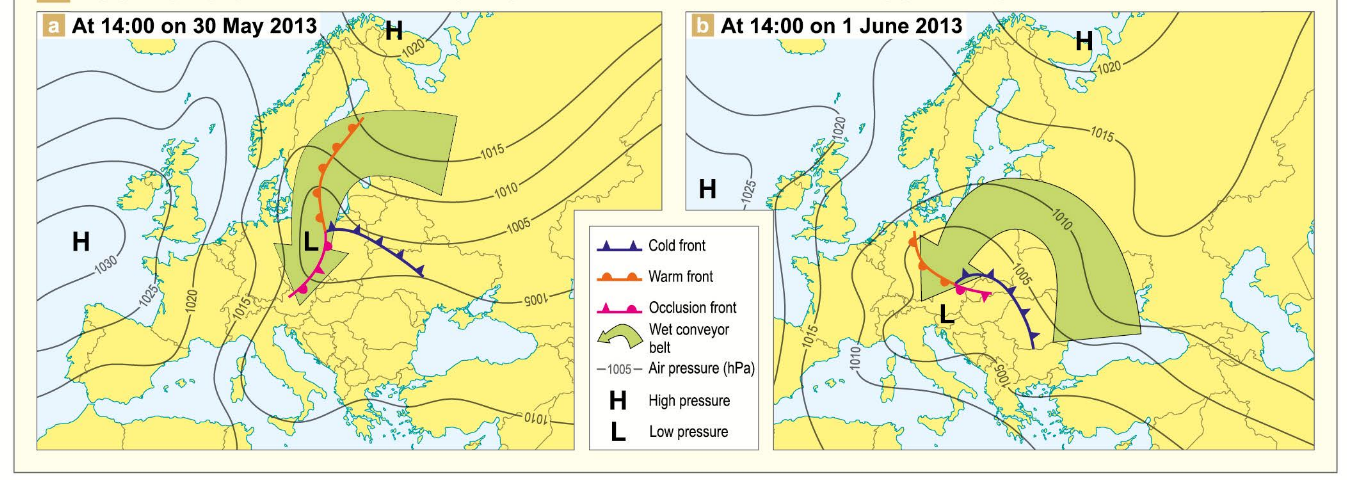


13 PRECIPITATION SUM IN CENTRAL EUROPE BETWEEN 7:00 ON 30 MAY 2013 TO 7:00 ON 3 JUNE



6 *Flood peak in Budapest, on 10 June 2013*

14 POSITIONS OF WEATHER FRONTS AND THE WARM AND WET CONVEYOR BELT



Drought

At first approach, drought means a significant lack of precipitation, this is meteorological drought. Furthermore, it means the lack of surface water and groundwater, this is hydrological drought. Agricultural drought occurs when the amount of soil moisture is insufficient for the plants' needs. Physiological drought happens when the water uptake of plants are prevented by low soil temperatures or other conditions. Moreover, the lack of water causes problems in almost all areas of society's life, damages human comfort and well-being, and makes life impossible at the very worst.

A characteristic feature of drought is that it extends to larger scale both in time and space. It develops slowly, a few months are needed to its formation. Estimating the damages caused by droughts is more difficult than in the case of other hazards, because consequences do not pass immediately after that the drought had ended. There have already been several drought catastrophes with great damages in the Carpathian Basin, and the observed global climate change – which is manifested in rising temperatures and higher variability in the amount and distribution of precipitation – significantly increases the risk of droughts.

The standardized precipitation index (SPI) is one of the most frequently used methods to characterise drought. The index is solely based on precipitation values, which is the number of standard deviations that observed cumulative precipitation deviates from the climatological average during a given – yearly or seasonal – period. Finally the index is categorised 15. It can be calculated for various time scales – mainly for 1, 3, 6 and 12 months – according to the length of drought.

For comparing the aridity of consecutive years, longer time periods are most practicable. Time series of the annual mean values of the 6-month SPI values 16 well indicates that although 2011 and 2000 were the driest years regarding the precipitation amount in Hungary since 1901 (see Section *Climate* 22), the most severe drought appeared in 2003. The drought devastated across Europe caused serious damages in Hungary as well, there were serious crop shortages, wildfires, shipping problems and the water level of Lake Balaton was extremely low.

In Hungary, the commonly used measure is the aridity index, which was worked out by Imre Pálfai (1989). The aridity index characterise the given agricultural year by a single number, which equally expresses evaporation (temperature) and precipitation conditions, taking into account the changing water demand of the plants and also regarding the soil water level. The calculated index is categorised. The countrywide averages of the aridity index range within wide limits, however, in the last years, the strength and frequency of droughts and thus the average value of the index have increased 17. The drought risk map 18, which was calculated using the long-time data series of the index, defines six categories indicating that the risk of drought catastrophes is extremely high in the central and southern – heart-shaped – parts of the Alföld. Drought damages can hardly be measured and quantified, yet causing damages which can be expressed in millions of forints. As a whole, it can be said of natural hazards in Hungary that the drought catastrophes cause the greatest financial losses.

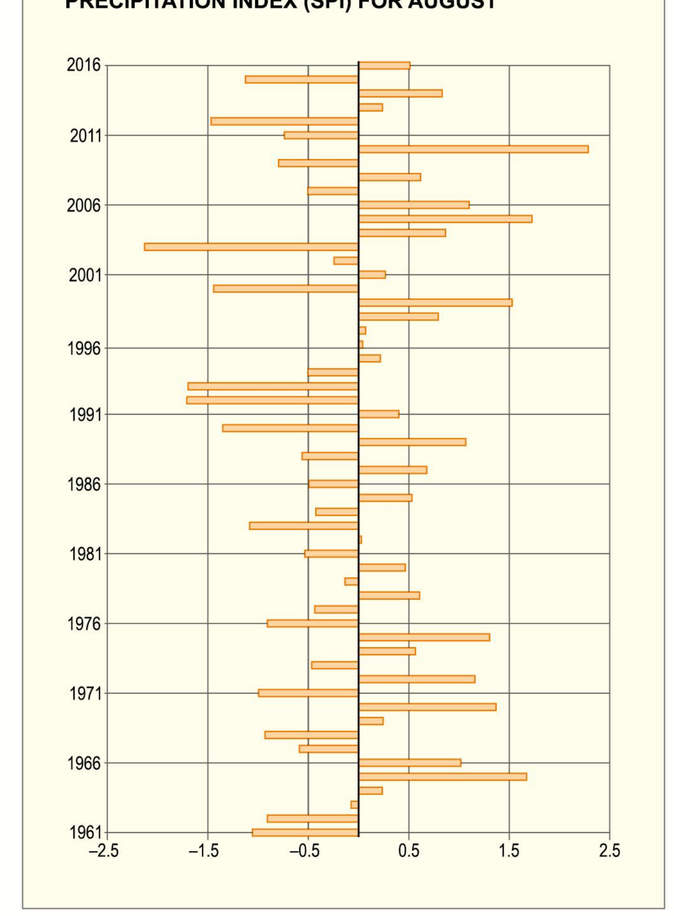
Wind erosion

Wind erosion occurs where there is no proper vegetation to protect the surface and wind energy is sufficient to dislocate rock and soil particles from the ground. In such areas various aeolian processes instantly begin to operate. In the areas prone to the geomorphic action of wind (deflation) the exposure of plant roots on the surface, while in the terrains of accumulation of material transported by wind it is the impact of sand grains (sandblasting) and the burial of plants that leads to the destruction of vegetation.

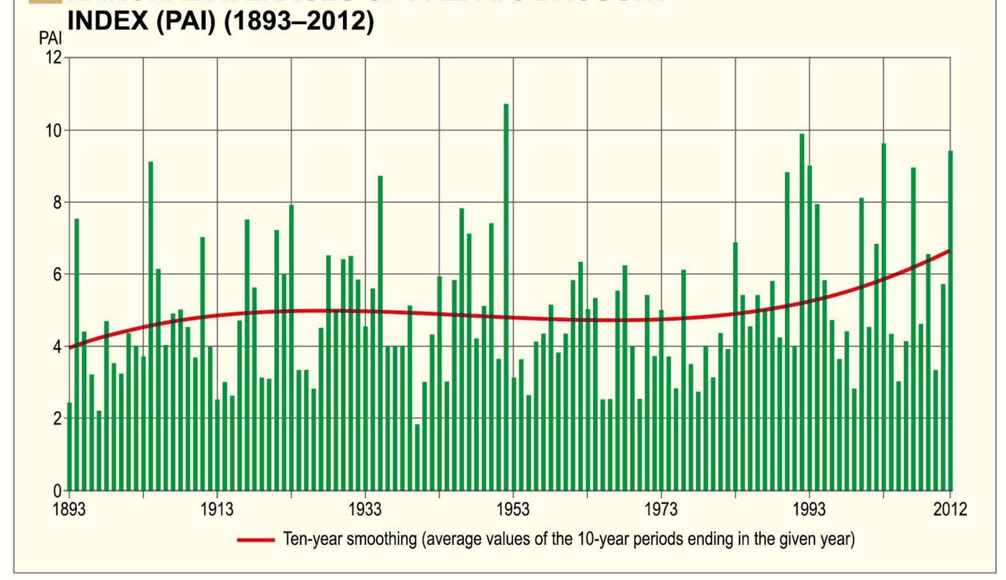
15 STANDARDIZED PRECIPITATION INDEX CATEGORIES

Standardized precipitation index	Category
>2.0	Extremely wet
1.99 – 1.50	Severely wet
1.49 – 1.00	Moderately wet
0.99 – -0.99	Near normal
-1.00 – -1.49	Moderate drought
-1.50 – -1.99	Severe drought
<-2.0	Extreme drought

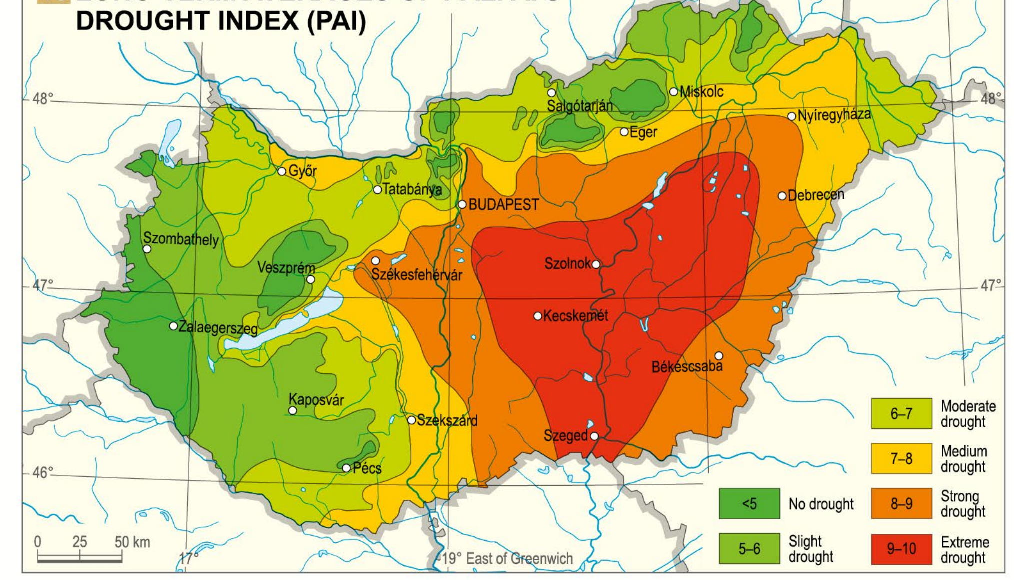
16 SIX-MONTH NATIONAL VALUES OF THE STANDARDIZED PRECIPITATION INDEX (SPI) FOR AUGUST

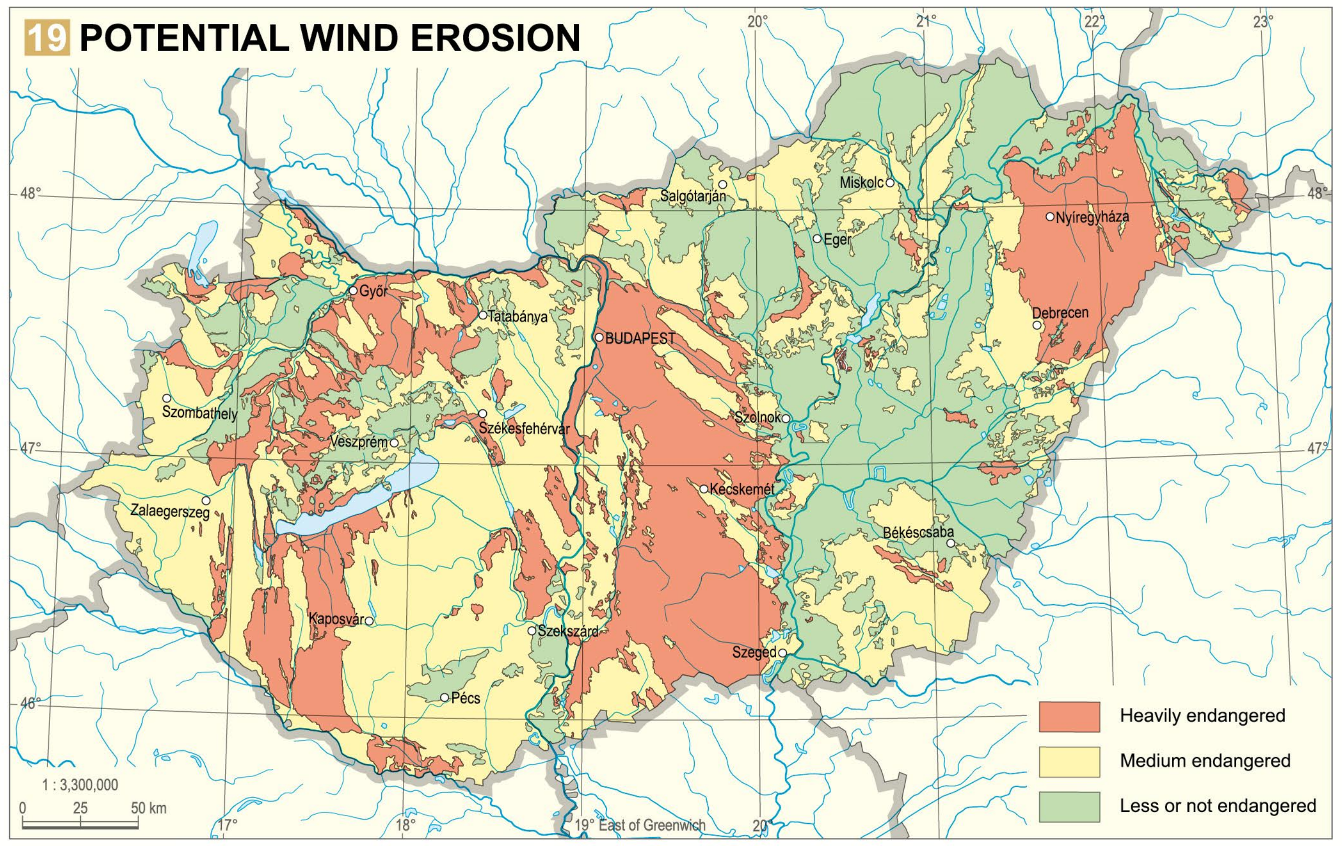


17 NATIONAL AVERAGES OF PÁLFAI'S DROUGHT INDEX (PAI) (1893–2012)



18 LONG-TERM AVERAGES OF PÁLFAI'S DROUGHT INDEX (PAI)





19 POTENTIAL WIND EROSION

7 *Wind erosion in spring in the Hajdúhát*

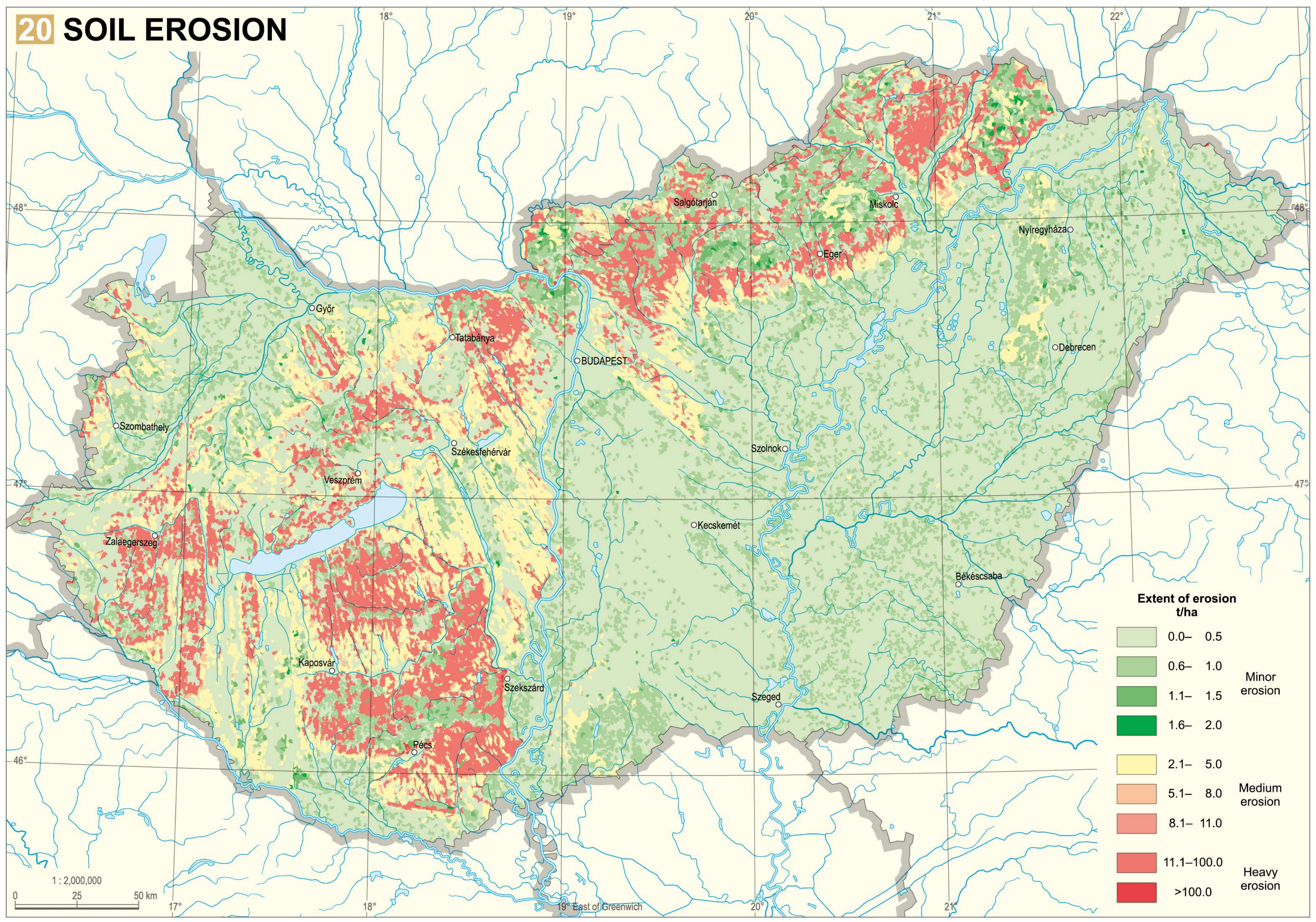
From arable fields wind transports dislodged fine particles, including chemicals (applied to increase yield or to fight pests) and pollen over long distances. In inhabited areas this causes respiratory or allergic diseases (see in detail later in the chapter on *Hazards caused by plants and animals*).

In the development of wind erosion in the dimensions of the damage caused the interaction of several factors is influential. When establishing the classes of potential hazard 19, the critical threshold velocities for soils of different texture, cohesion and roughness and the amount of redeposited soil have to be considered. In heavily endangered areas, not protected by vegetation, even winds with 6.5 m/s velocity are able to entrain soil grains. In moderately endangered areas wind erosion begins between 6.5 and 8.5 m/s wind velocities. In areas of the third category only winds with 8.6–10.5 m/s or higher velocities are a hazard, but the amount of redeposited soil is smaller.

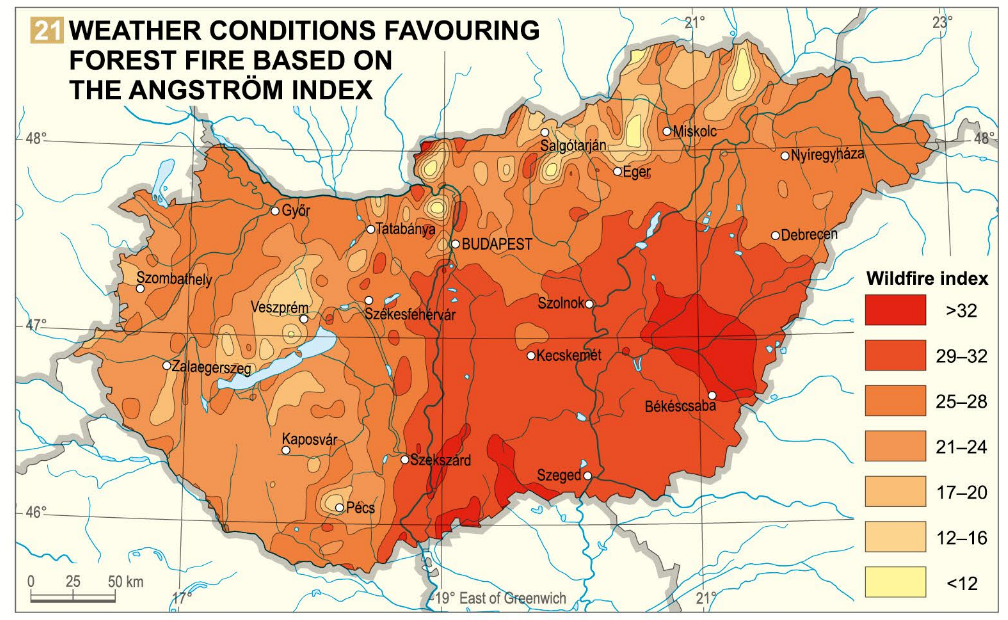
Under the present climate wind erosion hazard in Hungary has to be reckoned with on dry surfaces unprotected by vegetation and, first of all, in spring, at the beginning of the growing season 7, when wind energy surpasses the threshold starting velocity close to the ground. In autumn the importance of and damage caused by wind erosion is negligible. Recently, there is increasing hazard in winter without a thick snow cover when considerable deflation affects the fields ploughed in autumn. There are many ways to counteract wind erosion, such as planting shelter belts, applying irrigation and a protective crust or other techniques.

Soil erosion

Among the various types of soil degradation, in addition to wind erosion, soil erosion due to surface runoff is the most hazardous, as it may deteriorate the surface soil layer, or in extreme cases the total tilth layer. The rate of deterioration depends mainly on precipitation (especially quantity and intensity) and topography. As the average annual amount of precipitation is moderate in Hungary, intense rain showers are not too frequent, the dominance of flat lands is characteristic of the terrain, the erodibility rate of our soils is insignificant. 9.3% of Hungary's territory is slightly, 9.6% moderately and 6% is severely eroded. According to erosion assessments the average amount of humous surface soil 8 removed from sloping areas or blown away by wind is 80–110 million m³ annually, the organic matter loss due to this is approximately 1.5 million t. In addition to the soil loss due to surface sheet erosion, rill erosion and gully erosion (rills, channels, in extreme cases creating ditches and gullies) disunites the surface, impedes the uniform cultivation of the damaged field. Accumulation of the removed soil is also unfavourable, because the shifted soil may transport chemicals into surface waters, which may lead to water pollution, nutrient loads.



20 SOIL EROSION



21 WEATHER CONDITIONS FAVOURING FOREST FIRE BASED ON THE ANGSTRÖM INDEX

8 *Soil erosion near Somogydöröcske*

Erosion can be traced in many places, its countrywide occurrence and rate can be estimated with the help of numerical spatial modelling. The map of soil erosion 20 elaborated with the use of meteorological, soil and surface cover data, combines the results of two models and shows the estimated rate of the material shifting yearly and per hectares.

Other factors of soil deterioration (degradation) are discussed in more detail in the *Soils* chapter 14 – 17, while human-induced soil stresses are discussed in the *Environment protection* chapter 27 – 31.

Wildfire

Wildfires are among the most serious natural hazards. Primarily forest fires or the combustion of other vegetation causes major disasters since after fire the regeneration of the ecosystem takes a very long time. In Hungary 99% of wildfires are caused by human negligence and only indirectly influenced by weather. In forests surface or litter fires are typical. On reaching higher intensities, they may develop into crown fires. Although less often, underground fires may also occur, e.g. the temporary burning of the locally deep peat beds. In addition to forest fires, the burning of cereal or stubble fields sometimes extends over large areas in the summer.

22 VEGETATION AND FOREST FIRES IN HUNGARY (2007–2016)

Year	Number of vegetation fires	Forest fires	
		Number of events	Area affected (ha)
2007	6,691	603	4,636
2008	6,639	502	2,404
2009	8,658	608	6,463
2010	3,120	109	878
2011	8,346	2,021	8,055
2012	21,581	2,657	14,115
2013	4,602	761	1,955
2014	5,783	1,042	4,454
2015	5,318	1,069	4,730
2016	2,489	445	916

The origin, life cycle and spreading of wildfires are controlled by three natural factors: properties of the biomass, relief conditions and the weather situation. Within weather wind velocity and direction, air temperature and relative humidity as well as the spatial and temporal distribution of precipitation are decisive. In Hungary fires of natural origin are primarily due to lightning. The lightning season usually begins in May and ends in August. Estimations indicate that annually at least two thunderbolts happen per square kilometre.

In Hungary there are two periods of the year with increased fire hazard. One is associated with the time after snowmelt, from February to April, poor in precipitation, with low relative air humidity of air, before vegetation turns green and the biomass is dry. The other period is the warm and dry summer, when following enduring drought and high temperatures the vegetation fully dries out and flames up easily. Summer fires most often affect the Alföld 21. Although in the past decade the number of vegetation and forest fires has shown a great fluctuation 22, it is obvious that higher temperatures, less precipitation and fewer days with snow cover due to climate change contributes to the higher relative frequency of forest fires.

Natural hazards related to the hydrosphere

Floods

Hungary is a downstream country, with 95% of the water volume flowing in from abroad. Our flood waters – with the exception of a few small rivers with domestic water catchment areas – are generated by the waters collected at and coming down from the mountainous regions, and coming from neighbouring countries. Due to basin conditions, in historical times, before the start of domestic flood control, the extent of wetland areas sustained by floods was significant (*Waters* chapter 11).

Hungary's flood exposure is unique in Europe, regarding both the size of vulnerable areas (21,248 km² – 23% of the territory of the country) and the length of dikes (state water service manages more than 4,200 km first priority flood protection dikes) 23. Due to the climatic and geographic conditions of our river basin districts small or medium, significant and extraordinary floods can be expected in every 2–3, 5–6 and 10–12 years respectively at any time of the year. Because the upper section of our rivers is with an intense water regime, after a rapid snow melt or larger rainfall, flooding occurs in the domestic river sections within 1–2 days, causing several metres of floods in a short time. Particularly dangerous is the Upper Tisza region and its tributaries, as well as the Körös Rivers, where water levels may increase up to 8 to 10 m in 24–36 hours after the precipitation. The more significant flood waves can last 5 to 10 days in the upper parts of our rivers, 50–120 days in the middle and lower sections with less gradient. The magnitude of the hazard is indicated by the fact that in floodplains, where nearly 2.5 million people live, there are 700 settlements, 32% of railways, 15% of roads, 1/3 of cultivated land and nearly 2000 industrial plants.

There are several chronicles and archives documenting the prevalence of floods. The oldest data is about flood on the Danube in 1012. The first written record of flood protection – in which the king ordered the construction of flood protection works in Somorja (Šamorín) due to the series of floods – is from the time of King Sigismund dating from 1426. The largest flood protection works took place in the 19th century, the primary initiator was István Széchenyi and the design was mainly done by Pál Vásárhelyi.

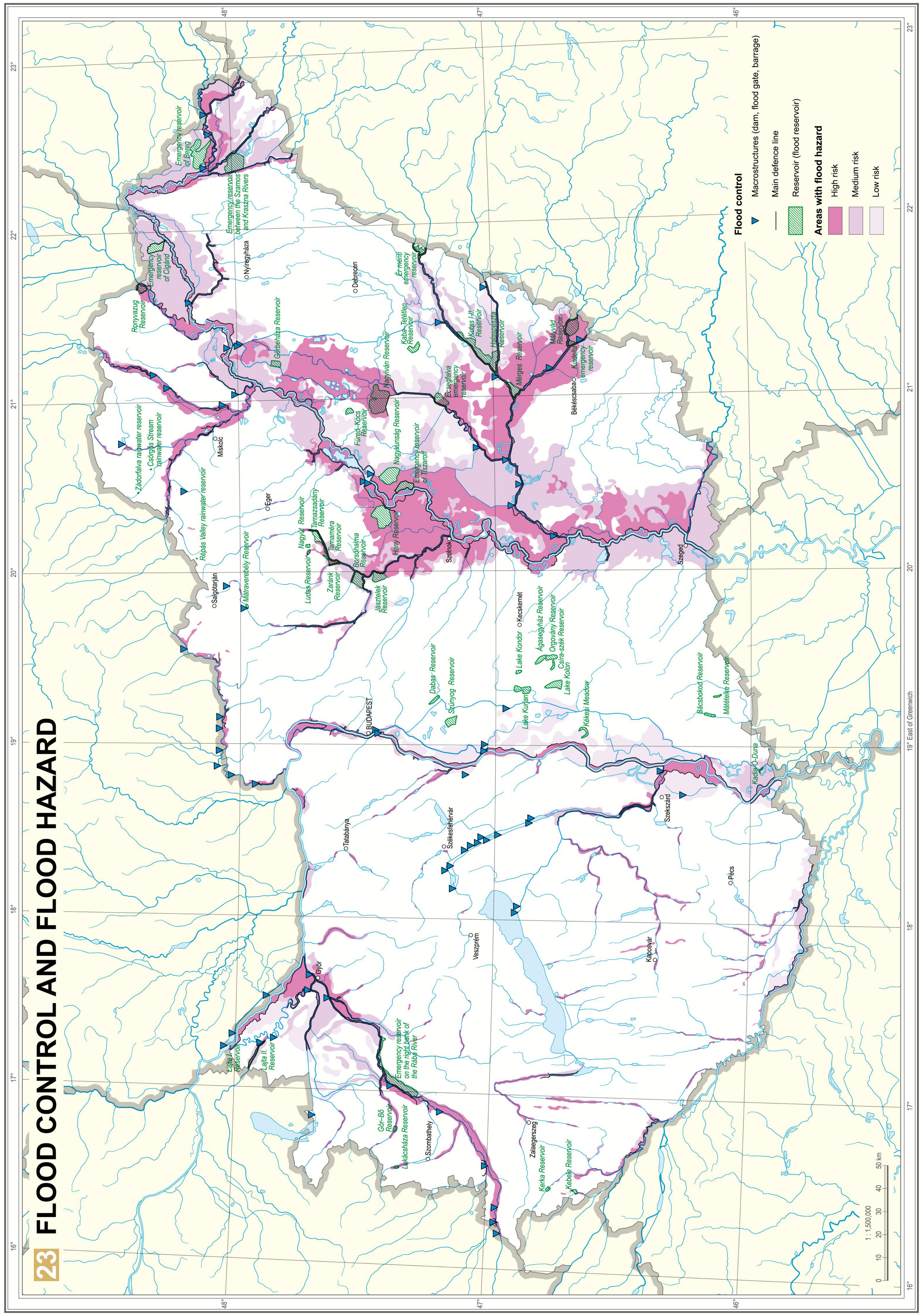
In the Hungarian flood chronicles, with regarding both the height of floods and the size of damage, a sad pre-eminence is the 1838 icy flood of Pest. Even though river control works were largely completed at the beginning of the 20th century, larger floods continued to occur. In 1899 and 1954 a flood which destroyed dams at Szigetköz ravaged, and in 1956 ice-flooding caused enormous damage between Dunaföldvár and the southern border. In 1965, six consecutive flood waves occurred on the Danube, resulting in an unprecedented 119 days of flood defence operations. Since 1991, seven large flood waves have occurred on the Danube, which further increased the maximum flood level in Budapest. Particularly dangerous was the year 2013 6, with its meteorological background 13 14 also discussed in the climatic threats sub-chapter of this chapter.

On the Tisza River the necessary price for successful flood protection was that the highest levels of flooding in the narrower cross-section were 2–3 m higher than before. Moreover, over the past two decades the series of exceptional floods (1998, 1999, 2000, 2001), which exceeded each other occurred, which also caused a dike breach in 2001 9. The above average flood damage and the effects of climate change made it necessary to elaborate the Development of the *Vásárhelyi Plan (VTT)* programme. This aims to reduce the flood levels of the Tisza by flood peak reducing reservoirs and by changing the floodplain land use.

Excess water

A large proportion of the lowland areas of Hungary – of which approximately 34,000 km² is in direct agricultural cultivation – around 60%, are threatened

9 *The Tisza dike break in 2001 at Tivadar*



23 FLOOD CONTROL AND FLOOD HAZARD

XIII.

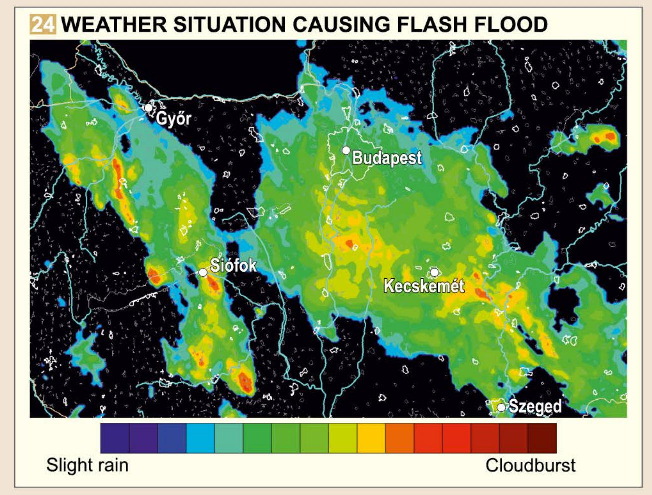
Flash floods

Flash floods are primarily distinguished from other floods by the fact that they form in a few hours due to high intensity precipitation on a small river basin. In extreme cases, up to 100 mm of precipitation can fall in a given area in 1–3 hours. Their duration is short, but rainwater can turn into a flood wave in gullies, crevices or small streams, the water masses can move boulders, twist trees, can sweep buildings and bridges away, form new riverbeds, its energy can be enough to wash away pavements or houses in settlements. The streets can turn into rushing rivers, basements and underpasses can become deadly traps when they are filled with water. The rapid increase in water levels can reach up to 10 m or more in a few hours. They can induce the start of catastrophic mudslides.

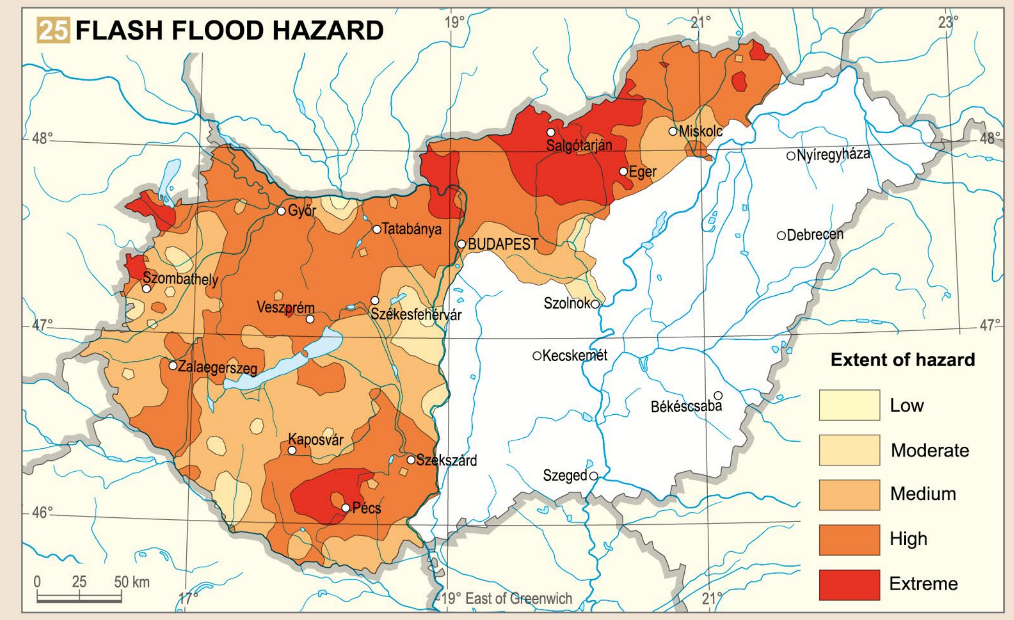
From a meteorological point of view, flash floods can be linked to convective rainfall systems, i.e. showers and thunderstorms, when thunderstorms move in a line one after the other, so that above an area over a short period of time – a multiplicity of intense precipitating – a thunderstorm cell can pass through. Such intense events can occur in almost any month of the year. On the weather radar image taken at 17.10 on 13 September 2017 it is visible 24 that during the day the cells moving from southeast to northwest released a precipitation of more than 60 mm near Kecskemét and the southern shore of Lake Balaton, resulting in a number of flash floods in the country.

The formation of flash floods is also influenced by the terrain; the most vulnerable are mountains and hills 25, and most of all their foregrounds and valley gates, where because of the sudden changes in the slope of the terrain, the flowing water masses slow down and build up. Sparse vegetation, high proportion of waterproof (impermeable) layers, bound soils or lack of maintenance of the rainfall drainage system will also facilitate the occurrence of flash floods. Cities are at high risk because of the dense urban buildings and the high proportion of paved surfaces, which increase the risk of rapid surface runoff.

24 WEATHER SITUATION CAUSING FLASH FLOOD



25 FLASH FLOOD HAZARD



significantly by excess waters 27. In the case of unfavourable meteorological and hydrological conditions enormous areas may be flooded. By the 1990s a 46,700 km long channel network was built for the drainage of excess waters.

Excess waters affect the lowland settlements and transport lines, but the greatest damage is to agriculture. The yield in years with excess waters – on national levels – is 15 to 25% lower than in the average year. The magnitude of damage depends on the duration of excess water inundation, temperature of the water, the tolerance of the crop culture and the fertility of the area. Therefore summer excess waters are rarer, but may cause orders of magnitude greater damage to agricultural land, than winter or spring events. Damage to buildings is also substantial, especially in the already disadvantaged farmland.

The frequency of excess water inundations is characterized by the fact that in the last 70 years there was only one year (1992) when there was no need for excess water protection operations. The maximum inundations (in 1940 and 1942) exceeded 500,000 to 600,000 hectares. But we also need to be aware that excess water is not only a potential threat, but also a viable value. There is a growing demand to keep a larger proportion of excess waters on site, to rationally manage excess waters: to build smaller and larger reservoirs, to create dikes and water retention in the excess watercourses. With the retention of excess water only atmospheric drought can be alleviated and because of quality reasons it can rarely be used as irrigation water.

Hazards caused by plants and animals

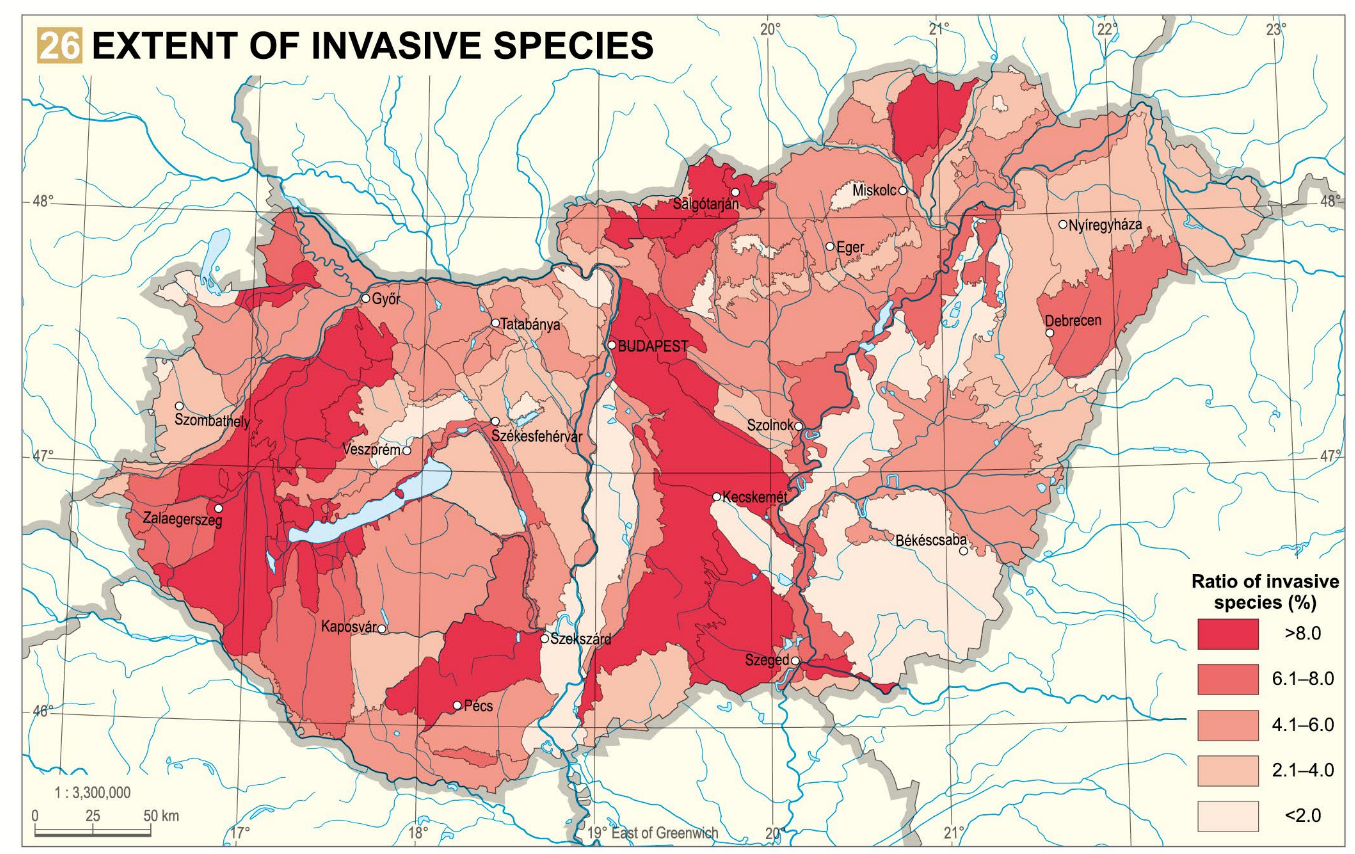
Non-native animal and plant species are called adventive or alien species. Some species colonized naturally, while others were introduced by humans. The latter include cultivated or naturalized plant species. These new plant and animal species can either spread naturally, or most often are introduced intentionally or inadvertently by humans to areas where they were unknown before. Their distribution is made easier by international trade, transport and travel and fast-growing tourism through increasingly open borders. The growing proportion of cultivated genetically modified organisms is also becoming an important factor.

In this day and age the appearance of alien species is common and their spread can be dramatic all over the world. That is why they are called invasive species. To be able to survive adventive species have to find suitable habitats where they often outcompete native species. In near-natural habitats non-native species can become dominant and so threaten the ecological balance of native communities and biodiversity. This applies to the Carpathian Basin as well where next to human activity the spread of invasive species 26 are considered the second most important risk to natural habitats. Currently 700 of the 2,400 wild species are non-native, and 70 are spreading rapidly. On the other hand, nearly 50 native species have disappeared in the last two decades and further 400 are endangered to some extent. Especially alarming is the decline of endemic species native to Hungary and the Carpathian Basin and of species with high historical, biogeographical and ecological significance.

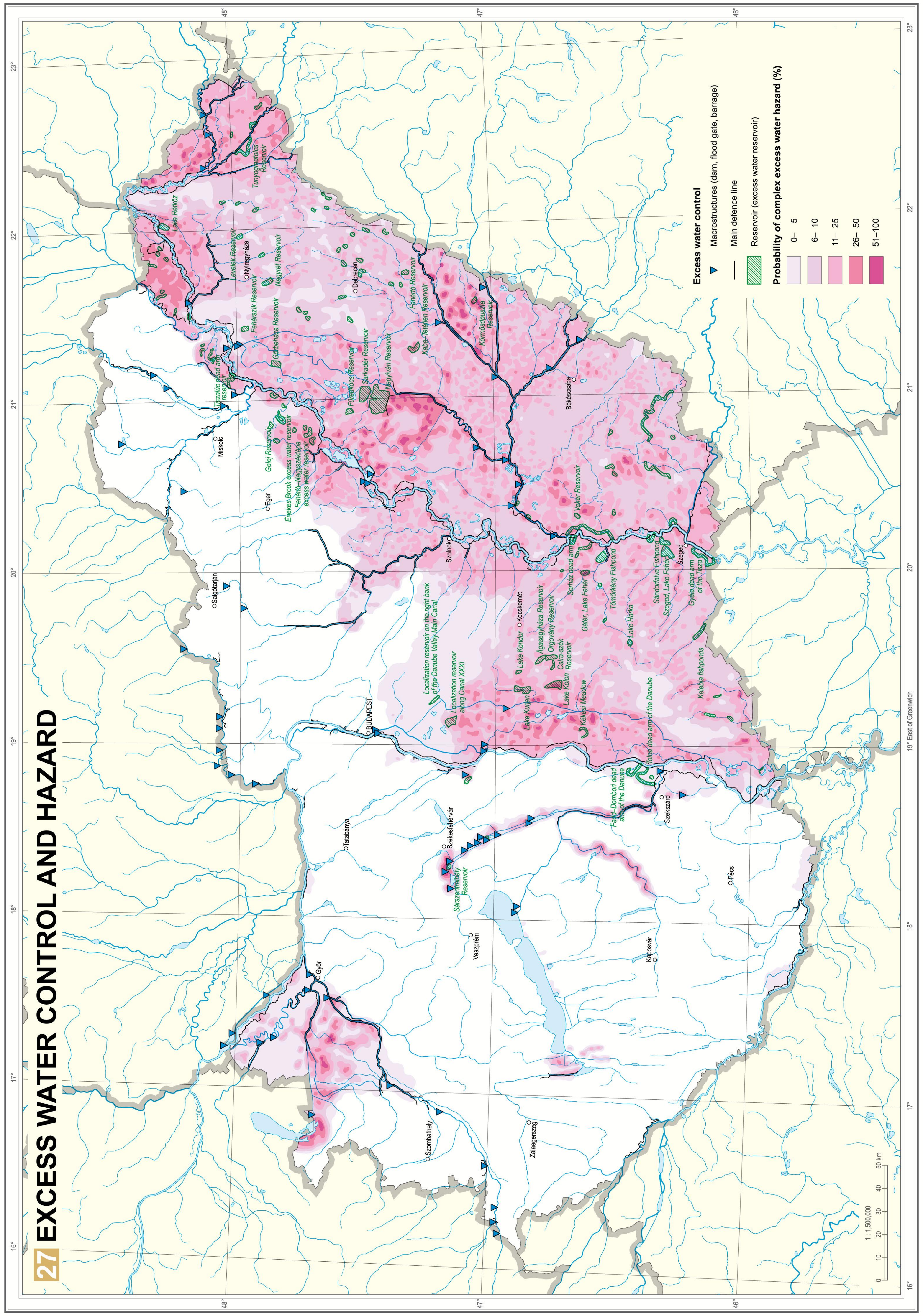
The cover of alien species in the Hungarian landscape is ever growing, especially of spontaneously spreading populations of invasive species. The common milkweed *(Asclepias syriaca)* endangers about two thirds of the open sand grasslands and juniper-poplar forests; giant goldenrod (*Solidago* spp.) species threaten nearly half of the marshes and hay meadows, and one third of the marsh meadows and tussock sedge communities (invasive species are detailed in the *Vegetation* chapter of our Atlas).

Also among animals there are rapidly spreading invasive species having adverse effects on other elements of the biosphere. For example they can outcompete other species bringing about their extinction, cause economic damage or present a nuisance

26 EXTENT OF INVASIVE SPECIES



XIII.



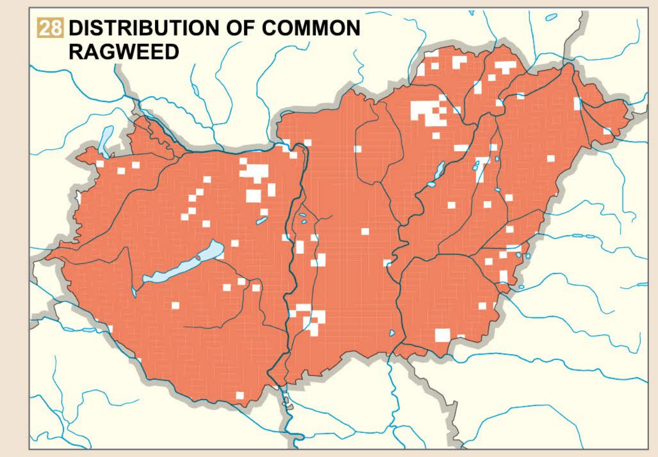
Allergenic pollens

Invasive species affect human life. One of the most well-known examples of introduced invasive species is the common ragweed (Ambrosia artemisiifolia), which has become the number one weed species of Hungarian arable lands **28**. *The originally North American species is still spreading. First it has appeared in the 1920s in the southern part of Somogy County and spread over southern Hungary. Later it started to colonize the northern regions first gradually, then explosively as it has become adopted to European climate. Common ragweed can reach 1.5 m height, and its seed is viable for up to 40 years. It is most abundant in recently abandoned arable lands, while in near-natural forests and closed grasslands only disturbed areas are affected. Up until the 1970s it had no considerable impact, since then it has become one of the most widespread allergenic invasive species as the concentration of its pollen – often together with other species' – has increased dramatically.*

The average concentration data of ragweed's airborne pollen in the atmosphere are provided by pollen traps of the National Public Health and Medical Officer Service (ÁNTSZ) installed on higher town buildings. Even a pollen concentration as low as 30 grains/m³ can cause allergy symptoms to those affected but concentration can reach several hundred grains/m³. Based on these pollen counts the Service operates an allergenic pollen warning system with open-access maps of the measured concentrations. The main objective is to illustrate the environmental-health burdens relevant for patients suffering from allergy and asthma.

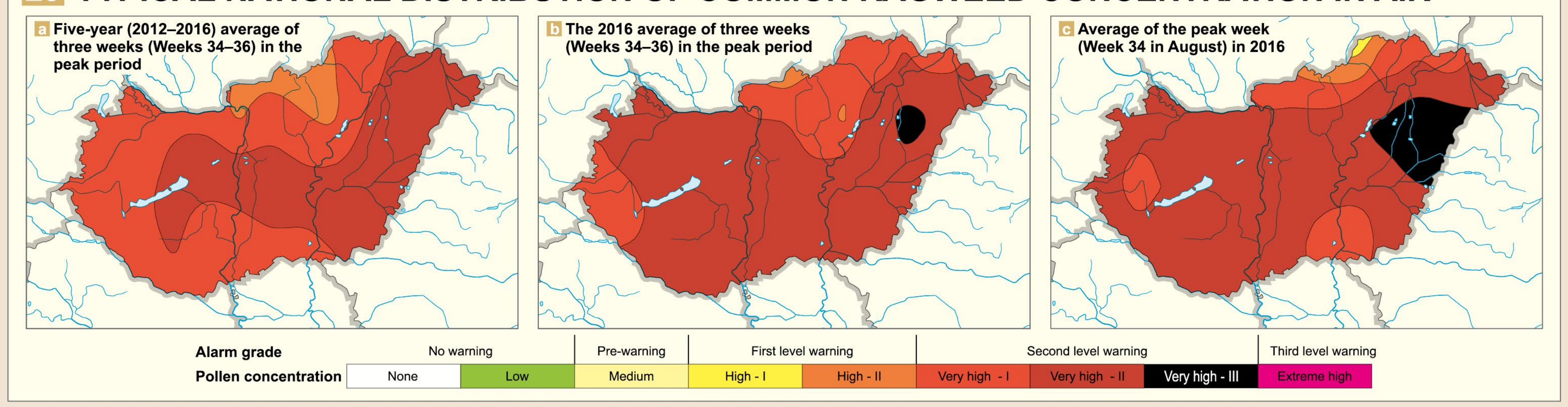
The peak of ragweed's pollen emission is the 34th to 36th weeks of the year (the end of August and beginning of September). Maps refer to this period and display the typical distribution of one-week or multi-week averages of atmospheric pollen concentration in Hungary. The first map **29a** *shows a long-term average, the five-year average values of the three relevant weeks*

28 DISTRIBUTION OF COMMON RAGWEED



from 2012 to 2016. The second map **29b** *shows the average of the three peak-time weeks in 2016. The third* **29c** *shows the average of the 34th week, the most burdened week of that year. Maps reveal that primarily the central and eastern parts of the country are affected and in 2016 extremely high pollen concentrations were measured in the Debrecen region.*

29 TYPICAL NATIONAL DISTRIBUTION OF COMMON RAGWEED CONCENTRATION IN AIR

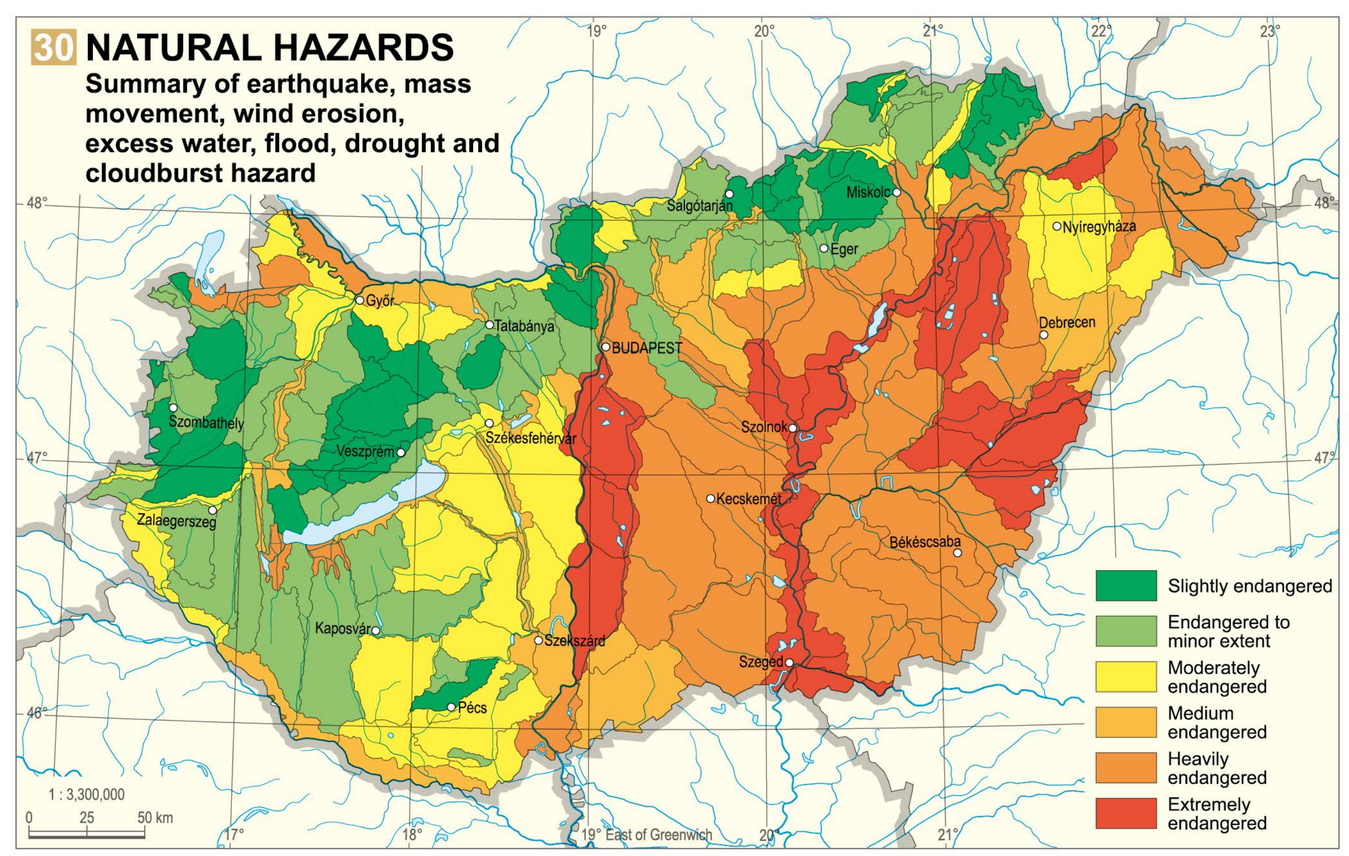


to mankind. Species introduced by human activities speed up the distribution of pests and diseases. Well-known examples are the phylloxera *(Viteus vitifoliae)* devastating vineyards in the 19th century or recently the horse chestnut leaf miner *(Cameraria ohridella)* damaging horse chestnuts. Some species are threatening human health, like pathogens spread by ticks (meningitis, Lyme disease). One of the results of climate change can be the range expansion of species spreading various diseases (e.g. yellow fever, malaria). In this way these diseases may appear in areas where they were never met before.

There is no real chance to keep the spread of invasive species under control primarily because thorough specialist knowledge, immeasurable work and financial resources are required to diminish these widely distributed species. Due to globalisation and misguided unsustainable economic developments the vulnerability of the biosphere is ever increasing. Beside the invasion of alien species other threats include the overgrazing by game, drainage of wetlands, mismanagement of meadows and pastures, spread of shrubs, and large-scale homogeneous forest management. Inappropriate mowing and grazing damage at least 19% of the grasslands, scrub encroachment together with the invasion by alien species threatens 28% of wetlands and 33% of grasslands, and mining, arable farming, urban development and afforestation threaten 13% of wetlands, 23% of grasslands and 6% of forests.

30 NATURAL HAZARDS

Summary of earthquake, mass movement, wind erosion, excess water, flood, drought and cloudburst hazard



Natural hazards: summary assessment

Natural hazards in Hungary were presented above one by one, grouped around the types which induce the most numerous and serious disasters. The analyses of hazards clearly pointed out that the spatial and temporal distribution of damage used to be uneven in the past as well, and the threat by natural hazards will affect the individual geographical landscapes to various extent. Based on the now available data, the map **30** presents an integrated picture on the distribution of natural hazards in the country. Seven types of hazard – earthquakes, mass movements, sandblasting (wind erosion), floods, excess water, drought and cloudbursts – are included and depicted by landscapes. The individual types – with the exception of cloudbursts – are referred into four grades of danger. (For cloudbursts only two grades are distinguished.) The grades were scored from 0 to 3 (for cloudbursts from 0 to 1). Since floods, excess water and drought are hazards of outstanding importance, in their cases the scores were doubled to give them weight. The six-grade scale shows the degree of threat for the individual landscape units.

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Ministry of Defence (Honvédelmi Minisztérium, HM)
- Zrínyi Mapping and Communication Servicing Non-profit Ltd. (Zrínyi Térképészeti és Kommunikációs Szolgáltató Közhasznú Nonprofit Kft.)

Ministry of Human Capacities (Emberi Erőforrások Minisztériuma, Emmi)

National Agricultural Research and Innovation Centre (Nemzeti Agrárkutatási és Innovációs Központ, NAIK)
- Forest Research Institute (Erdészeti Tudományos Intézet)

National Food Chain Safety Office (Nemzeti Élelmiszerlánc-biztonsági Hivatal, NÉBIH)
- Directorate for Plant, Soil and Agricultural Environment Protection (Növény-, Talaj- és Agrárkörnyezet-védelmi Igazgatóság)

National Institute of Environmental Health (Országos Közegészségügyi Intézet, OKI)

National University of Public Service (Nemzeti Közszolgalati Egyetem, NKE)
- Institute of Disaster Management (Katasztrófavédelmi Intézet)

Szent István University (Szent István Egyetem, SZIE)
- Faculty of Agricultural and Environmental Sciences, Institute of Environmental Sciences (Mezőgazdaság- és Környezettudományi Kar, Környezettudományi Intézet)
- Faculty of Agricultural and Environmental Sciences, Institute of Nature Conservation and Landscape Management (Mezőgazdaság- és Környezettudományi Kar, Természetvédelmi és Tájgazdálkodási Intézet)
- Faculty of Landscape Architecture and Urbanism (Tájépítészeti és Településtervezési Kar)

University of Debrecen (Debreceni Egyetem, DE)
- Faculty of Science and Technology, Institute of Biology and Ecology (Természettudományi és Technológiai Kar, Biológiai és Ökológiai Intézet)
- Faculty of Science and Technology, Institute of Earth Sciences (Természettudományi és Technológiai Kar, Földtudományi Intézet)

University of Miskolc (Miskolci Egyetem, ME)
- Faculty of Earth Science and Engineering, Institute of Geography and Geoinformatics (Műszaki Földtudományi Kar, Földrajz-Geoinformatika Intézet)

University of Pécs (Pécsi Tudományegyetem)
- Faculty of Sciences, Institute of Geography and Earth Sciences (Természettudományi Kar, Földrajzi és Földtudományi Intézet)

University of Sopron (Soproni Egyetem, SoE)
- Faculty of Forestry, Institute of Botany and Nature Conservation (Erdőmérnöki Kar, Növénytani és Természetvédelmi Intézet)
- Faculty of Forestry, Institute of Forest Resources Management and Rural Development (Erdőmérnöki Kar, Erdővagyon-gazdálkodási és Vidékfejlesztési Intézet)

University of Szeged (Szegedi Tudományegyetem, SZTE)
- Faculty of Science and Informatics, Institute of Geography and Geology (Természettudományi és Informatikai Kar, Földrajzi és Földtudományi Intézet)