6 Climate change and disasters (László Földi)

6.1 Introduction

Climate change may essentially affect a large number of elements and areas of security (such as infrastructure, home defence, police forces, disaster management forces, ambulance and fire department, as well as some other elements of essential (critical) infrastructure). The primary and other consequences of climate change threaten stability in Hungary and in the adjacent regions, meaning that security issues inevitably arise.

Extreme weather conditions, as the primary consequences of climate change, as well as an increase in the frequency and intensity thereof (storms, extreme temperatures, extreme rainfall), lead to an ever increasing amount of work for organisations eliminating the consequences of disasters and the damage resulting from them (traffic regulation, complex technical rescue, guard functions, evacuation, life saving, etc.).

The increased intensity of secondary consequences (floods and inland waters, mudflow, landslide, drought, desertification, intense fires, increased explosion hazard, damage to critical infrastructure, disturbances in public utility services and other supply systems, development of shortages, operation disturbances in society in the financial, economic and public administration sectors, etc.) also result in an ever higher workload in terms of defence activities.

New types of health impairment appearing as a consequence of changing climate, such as viral and bacterial infections (pandemics, epidemics), mycoses, or the expected appearance of new species of dangerous animals or plants pose a lot of additional burden on the defence sector of infrastructure in terms of preparation, planning, organisation and prevention.

Virtually all basic elements of climate exert a significant impact. The problems arising manifest themselves in ever more frequent temperature extremes, a more uneven distribution of rainfall and more frequent wind storms.

If the capacities of the defence sector are not strengthened, or cannot follow the increase of demand caused by climate change, as a result of the changes listed in the paragraphs above:

- The risk of health-impairing effects threatening the population may grow rapidly (infectious diseases, thermal stress, dehydration, or frostbite, low body temperature, more frequent cardiovascular and nervous system-related complaints, etc.);

- The damage caused by extreme weather phenomena and their consequences (storms, heavy rains, snowfall, floods, forest fires, etc.) may increase dramatically;
- The security of other elements of the essential (critical) infrastructure (public utilities, financial and information systems, transport network, etc.) may be reduced.

6.2 The perceivable impacts of the global climate change

A rise in global average temperatures as an input effect changes the location and intensity of updrafts, the humidity of air masses over oceans, the system of precipitations (rainfall), as well as the route, intensity and structure of the general air circulation and water circulation in the oceans. Local and regional reflectivity changes in many places, as a result of which the planetary albedo and the amount of useful sunshine changes, further modifying the climatic system.

6.2.1 Changes in the distribution of rainfall

Reconstructions of the past fifty years have shown that the system of trade and anti-trade winds is changing, which plays a key role in the formation of cool and wet winds in Hungary coming from the Atlantic Ocean. This wind pattern has brought the all-important rains to the Carpathian Basin. The modification of typical cyclone paths and their shift to the north may cause the characteristic rain zones of Europe to move further to the north, meaning that there will be less rain in Southern Europe and more rain in Northern Europe. It would be difficult to draw accurate conclusions regarding the territory in between, i.e. Central Europe. Currently, we can expect more precipitation in winter and less in summer, at more or less unchanged, or somewhat lower, average annual temperatures.

6.2.2 A tendency to the extremes

Due to the increasing evaporation of sea surfaces and the higher vapour absorption capacity of warmer air, the atmosphere will be more humid, evaporation and rainfalls will become more intense, and there will be a stronger hydrological cycle. The system will contain more thermal energy, leading to more intense rainfalls: the given quantity will arrive more suddenly, more tropically, like a deluge. The average amount of rain on a rainy day may grow, without an increase in the annual amount. As a result, our weather will become more extreme: long dry periods alternate with short and intense rainfalls coming with heavy storms. The number of hails may grow as well.

The shift towards more extreme amounts of precipitation will be accompanied by a change in temperature. Obviously, rising average temperatures lead to more frequent extreme heat and a lower a number of extremely cold days. The number of dry, hot and sultry days, the number of summer days with heat waves, as well as the length of permanently hot periods may grow.

These changes are already exerting their unfavourable effects, and may soon lead to really critical situations, threatening the fundamentals of our civilisation.

6.3 Extreme weather phenomena and their consequences

6.3.1 Effects and indicators

According to forecasts and the climatic models published, it can be generally concluded that the risk of disasters and the load on the critical infrastructure will considerably increase. In Hungary, increased load on the critical infrastructure is caused by the fact that the number of natural disasters arising from climate change will grow and they are likely to have severe consequences. Nevertheless, extreme weather events do not necessarily lead to disasters. The difference in meaning can be clearly understood based on the definition of disasters.

The secure and continuous operation of critical infrastructures faces a greater challenge due to the global climate change than in regions subject to a high risk of terrorism and disasters. Primary impacts and the resulting secondary impacts may together lead to disaster-like situations, depending on their size, the duration of their occurrence, and weather nation-wide cooperation is required to manage them.

Primary impacts are ones that may be triggered by climate change directly:

- extremely high/low temperature;
- extreme amounts of rainfall (permanent rain, downpour, hail, or snowfall resulting in a long-term, permanent snow layer and/or snow drifts);
- wind storm (gale, tornado)

Secondary impacts, which may, per definition, arise from the above (at times in combination with one another):

- flood and inland waters;
- mudflow, landslide;
- drought, desertification;
- intense fires, increased explosion hazard;
- damage to critical infrastructure, disturbances in public utility services and other supply systems, development of shortages;
- negative health, psychic and human comfort consequences;
- operation disturbances in society in the financial, economic and public administration sectors, etc.

Primary and secondary impacts can be described with the help of indicators, the so-called primary and secondary climate indicators.

Primary climate indicators

Meteorological indicators:

- air temperature (average temperature, maximum and minimum values, length and duration thereof),
- surface water temperature of seas,
- amount of rainfall (average amount, maximum rainfall within a short period of time, frequency of heavy rainfalls and snowfalls),
- wind velocity and direction (average wind speeds, maximum values)
- frequency and intensity of storms.

Secondary climate indicators

Indicators describing the effects of climate change can be classified on the basis of environmental, ecological, health and socio-economic impacts.

Environmental indicators:

- amount of polar and Greenland ice (size of area covered by ice),
- see level, level of lakes and rivers,
- date when the freezing point occurs, period of time in which the soil is covered by snow,
- level of groundwater,
- water quality, air quality,
- ground humidity,
- development of forest and brush fires, etc.

Ecological indicators:

- foliation, blooming and defoliation times of trees,
- appearance and disappearance of butterfly species,
- date of the arrival of migrating birds,
- nesting time of birds,
- changes in population,
- mass appearance of insects, etc.

Health indicators:

- number of deaths due to extreme weather,
- change in the distribution of vectors,
- appearance of new diseases, etc.

Socio-economic indicators:

- water supply (water restrictions),
- changes in agricultural cultures
- weather-related losses (insurance costs),
- changes in lifestyles, etc.

6.3.2 Increasing climate sensitivity

Over the past 100-150 years, not only the climate has changed, but certain processes and events taking place in society also resulted in an increase in climate-based risks. The most important of these in Hungary include:

- Life expectancy has increased, meaning that there are more old people, who are more sensitive to weather events;
- The rate of urban population has tripled, so the detrimental impacts of heat waves affect a larger number of people;
- Dependence on electric energy has appeared; technical problems arising from extreme weather may disable public transport, as well as the heating, cooling and illumination of homes;
- Extreme meteorological events may also threaten drinking water supply in the case of vulnerable water bases;
- Energy-intensive air conditioning devices have appeared;
- There are more expensive devices and equipment in the open air than earlier, which can be badly damaged as a consequence of weather conditions.

This means that arguments like "there have always been storms, hails and very hot periods, and we have survived" are only partially true, because the (material and health) impact of these on society is very different in nature and extent form that seen earlier.

Society is today a lot more sensitive and vulnerable to climate than 100-150 years ago. This fact explains why security risks should be a primary concern. Obviously, there have been favourable and beneficial changes over the years as well. Just think of the reliability of weather forecasts. Defence procedures and technologies have also advanced. Local teams and organisations have been established for disaster management and remediation. New communication systems (such as mobile phones) improve the efficiency of defence by means of various methods of detection, alerting and contact. Overall, we can conclude that it is appropriate to examine all changes and trends in climate and society as a uniform system [6.1.].

6.4 Disasters caused by extreme weather conditions

Weather extremities caused by climate change can lead to various disasters, or severe short- or longer-term situations or series of events. There have been many examples of such events in Hungary in the near past. Just think of the extreme cold and blizzard on 15 March 2013 (actually lasting for several days) or the flood on the Danube in June 2013, hitting all-time records in several places in terms of water levels.

Apart from the fact that both above-mentioned examples were the consequences of above-average precipitation, they have very few things in common. Looking at the activity of disaster management organisations, we can see that they were able to adapt their reactions to the situation in question. The extreme snowfall in March caused a severe breakdown in transport, with thousands of people trapped in their cars for days, some of them without any supplies, first of all on the motorways. Due to the unexpected nature of this situation, disaster management bodies were unable to properly prepare for it, and it was not really possible to use preliminary plans. Because the disaster (also) hit the transportation network, remediation and ambulance bodies had difficulties accessing the relevant locations and providing assistance to them. According to media reports, several victims were dissatisfied with the services of the disaster management bodies, missed timely and correct information, and criticised the slowness of measures, the lengthiness of the rescue activities, and the supply system. In the defence of professional disaster management bodies, let me point out that such extreme and unexpected meteorological phenomena are always associated with a lot of risk and responsibility. There has been special focus on this aspect since the storm in Budapest on 20 August 2006, and ever since the authorities have issued an alert even in situations where the occurrence of the event is not yet sure to prevent a tragedy like the one on that day, which also led to fatal injuries. It must also be noted, however, that the issuance of false alerts is not advisable either, because if they occur repeatedly, people will not take such warnings seriously. This is probably the reason why measures concerning traffic restrictions and road bans were passed too late in March.

In this respect, the flood on the Danube in June was a total opposite of the event in March. The expected severity of the situation was known already more than a week before, there was extensive media coverage regarding the critical situation along the upstream parts of the Danube in Germany and Austria. Water level forecasts proved to be accurate, so the way things would develop, and also the defence measures to be taken, could actually be determined in advance. Also, there was sufficient time to inform the population, and the notice requesting general cooperation proved to be effective. Disaster management bodies received top marks in connection with these tasks, and the whole country could be proud of the exemplary defence efforts.

6.4.1 Extreme precipitation, extreme amounts of rain

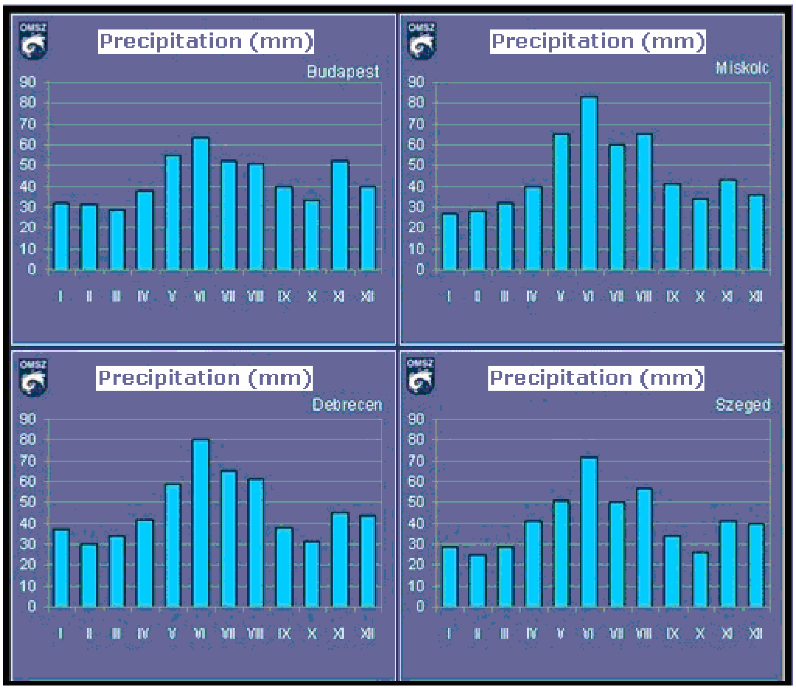

Figure 6.1.: *Monthly distribution of precipitation (source: Hungarian Meteorological Service, OMSZ)*

The average annual amount of precipitation in Hungary is around 600-650 mm, but there are significant differences between individual regions. The wettest territories are the southwest of the country and the hilly areas, which receive almost twice as much rain as the middle of the Great Plain. The most rain falls in May and June, the least in January and February. These data have been confirmed by the results measured by the Hungarian Meteorological Service between 1961 and 1990 at 4 measuring stations, as shown in Figure 6.1. [6.2.]

This means that the distribution of average annual precipitation is uneven, with fluctuations even from year to year. As a result of this fluctuation, in the wettest years, the amount of precipitation may be three times the amount measured in the driest years. Furthermore, any month may pass without any precipitation at all. [6.3.] However, in spite of the extremities, the annual amount of rain shows a decreasing trend, as shown in Figure 6.2.

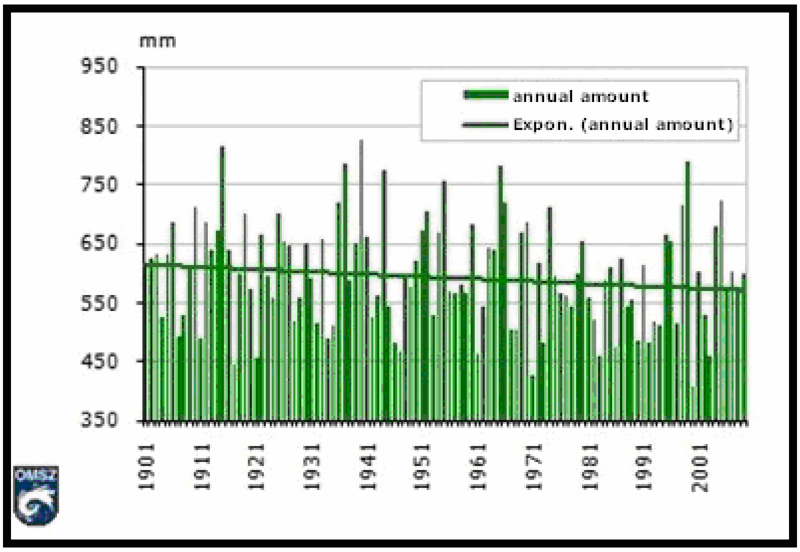

Figure 6.2.: *Changes in the total annual amount of precipitation between 1901 and 2009 (source: OMSZ)*

Extreme amounts of precipitation may fall in the form of long-lasting extensive rains, but also within a short period, in the form of downpours.

Sudden downpours with large volumes of rain are a characteristic of summer thunderstorms. [6.3.] In the close proximity of high-flying thunder clouds, areas with strong updrafts and downdrafts alternate within a short distance, meaning that accompanying phenomena limited in space (local) but very dangerous in nature can be expected.

In the event of heavy thunderstorms, hails with large blocks of ice (with a diameter of min. 2 cm) and intense storms (gusts above 90 km/h) may also occur. In an extreme case, however, the size of ice blocks may be a lot larger, and hurricane-level gusts (above 119 km/h) may also be generated. In addition, intense storms may be accompanied by large volumes of precipitation falling within a short period of time, as a result of which brooks with a low flow rate may widen to rolling rivers within a few minutes. Thunderstorms may lead to mass panic at large events frequently organised during the summer, potentially resulting in the death or injury of several people. Since thunderstorms usually affect only a small area, the current system is all but unsuitable for predicting them accurately.

Thunderstorms are usually of a local nature, but if several heavy thunderstorms are linked together, chains (or systems) of thunderstorms develop, whose dangerous accompanying phenomena do not only affect a single settlement but entire counties or even several regions. In addition, in the event of permanent rainfall, the risk of landslides must also be taken into account in hilly areas. This is what exactly happened on 14 April 2010, when a section of the railway track in Lillafüred was washed away by a downpour, and approx. 120 m^3 soil (mudflow) was carried to the paper mill located nearby. Furthermore, on the same day, landslides occurred at 2 other places as well. [6.4.] The risk of landslides also affects houses built on the hillsides.

Many countries in Central Europe were hit by extreme floods in 2010. People faced floods not only in Hungary, but also in Poland, in Slovakia, in eastern part of Germany and in the Czech Republic. 79 villages found themselves under water on the territory of the Czech Republic, seven bridges were completely damaged, total property damage amounted to more than 200 million euros and five people were died. Also critical infrastructure was affected truly significantly, as flood waves statically disrupted more than 20 bridges. Czech Army and many others authorities participated during the aftermath of floods. Czech army helped to design and to erect 20 temporary bridges using modern information technologies. „There were three units of Czech Army participating in this operation - University of Defence, Military Geodetical and Hydrometeorological Office, and 15th Engineer Brigade. Every mentioned unit organized particular team or teams that were included in this operation." [6.5.] [6.6.] [6.7.]

2010 was the wettest year over the past 110 years. As a consequence of the extraordinary amount of precipitation, flood and inland water alerts were active throughout the country almost during the entire year. [6.8.] The flood was so intense that the Government announced an emergency situation in the area of 10 counties (Borsod-Abaúj-Zemplén, Szabolcs-Szatmár-Bereg, Heves, Jász-Nagykun-

Szolnok, Pest, Nógrád, Bács-Kiskun, Békés, Csongrád and Fejér). [6.9.] Agriculture, as well as the natural and built environment suffered extensive damage. Figure 5 illustrates the consequence of the flood on the river Sajó in June 2010, showing that the water flooded everything and the inhabitants had to be evacuated.

Analysing the 2010 precipitation conditions based on the 1971-2000 norm, OMSZ registered above-average values each month, except in March and October, and therefore the total annual amount was also very high (969 mm), breaking the earlier record of 824 mm from 1940. The most extreme month was May, when the amount of precipitation was three times the average volume. It was followed by September (2.5-fold) and February (2-fold). The total precipitation amounts in January, June, August and December were also at least 1.5 times higher than the average values.

As far as total precipitation at the stations is concerned, records were broken at 2 locations. Until that year, the highest annual average recorded by OMSZ was 1510 mm in 1937, at the station in Kőszeg-Stájerházak. However, the amount of precipitation was higher than that in 2010 at the stations on Kékestető and in Miskolc Lillafüred-Jávorkút (1517.5 mm and 1554.9 mm, respectively. [6.8.]

6.4.2 Flood

Hungary's climate is strongly influenced by 3 air currents, which may not be disregarded from the point of view of flood protection:

- Atlantic air current;
- Continental air current (from Eastern Europe);
- Mediterranean air current.

Continental air currents cause drought and heat in summer and long-term cold in winter. The humid air currents from the Atlantic Ocean and the Mediterranean Sea, on the other hand, may moderate the extreme temperatures but may also bring large amounts of rain. These air currents can lead to intense and extensive rainfalls in any period of the year. As a result, heavy and long-lasting floods, as well as inland waters can be expected on any river and in their catchment areas. [6.10.]

From a flood protection perspective, water coming from the melting snow in the mountains surrounding the Carpathian Basin must also be added to the average annual amount of precipitation in the country. [6.11.] The observance of precipitation falling in the catchment areas of rivers coming from other countries is important because our country is situated in the lowest territory of the Carpathian Basin, with 24 different rivers entering and only 3 leaving the country across its borders. Expressed as a percentage, this means that approx. 95 % of surface waters in our country come from abroad, and there are only four rivers that are located within the country in their total lengths. As a consequence, the most common natural disasters hitting Hungary, namely floods, most often originate in other countries.

Flood exposure of Hungary's infrastructure

The rivers in Hungary with the highest flow rate are the Danube and the Tisza. Their tributaries also play a major role from the point of view of flood protection. The water regime of the Tisza and its tributaries (Körös rivers and Maros) is much more extreme than that of the Danube.

This difficult flood situation is further exacerbated by the fact that, owing to its topographical characteristics, 23 % of the country lies lower than the flood protection level of our rivers. To make things worse, the majority of these flood-exposed territories are the most densely-populated and most valuable areas of Hungary. [6.10.] Approx. one-third of the arable lands in the country (1.8 million acres) is located in flood areas. These areas accommodate 32 % of railways, 15 % of roads and more than 200 industrial plants. In addition, there are more than 800 settlements in these regions with a population of 2.5 million, producing 30 % of the GDP. These kinds of flood management problems are unique in Europe. [6.2.] The flood-exposed areas of Hungary are shown in Figure 6.3.

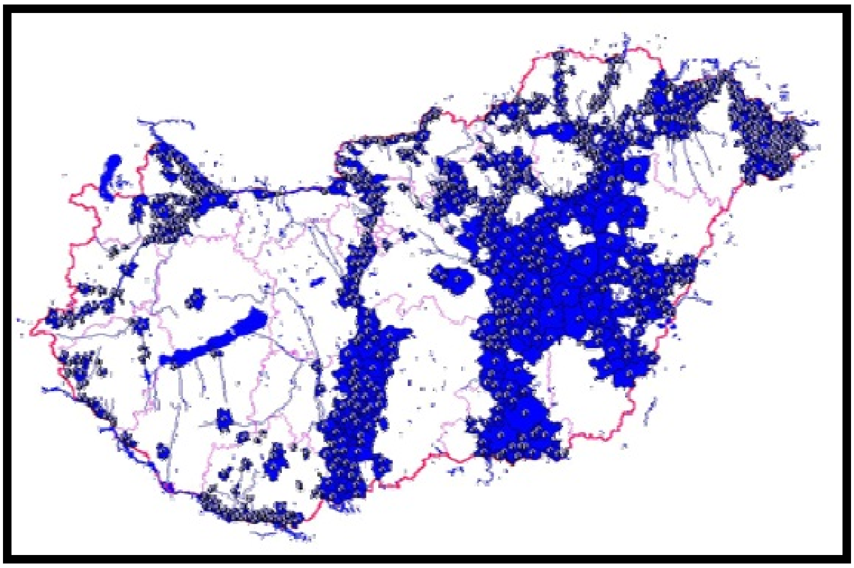

Figure 6.3.: *Flood-exposed areas of Hungary [6.10.]*

Frequency of occurrence of floods

In our country, small to medium floods are expected every 2 or 3 years, large floods every 5 or 6 years, and extreme floods every 10 or 12 years. The duration of large flood waves is 5 to 10 days in the upper and 50-120 days in the middle and lower sections of the rivers. Most of the tributaries are fast-flowing. The great amount of water generated by them appears in larger rivers within 1 or 2 days, causing a one meter rise in water levels within a few hours. [6.2.]

Even through heavy and long-lasting floods may be generated in Hungary in any part of the year, there is some regularity in their occurrence. There are two periods in Hungary with a high risk of flood:

- Ice floods: due to the melting snow, ice drifts, and ice jams;
- Summer floods: due to intense rains in spring and summer.

NAGY ÁRVIZEK MAGYARORSZÁGON 1970-2010

ÉV	HÓNAP
1970	május – július
1974	június
1980	július
1989	május
1998	október – november
1999	február – március
1999	június – augusztus
2000	április – május
2001	március
2002	március
2002	augusztus
2005	augusztus
2006	április 2-10
2006	április 14 – 29
2010	január – június

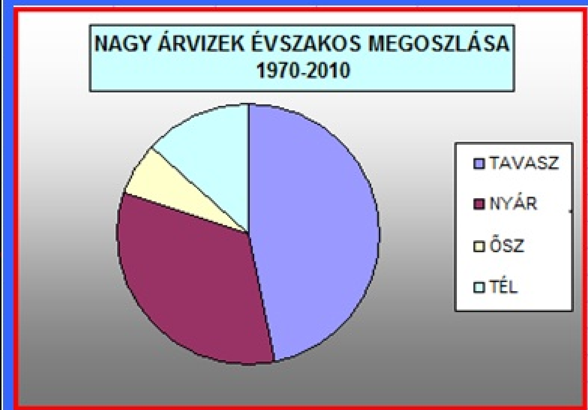

Figure 6.4.: *Distribution of floods in Hungary between 1970 and 2010*[1]

[1] NAGY ÁRVIZEK MAGYARORSZÁGON = GREAT FLOODS IN HUNGARY; ÉV = YEAR; HÓNAP = MONTH; NAGY ÁRVIZEK ÉVSZAKOS MEGOSZLÁSA = SEASONAL DISTRIBUTION OF GREAT FLOODS; TAVASZ = SPRING; NYÁR = SUMMER; ŐSZ = AUTUMN; TÉL = WINTER; május = May; július = July; június = June; október = October; november = November; augusztus = August; április = April; március = March; január = January

High waters on the Danube and the Dráva occur in spring, because of the melting snow, and in summer in case of a large amount of precipitation. According to statistical data from the past 100 years, the largest floods without ice have taken place in the summer.

High waters on the river Tisza, whose water regime is more extreme than that of the Danube, are expected in March and April. However, summer floods occur in July, usually with a lower flow rate compared to the spring floods.

As already mentioned above, the most precipitation in Hungary falls in late spring, early summer. During the summers, extreme rainfalls are also expected, which may be permanent rains or sudden downpours with large volumes of water, primarily caused by the fact that oceanic, continental and Mediterranean climatic effects are all present in the catchment areas of our rivers. Therefore, floods may be generated in any period of the year, although, because most of the rain falls in during the summer, floods caused by precipitation are mostly likely to occur in the summer period. These floods are characterised by their local scope and short duration. Nevertheless, they may cause extraordinary floods. [6.10.] Figure 6.4. shows the seasonal distribution of floods in Hungary over the period 1970-2010.

As you can see in the diagram, the largest number of extraordinary floods occurred between 1970 and 2010 in the spring, and afterwards in the summer. Furthermore, it can be noticed that there were 8 extraordinary floods between 1970 and 2000, and 7 between 2001 and 2010. If we disregard the fact that extraordinary floods may have occurred more than once within a month, this proportion in the period 2001-2010 is more or less equal to the 41-year average.

The frequency of extraordinary floods increased dramatically from 2000 in comparison with the period 1970-2000, without the century-long volumes changing significantly. This leads us to the conclusion that if precipitation occurred, it fell suddenly in large volumes or in the form of extensive permanent rainfalls.[2] Several flood protection records have been broken since 1998, and flood waves now last a lot longer, which gives rise to the conclusion that the already very high water levels were supplemented by large volumes of precipitation falling within a short time, possibly on several occasions, one after the other, within a relatively short period. Alternatively, long-lasting, extensive rainfalls may have occurred.

Since spring floods are generated by the melting snow and spring rains (precipitation of 2 seasons), and summer floods are only caused

[2] Due to the lower amount of precipitation and the growing number of extraordinary floods.

by rainfalls, the number of phenomena brought about by a large amount of precipitation grows in the summer.

The VAHAVA project and the National Climate Change Strategy forecast increasing extremities on our large and medium rivers. According to the estimates, damage arising from floods is expected grow by 20 % during the 21st century, which is already a noticeable level. The forecasts make it clear that the frequency of heavy flood waves with a quick progression will increase as a result of events brought about by a large amount of precipitation on smaller rivers in hilly and mountainous areas. [6.12.]

Devastating effects of floods

We make a distinction between the primary and secondary devastating effects of floods, which are the following:

- Primary devastating effects of floods:
  - The shock wave of water after a dam failure demolishes houses;
  - Humans and animals may suffocate;
  - Surrounding the areas at a higher elevation, its cuts off people living there from the outside world, making escape and access roads unusable;
  - The infrastructure is destroyed, production at industrial and agricultural plants stops.
- Secondary risks of floods:
  - Buildings in permanently flooded areas suffer further structural damage;
  - Epidemics may develop as a result of the decomposition of dead animals;
  - Contamination of wells, public utilities;
  - Production loss negatively affecting the economic situation of the country. [6.11.]

The devastating effects of floods pose a threat to human health, life, the natural environment and the elements of the infrastructure alike. Therefore, effective protection against the damage caused by floods may require government-level measures (announcement of emergency), particularly in the following cases, as defined by the Act on Civil Protection[3]:

"g) in the period of flood protection, if the flooding water is forecast to approach the highest level ever seen, and further significant

[3] Act XXXVII of 1996 on Civil Protection, Art. 2 (2)

flooding is expected, or an unmanageable ice jam is present, or if there is a risk of dam failure"

"a) appearance of a serious pathogen causing the death of several people and leading to a mass infection, if that pathogen comes from human excrement, a corpse containing the pathogen, food contaminated with the pathogen, water, soil, objects, materials, air, animal or animal corpse"

The importance of the implementation of the necessary immediate actions is graphically illustrated by the pictures in Figure 6.5, taken of the great flood in 2010, more specifically the flood of the river Sajó in Felsőzsolca, in June.

Flood protection planning

Figure 6.5.: *Flood on the river Sajó in Felsőzsolca, June 2010*[4] *Photos by Ákos Stiller*

[4] Touching photos of the evacuation during the flood: http://hvg.hu/nagyitas/20100606_kitelepites_felsozsolca_nagyitas (downloaded on 21/03/2011)

In Hungary, flood protection planning is based on the standard flood level, which is in turn based on the greatest flood over the last 100 years or, in the case of the most important river sections, over the last 1000 years. On several rivers, for instance on the Tisza and its tributaries, the highest water levels are continuously changing. This is presumably caused by the formation of deposits in the flood plain, the effects of regional development and climate change. [6.10.]

6.4.3 Inland waters

Inland water is defined as "surface water consisting of rainwater and melted snow, groundwater emerging to the surface, and water leaking through embankments." [6.13.]

Hungary's inland water exposure

From the approx. 3,200 settlements in Hungary, 1,000 are located on lowlands and 2,200 are situated in hilly areas. Due to its natural conditions, our country is exposed to potential damage caused by water almost everywhere. There is a high risk of floods in 40 % of the settlements, while at least some degree of risk is present in 80 % of them. Only 20 % of the settlements are located in areas where water damage is very unlikely to occur. Inland waters are so frequent in the country that only 3 out of the past 57 years have passed without inland waters (1973, 1976, 1990).

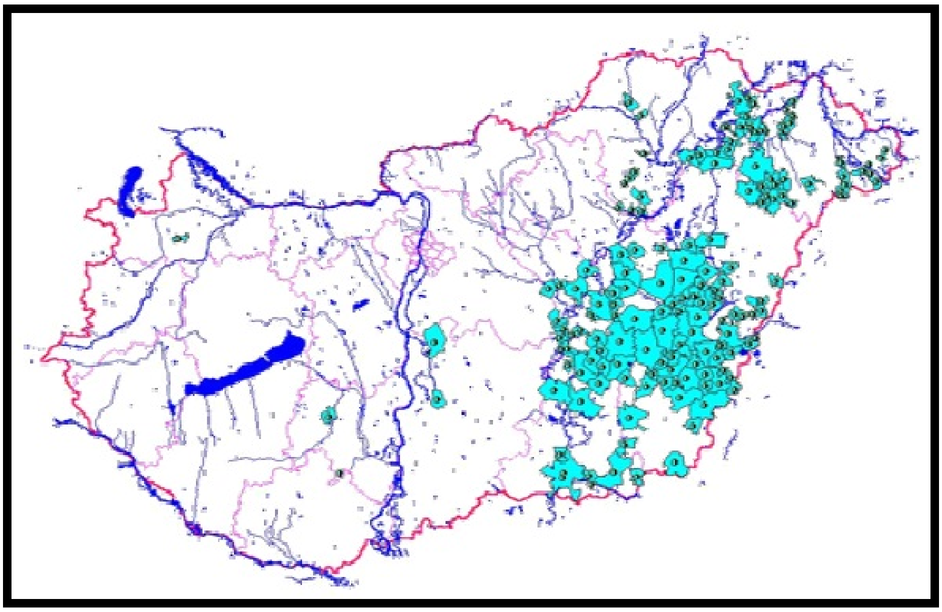

Figure 6.6.: *Hungary's inland water exposure*

Inland waters, a characteristic feature of lowland areas, threaten approx. 45 % of the country to some extent. Hungary's inland water exposure is illustrated by Figure 6.6. [6.13.]

FACTORS OF INLAND WATER RISK	
NATURAL FACTORS	**FACTORS RELATED TO HUMAN ACTIVITY**
Weather elements Excessive precipitation Rapid warming Reduced evaporation	**Agricultural activity** Methods of tillage Silvicultural activity
Soil-related factors Degree to which the soil surface is overgrown Soil frost Soil layers Composition of soil particles	**Technical interventions** River regulations Condition of drainage systems Effects of irrigation River canalisation;
Topographical factors Subsurface water flows Areas without natural drain Size of areas at a low elevation	**Other factors** Changes in land use Inadequacy of engineering activities Effects of built structures

Table 6.1.: *Factors determining inland water exposure [6.13.]*

Factors determining inland water exposure

The inland water exposure of a given region is determined by a number of natural and human factors, which are summarised in Table 6.1.

Natural and human factors exert a joint effect on the inland water exposure of a specific area, in different combinations.

From the various factors of inland water exposure, the most important one is the improper use of the given area, manifesting itself in inappropriate agricultural and silvicultural operations in the outskirts, and in populating areas situated at lower elevations within municipal boundaries. A quarter of the area of our country consists of lowlands from which water cannot naturally drain.

Surface floods appearing in agricultural areas are the consequences of natural water flows and artificial canals, as well as the poor condition of drainage facilities in areas exposed to inland waters and the rising level of groundwater.

The risk of inland water floods is increased by the fact that several settlements are not appropriately equipped with sewage facilities, or if such facilities are present, they are not properly maintained. In a nation-wide context, drainage facilities are not adequately maintained, and 2/3 of them need to be renovated.

As a consequence, a large amount of precipitation floods lower areas, since the network of canals or ditches serving to drain off the water is unable to collect and lead away the accumulated water.

High groundwater levels and heavy rains or series of rains may lead to long-lasting inland water floods in the lower areas of settlements. Inland water soaks the walls of houses, which then become instable as they dry out. This accelerates the amortisation of buildings, which ultimately become uninhabitable.[5]

Under certain circumstances, intense rainfalls may result in a severe inland water situation in the winter period as well. This is what happened in Eastern Hungary in 2005, when, as a consequence of rainfalls during the summer and the autumn, the soil became so saturated that is was unable to take in the large amount of precipitation suddenly falling in January 2006 and the water coming from melting snow. To make things worse, the escape of water in the soil was hindered by the frozen ground. In addition, the constantly damp, overcast and cold weather also prevented the water from evaporating. This situation was further exacerbated by intense rains throughout the month. The combination of the above led to the most severe inland water situation over the past decades.

The alternation of warming/cooling/snowfall and the rains during the spring and in early summer resulted in the recurrence of the same events.

As a big problem, the majority of those affected by the risk of inland waters fail to take measures even for the basic protection of buildings (cleaning of ditches and culverts), most probably because they hope to receive housing assistance or compensation from the state. The lifetime of foundationless adobe houses built 40-50 years ago is approaching its end, their tolerance against inland waters has dramatically decreased. This will require more active participation from the national and local governments in the near future with respect to compensation. [6.2.]

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[5] Medium-intensity but long-lasting rainfalls may lead to the same problems as large volumes of rain falling within a short period of time.

Figure 6.7.: *Inland waters in Rábagyarmat, 29 June 2009 Photo by: Viktória Németh [6.13.]*

Devastating effects of inland waters

The devastating effects of inland waters are similar to those of floods:

- Destroyed seeding or delayed cultivation, uncertain agricultural output;
- Risk of epidemics and infections;
- Contamination of water in dug wells;
- Flooding of cemeteries;
- "Rinsing" of wastewater storage pits;
- Buildings becoming ruined and uninhabitable;
- Soil erosion in cleared forest areas due to rain and unfavourable inclination conditions.

Similarly to floods, inland waters also pose a threat to human health, security, the natural environment and the elements of the infrastructure. Therefore, effective protection against the damage caused by inland waters may require government-level measures (announcement of emergency), particularly in the following cases, as defined by the Act on Civil Protection[6]:

"a) appearance of a serious pathogen causing the death of several people and leading to a mass infection, if that pathogen comes from human excrement, a corpse containing the pathogen, food contaminated with the pathogen, water, soil, objects, materials, air, animal or animal corpse"

j) in the period of inland water defence, if the inland waters threaten inhabited areas, industrial areas, major roads or railways, and further floods are expected."

The devastating effects of inland waters are illustrated by Figure 6.7, showing a photo taken on 29 June 2009 in Rábagyarmat after a downpour. A part of the settlement was flooded by the water running down from the hills around it. The situation was further exacerbated by the flooding of the brook Rábagyarmat. [6.13.]

Managing inland waters

In addition to endeavours within the country, the management of inland waters largely depends on the transformation of the landscape beyond our borders as well, including activities related to river regulation and silviculture. This means that the Hungarian inland water situation can only be effectively managed if the characteristic features of the Carpathian Basin are taken into account, and only in cooperation with the neighbouring countries.

6.4.4 Hail

Hail is usually an accompanying phenomenon of heavy thunderstorms (and therefore local in nature), with wind storms. It occurs when updrafts in a thunderstorm transport raindrops into the extremely cold layers of the atmosphere, and the drops freeze there to a solid state. The hailstones formed in this way fall on the ground with a downdraft of the storm. Hailstones are almost always formed in a hail storm, but in most cases they melt by the time they reach the ground. Whether hail is generated depends on the size the hailstones reach in the cloud. After a certain size threshold, hailstones can no longer melt while they are falling. The more intense a thundercloud is, the bigger are the hailstones reaching the ground. Typical diameters of hailstones are the following in Hungary:

- Size of a wheat grain (3-4 mm);
- Size of a pea (5-8 mm);

[6] Act XXXVII of 1996 on Civil Protection, Art. 2 (2) (a), (j)

- Size of a hazelnut (9-12 mm);
- Size of a cherry (13-18 mm);
- Size of a walnut (19-25 mm);
- Size of a golf ball (26-35 mm);
- Size of a tennis ball (36-50 mm). [6.11.]

The months with the highest risk of hail in Hungary are April (15 % likelihood), May (21.9 %), June (22.2 %), July (19 %) and August (13 %). The frequency of hail in September is approx. 6 %, in February 0.8 %, in March 1.4 %, as shown in Figure 6.8. [6.14.]

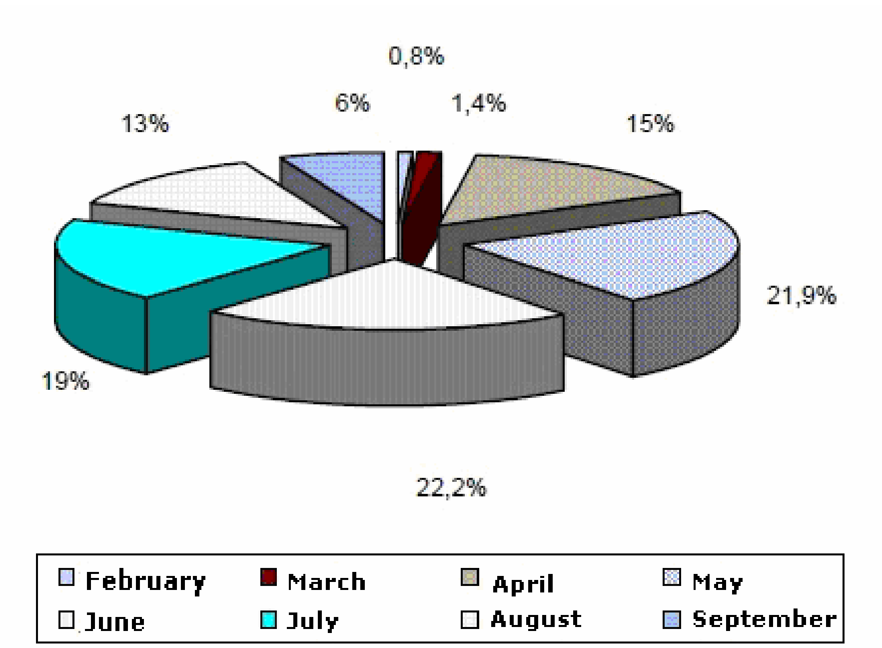

Figure 6.8.: *Frequency of occurrence of hail in Hungary*

According to statistical data, hail most often occurs in the summer months.

In addition, hail may be an accompanying phenomenon of other devastating weather events like supercell storms. Supercells are differentiated from other storms by their rotating updraft. The low air pressure associated with this strong updraft is called a mesocyclone. However, a mesocyclone itself does not necessarily indicate a supercell, it may also be formed in the event of heavy thunderstorms.

Devastating effects of hail

The devastating effects of hail are graphically illustrated by the event that occurred on 18 June 2010 in Mezőhegyes and in the neighbouring settlements, as shown in Figure 6.9.

In the afternoon of 18 June 2010, Mezőhegyes and the neighbouring settlements were hit by a storm accompanied by very strong wind and hail. The hailstones were the size of a glass marble.

The storm completely destroyed the crop in the biggest agricultural plant of the region (Ménesbirtok Zrt.) and caused extensive damage in the built environment. Electricity and telephone services were out, and personal injuries also occurred. Roofs were ripped off by the wind in entire streets and trees fell down, with only a few left, but even those without any leaves.

Figure 6.9.: *Hail in Mezőhegyes, 18 June 2010 [6.12.]*

The wind toppled trees, tearing out their roots, near the community centre, where a gastronomic festival called "Lángosolimpia" would have been held, but it was cancelled in time. However, a show jumping contest was already going on when the storm arrived. Because the racecourse was in an open field, the visitors had no chance to escape. 4 people were severely injured by the hail, and 7 or

8 suffered slight injuries. They were carried away by the ambulance. Many of the bolting horses were also injured, and 2 of them had to be narcotised.

Ménesbirtok Zrt. performs its agricultural activity in an area of 8 thousand acres, from which over 5 thousand is continuously irrigated. The hail damaged the plants to such an extent that it was impossible to recognise the types of seed that had been sowed, and the irrigation system was also destroyed. There was 100 % damage.

Furthermore, as a consequence of the storm, power lines were torn down, there was a blackout in the town, and there were interruptions in the telephone service.

The 20-25-minute hail damaged 400 properties, from which 120 were residential units in a housing estate, mostly with broken windows. Local government institutions also suffered severe damage, including the school and the primary care centre. Also, the hailstones broke the windscreens of several cars and damaged a lot of car bodies.

It is estimated that the damage of the residents and the agricultural plant amounted to approx. HUF 100 million and one billion, respectively. The mayor did not initiate a procedure for declaring the town a disaster-stricken area but submitted a force majeure application. There were no uninhabitable properties but the damage was so extensive that the town would have been incapable of performing the restoration from its own resources. The hail was so powerful that 2 hours after the storm the streets were still covered by a 15-20 cm thick ice sheet. [6.12.]

Anti-hail system in Hungary

"The idea of preventing hail conceived as early as in the late 1940s. It was Frigyes Dési who first argued publicly for practical implementation on 8-10 September 1965 in his opening speech at a cloud physics conference organised by the Meteorological Society. In the following year, at the opening ceremony of the 38th general assembly of MMT[7] on 27 January 1966, Dési introduced the research agenda of OMI[8]. Quick implementation was hindered by legal, financial, organisational, licence and other similar problems. The process of establishing the national anti-hail system, which was controlled from Budapest until 1975, was delayed for many years. The Anti-Hail Coordination Committee was created to accelerate the slow progress. The majority of the necessary facilities had been established

[7] Hungarian Meteorological Society

[8] National Meteorological Institute

by spring 1975, by which time the required devices, rockets, stands, radio network and radars were had also been acquired. The first rockets were fired on 7 May 1975. At the opening ceremony, 1 Oblako and 4 PGI-M anti-hail rockets were launched. The service was started with 11 launch stations, and the first independent active intervention took place on 16 July 1975.

There were some problems, though. For example, the southern border of the experimental area was identical with the southern border of the country, so it was problematic to influence the thunderclouds arriving from south-southwest (Yugoslavia), which were already in a fully developed state. However, the defence activities could not target the border zone due to inter-state treaties. The anti-hail experts of the two countries prepared a cooperation agreement, which could have provided a solution without violating the borders. The main idea of the agreement was to establish a radio network between the two parties performing active anti-hail activities, which serves to request the other party to start to prevent the hail forming over its territory at the expense of the requester. Although the agreement was signed by the delegates of the two countries on 2 March 1978, activities based on the principles laid down in it never took place.

This anti-hail system was in use for several years. In the meantime, the system in Baranya county was finalised, and a similar system was established in Bács-Kiskun county in the mid-1980s. The Oblako rockets were meanwhile replaced by the more efficient Alazany-2M rockets with a self-destruct mechanism.

After many years of operation, the financing contract of OMSZ with Állami Biztosító (National Insurance Company) was terminated in 1989, and the two anti-hail systems were gradually decommissioned. In the meantime, more and more evidence was found for the applicability of ice-forming seeds transferred into the near-surface layer. The efficiency of earlier anti-hail activities was confirmed by several observations. The personnel of launch stations detected the presence of snow and slush instead of ice-stones several times after interventions, even on the hottest summer days. This means that the system was really useful during those years. Finally, anti-hail activities in Baranya were not terminated completely. The NEFELA Association for Hail Suppression in Southern Hungary, founded in 1991, is still active, using French technology: in situations where there is a risk of hail, ice-forming seeds are transferred into the near-surface layer using an aerosol generator network (OMSZ, 1995). [6.16.]

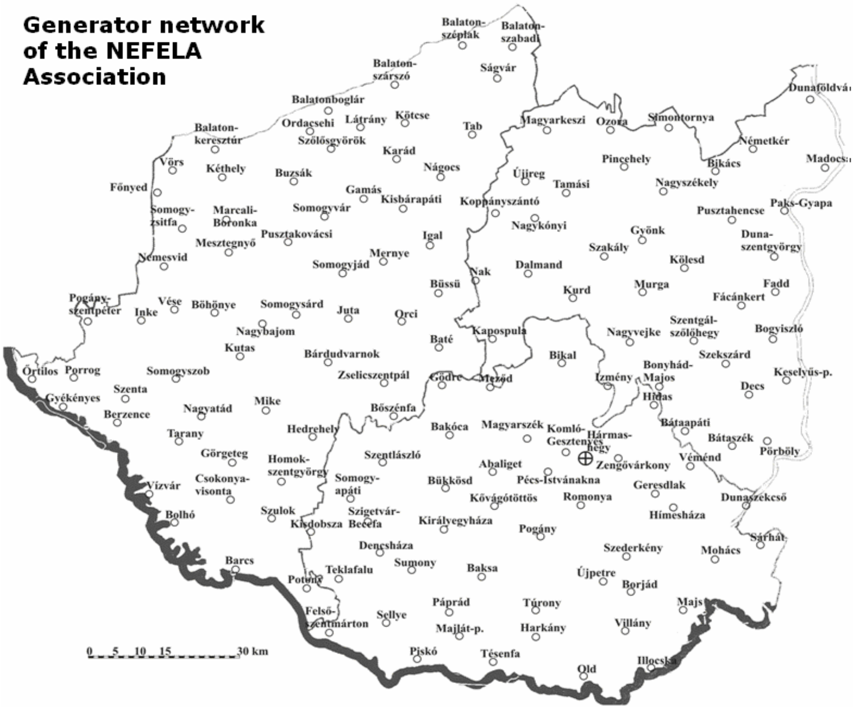

Figure 6.10.: *Area covered by NEFELA*

The map shown in Figure 6.10 indicates the stations belonging to NEFELA's network. It is visible that the system protects almost the entire territory of Somogy, Tolna and Baranya counties.

As explained above, the prevention of hail through appropriate technology is not a recent idea. Hungary has a fully functional anti-hail system in the territory of the Transdanubian Hills. The fact that NEFELA exists and functions is quite promising, and in my opinion a system with similar technology should be established throughout the entire territory of the country. Further information on NEFELA's network can be found on their website. [6.17.]

This issue is being addressed in other areas of the country as well. The researchers of the University of Debrecen tested an ice cannon developed in Belgium, which transmits the shock wave of a gas explosion into the atmosphere. [6.18.] Its operating principle is based on the fact that a shock wave mixes air masses with different electric charges and temperatures. This results in a lower likelihood of hail.

According to media reports, already seven such structures are used by different enterprises. As an important characteristic of the cannon, it is capable of covering an area of eighty acres and can be operated remotely; it can be activated or deactivated with a simple telephone call or an SMS message. [6.18.]

The operating principle of anti-hail cannons is based on the idea that the shock wave of a powerful and concentrated explosion, generated in the explosion unit of the equipment using a mixture of acetylene gas and air, is transferred by the gun barrel into the atmosphere. Mixing air masses with different electric charges and temperatures, the shock wave eliminates or mitigates an important condition of hail generation and limits the formation of ice particles. This effect is exerted at a height of 5-10 km in a circle with a diameter of a few kilometres. Projected to the surface of the earth, this affects an area with an approx. 500-600 meter radius, protecting fruit plantations in territories as large as 80 acres.

Due to the global climate change, hail is currently the weather condition that poses the most threat to fruit crops. At the Research and Development Institute of the Centre for Agricultural and Applied Economic Sciences of the University of Debrecen, experts have been conducting research into possible protection methods and systems for one and a half years. Their findings confirm that anti-hail cannons may provide a solution for horticultural businesses in the fight against hail. The main advantage of the equipment is its ease of use, as well as the fact that it does not require any special knowledge and that it can be activated or deactivated manually or from any distance with an SMS message or a telephone call. As another argument for the cannons, their investment cost is relatively low, amounting to HUF 150-400 thousand per acre, depending on the size of the area that needs to be protected, while the installation costs of an ice net are about ten-times as high. A further benefit is that it can be used, in addition to plantations, to protect greenhouses, foil tents or other high-value and vulnerable structures. [6.18.]

Based on the above, we have good reason to declare that the problem of hail protection must be addressed, and it is an issue to deal with. The different private projects are promising, but are not able to provide uniform protection. Presumably, there will be areas where the owners cannot or do not want to take the necessary action for the prevention of hail. This is why central regulation would be very desirable.

6.4.5 Freezing rain

The phenomenon when falling raindrops immediately freeze after they have reached the ground or any other object, forming a coating with a silvery glimmer, is called freezing rain. *"Freezing rain is most often formed when, within an air layer with a temperature below 0 ºC* *in its total thickness, a warm air mass penetrates between the lower edge of the clouds and the frozen soil. As the snowflakes fall through this warm layer, they melt partly or completely. The precipitation reaches the surface of the ground in the form of graupel or freezing rain, depending on whether the particles had enough time to freeze into ice or not. In the latter case, the droplets are supercooled (meaning that their temperature is below their freezing point), and when they hit the surface of the ground or another object, they freeze into solid ice with a silvery glimmer. The greatest damage is caused when there is a big difference between the temperature of the cold and warm air masses on the two sides of the warm front bringing the freezing rain. In that case, the freezing rain may be followed by a heavy ice storm... "*[6.19.]

The time of the year when freezing rain may occur is the winter season. The ice coating formed on the surface of the streets and pavements presents a major threat to elderly people, who are often no longer able to recover from a bone fracture. In addition to that, it prevents the safe flow of road traffic and leads to mass accidents. [6.20.] Furthermore, it makes the timely arrival of emergency services at the location of accidents a lot more difficult. Power lines may also be torn down, and trees may fall due to the weight of the ice sticking on them.

In the morning of 14 January 2009, OMSZ issued a red alert for 4 regions (Southern, Western and Middle Transdanubia and Central Hungary) because of the heavy snowfall and ice accretion. Large numbers of cars slid into one another and several people were hit by cars.

Delays of 10-15 minutes occurred in rail traffic due to the weather conditions in Zala, Vas and Veszprém counties. The ambulance was called on 36 occasions due to broken arms or legs only in Veszprém. In Zirc, an ambulance worker suffered an accident on the icy road while caring for a patient, and had to be taken to hospital. In Bács-Kiskun county, a biker and a pedestrian were hit on the icy streets, and five people were injured in a car that had slid into a ditch. Cars skidding on the ice coating also ran over pedestrians in Kiskunmajsa and in Kecskemét.

There were 6 accidents on the roads of Győr-Moson-Sopron county, with several injuries. Kisalföld Volán Zrt. suspended its bus services for security reasons. In addition to long-distance coaches, Kisalföld Volán Zrt. suspended local services too in Győr and in Sopron. Also, a semitrailer carrying hazardous materials fell into a ditch between Csorna and Szil, causing traffic restrictions. [6.21.]

6.4.6 Intense snowfall, blizzard

Snowfalls and snow drifts are natural phenomena in the winter period, capable of resulting in disastrous situations already in case of a relatively low amount of snow, hamstringing entire settlements, or even regions. Due to the intense snowfall and the snow drifts, settlements with a dead-end structure[9] may be cut off from the outside world, preventing the transportation of sick people and food by road.

Freeing these settlements is even more difficult if they are situated in a distance from one another and from the highways, meaning that they need to be freed one by one, which requires significant human and equipment resources. It is necessary to ensure the transportation of sick people and food, and the rescue activities may require the use of helicopters and the defence forces (along with their equipment). The risk of snow drifts must be taken into consideration in the entire territory of the country with a frequency of 3-5 years. [6.21.]

The Government may announce an emergency situation because of the intense snowfall or blizzard in the following cases:

"h) continuous, intense snowfall lasting for more than three days

i) unusable railways, highways and at least five side roads within the same region"[10]

As demonstrated by Subsection (i), intense snowfalls or snowdrifts may, in addition to road transport, also hinder rail transport. In the context of road transport, snow banks, collisions and a traffic chaos may be generated, which may negatively affect goods transport and emergency services. The response time of emergency services may significantly increase, in certain cases resulting in lost lives. The situation may be exacerbated if settlements are cut off from the outside world, because in this case the emergency services will not be able to access the relevant location, or will arrive with a considerable delay.

In 1995, for instance, there was an extreme snowfall in Békés county, as a consequence of which several smaller settlements were cut off, highways and side roads became unusable, and there were disturbances in supplies to the population. [6.22.]

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[9] Those that can only be accessed from a single direction. Without any transit traffic (road or railway).

[10] Articles 2 (2) (h), (i) of Act XXXVII of 1996 on Civil Protection.

6.4.7 Wind storms

In Hungary, wind conditions are determined by two factors. One of them is general air circulation, the other one is the basic current. The general air circulation comes from the northwest, which can primarily be felt in Transdanubia and in the Danube-Tisza Interfluve. However, in the Trans-Tisza region, air currents come from the northeast. The most windy area is the Little Hungarian Plain, the Trans-Tisza region is more moderate in this respect, while the Transdanubian Hills are the least windy areas of the country.

The usual wind velocity is 2-4 m/s (5-12 km/h), but values much higher than that may also occur, called gusts. The average values of gusts have been between 20-40 m/s (72-144 km/h) over the past few decades. However, a gust of 100 m/s was measured in 1924 in Bia, which broke down a smoke stack. In this case, the expressions tornado, typhoon or hurricane were used in the reports, rather than gust, justified by the type and speed of the wind. The frequency of wind storms may be as high as 30-40/year in Hungary. Wind storms may occur in themselves, but are also often the accompanying phenomena of thunderstorms. [6.23.]

Wind storms may lead to mass panic at large events frequently organised during the summer (when they arrive unexpectedly), potentially resulting in the death or injury of several people.

6.4.8 Extremely hot weather

The consequences of climate change manifest themselves in increasingly obvious forms, including health consequences. The analysis of health effects was also considered as a key point at the 3rd Ministerial Conference on Environment and Health, organised in 1999 in London. The World Heath Organisation (WHO) shaped its agenda on the basis of the recommendations included in the Final Statement of the Conference. The Hungarian national research agenda was developed accordingly within the framework of the National Environmental Health Action Programme (NEKAP) from 2000. This project included the assessment of the direct health-impairing effects of climate change by summarising death and meteorological statistics in Budapest between 1970-2000. The findings showed that each heat wave[11] caused 30-100 more people to die in Budapest. According to measurements so far, the number of extremely hot days is increasing in Hungary. 6 heat waves reached Hungary between 1992 and 2000, with a total of 27 very hot days. However, there were 14 heat waves between 2001 and 2008, with 57 very hot days. [6.24.]

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[11] If the average temperature exceeds 26.6 °C [7.38] for more than 3 days

After NEKAP, within the PHEWE research programme supported by the European Union, a medical meteorological forecast system (a system of heat alerts) was established in 2004 and then tested in 2005 in Budapest, which was later extended throughout the country and is still in operation. [6.25.]

6.4.9 Extreme shortage of precipitation (drought)

"A drought means a period in which the amount of precipitation is far below the average, or, even if the total amount of precipitation reaches the average value, evaporation loss from the soil increases significantly due to the high temperature, and therefore, permanently dry weather occurs, and the shortage of precipitation prevents plants from normal development, sometimes even causing plants to die."[6.10.]

Because protection against drought is not a standard task of disaster management, it is only covered briefly in this document.

The shortage of precipitation and drought hit our country several times during our history. It was always followed by famine and mass animal deaths. This is what happened in the 19th century. The most severe drought took place in 1863 in most of the Great Plain, as a result of which the crop was totally destroyed and livestock died in large numbers. Attempts were made to drive the animals to Transdanubia, Upper Hungary and Transylvania to avoid their starving to death, but in vain. People suffered from famine, and it took years to make up for all the loss incurred due to the drought.

In Hungary, droughts almost always affect the whole country, at least indirectly, but the areas mostly influenced are those in the flatlands. Damage caused by them may reach, or even exceed, that arising from inland waters due to the longer development and decay periods.

As a major difference between dry weather and drought, the former means a constant state with a low amount of precipitation in some regions of the Earth, the latter (drought) refers to a temporary state. The consequences of permanent drought follow one another in the following sequence: lower groundwater level, transformation of soil-forming processes, change in plants, modification of surface-forming processes.

Based on earlier experience, drought can be expected in Hungary in 4 out of 10 years. Drought occurred in 3 years between 1976-1985, and in 7 years between 1986-1995. As a consequence of the global climate change, our country is experiencing a process of desertification. All around Europe, Hungary is the most exposed to the reduction in the amount of precipitation. According to the classification of the UN Convention to Combat Desertification (UNCCD), the total territory of our country must be regarded as a drought-stricken area. Groundwater levels in the Danube-Tisza Interfluve fell by 6-7 meters compared to the original value. [6.10.]

Based on the research findings of the VAHAVA project, the National Climate Change Strategy also foresees an increase in the length of dry periods, as a result of which the water surface of smaller lakes and cutoffs in the Great Plain and in the Danube-Tisza Interfluve may dramatically decrease, or they may even dry out completely. Moreover, within a few decades, the water levels of rivers in Hungary may fall to half of the current values during summers. And due to the lower volume of water, the self-purification ability of waters may also decrease, leading to a slower decomposition of certain contaminants, which would negatively influence water quality. Furthermore, as a consequence of increasing average temperatures, the temperature of surface waters will also grow, which may entail the eutrophication of rivers and lakes[12]. Measurements have confirmed that there has been a continuous increasing trend in the temperature of our rivers and lakes since the last century. [6.23.]

Due to global warming, a rise in average temperatures and an increasing frequency (and duration) of extreme heat waves and droughts can be expected in Hungary, leading, among other things, to a higher likelihood of occurrence of fires generated in nature. Warming will not only increase the frequency of fires, but also their devastating impacts, resulting in higher propagation speed and intensity, which will make the work of fire departments a lot more difficult. Nevertheless, problems more important than the rising number of natural fires must also be expected.

The increase in average temperatures and in the number of droughts will present a major threat to the drinking water resources of our country because, as described above, a dramatic fall in the water levels and the eutrophication of our rivers and lakes is expected, which will affect water quality. In addition, as a consequence of global warming, our subsurface water resources are also expected to decrease[13] because of the lack of supplementary supply and the increasing evaporation. This means the negative consequences of climate change will, on the one hand, lead to a fall in the amount of available water, on the other hand, to a deterioration in quality. Due

[12] “An excessive accumulation of nitrogen in rivers, lakes and seas. This promotes the development of algae and bacteria that will use up the oxygen in the water, which will therefore become unsuitable for accommodating fish and other living organisms.” In: Új alapismereti kislexikon, Alföldi Nyomda Rt., Debrecen, 1997, p.170.

[13] Public utility water supply is 90% based on subsurface waters. (NÉS p. 61.)

to its peculiar hydrological situation (rivers coming from abroad), Hungary's biggest problem in the future will be access to clean drinking water, as confirmed by the forecast of IPCC.

A drought is a special type of natural disaster, since, in contrast to other disasters, its devastating effects do not arise immediately and unexpectedly, but slowly and gradually. The devastating effects could be partly prevented, through better water management and by improving agricultural irrigation techniques, and partly mitigated, but this would necessitate huge long-term investments. [6.10.]

6.5 Possibilities for preventing or mitigating damage to the critical infrastructure

Changes in the climate threatening the critical infrastructure must be analysed from various perspectives. These affect partly the locations where the resources interconnected on the basis of its functions are generated and the availability end-points. Another area of failures and outages, also threatening security to a large extent, is the crash of the technological system itself, as well as the environmental damage caused by it. A third aspect, which requires the most in-depth analysis, is the detection of the nature of risks arising as a consequence of interdependencies.

Based on the above, effects on the security of supply must be analysed if:

- raw materials, products or services (hereinafter resources) cannot be supplied to the users via the critical infrastructure ensuring their availability because the change in environmental weather conditions prevents this;
- even though the source side is securely available via the critical infrastructure, the system that has already been functionally damaged can no longer deliver it to the users due to the outage occurring because of the climatic extremities;
- weather conditions capable of causing damage to the system providing protection against the negative environmental impacts of a dangerous technology or resource used for the operation of the critical infrastructure; or
- disturbances arise in the operation of a critical infrastructure depending on other infrastructures due to exposure to the above-mentioned extreme weather elements.

In the context of the protection of critical infrastructures, the increasing effects of climate change appear as a new and more and more important aspect, augmenting their vulnerability. The likelihood of malfunctions resulting from extreme weather events is expected to increase in road and rail traffic with respect to electricity supply (damage to power lines), drinking water supply (damage to water resources) and, in connection with these, public supply and info-communication [6.26.] [6.27.].

Extreme weather events may trigger a domino effect in road and rail traffic. The consequences of a few minutes of power failure exert an effect not only locally but may also reach a regional, national or even international level. Power failures in Western Europe in previous years provide useful experience in connection with the tasks to be performed in this respect. In 2003, 30,000 passengers were trapped in the open lines, and arrangements had to be made to tow them to the closest stations. Addressing such extraordinary situations is made even more difficult by the fact that the effects appear, directly and indirectly, in several sectors simultaneously.

Extraordinary weather conditions may cause the events described above by:

- directly affecting the physical elements of critical infrastructures;
- triggering an environmental change that cannot be prevented either in the planning period prior to establishment or by the security system serving to address critical situations.
- Accordingly, based on the predicted climatic changes, the effects of the following must be analysed in the context of threatening the operational continuity of critical infrastructures:
- extremely large amount of precipitation;
- stormy wind;
- extraordinary change in temperature;
- other radiations originating in extremely intensive natural sources (e.g. solar flares).

Special attention must be paid to the fact that these weather parameters, which are dangerous in themselves, may induce further risks by triggering large-scale changes in other environmental elements.

For instance, an intense precipitation zone may trigger flood waves along surface waters that could even threaten the stability of embankments or, at worst, cause floods. Landslides that often accompany heavy rainfalls may have a similarly significant impact on critical infrastructures.

Permanent heat waves are equally dangerous to those critical infrastructures that may be rendered unusable due to structural damage. Water shortages accompanying heat waves not only prevent technological water withdrawal in infrastructure facilities requiring heat extraction but may also reduce the quantity of drinking water.

Critical infrastructures have been analysed in Hungary by the National Disaster Management Directorate since 2001, mainly focusing on residential supply and the security of settlements. In the context of a key annual function that has become part of its internal norms, the Directorate examines the condition of electricity, gas and drinking water (wastewater) services as crucial supplies to residents, the various forms of transportation (road, rail, water, air), telecommunication, information networks, energy supply (electricity, fuel, coal, gas and district heating), as well as flood-control facilities.

The climate change may amplify the above phenomena, leading to an increasing risk of damage to critical infrastructures. The expected effects of climate change in Hungary are the following [6.28.]:

- Summers will become hotter and drier;
- Winters will become more moderate and rainy;
- Extremities and extraordinary weather phenomena;
- More heat days and fewer frost days are expected;
- The risk of severe droughts and floods will increase simultaneously;
- More frequent and heavier storms are expected.

It can be concluded that the climate change is a phenomenon increasing the frequency of disturbances in the operation of critical infrastructures. However, this effect may be further intensified by certain circumstances. These include failure to perform costly maintenance activities necessary to prevent or remedy damage arising from the more and more frequent hectic changes in weather conditions or from the occurrence of intense weather events; furthermore, in the context of operational continuity, reduced attention to the operability of security structures in order to reduce costs weakens the essential elements of infrastructures, which therefore cannot always meet the increased demand arising from recurring crises and the expectation of continuous availability.

Other elements of the critical infrastructures are already mostly operated at maximum capacity, which is often unable to meet the increased requirements resulting from the critical situations caused by weather anomalies.

Under certain circumstances, on the basis of interdependencies, developments that are lagging behind the increasing rate of demand also delay the modernisation of other critical infrastructures with an appropriate financial background, thereby becoming obstacles to societal development or even the operability of society.

Due to failure to take the necessary measures for the mitigation of risks on the source and consumer sides, there will be more and more difficulties in managing the critical situations resulting from interruptions in operational continuity.

To address some of the problems that are already present:

- Minimum requirements must be set up for critical infrastructures with respect to factors influencing operational continuity and availability.
- A funding system providing an appropriate financial background must be established in order to improve the conditions causing the reduced operability of critical infrastructures.
- In the case of the climate change-dependent segments of critical infrastructures, changes in weather impacts must be included in the regular reviews conducted for operational continuity planning.
- The modification effects of climate change must be integrated in the measures and programmes for the protection of critical infrastructures.
- Critical infrastructure elements potentially affected by the detrimental effects of climate change must be identified.
- In accordance with the relevant climate models, risk assessments must be performed to identify the measures to be taken for the continuous and secure operation of critical infrastructure elements.
- Common mechanisms must be established for the protection of critical infrastructures with global and regional interdependencies, in alignment with national protection structures.
- While planning the protection of the life and property security of the population, the necessary reserves and the possibilities to use alternative solutions must be expanded.
- As far as the critical infrastructure is concerned, potential capacity shortages are also expected due to large numbers of people arriving from areas hit by the climate change, so-called climate refugees.
- The challenges of global climate change must be incorporated in the institutional and technical development concept of emergency systems.
- The tasks, rights and competences of the state, local governments, owners and operators must be determined in

the context of maintaining, operating and protecting the critical infrastructure.

- The population must be prepared to ensure that, in the event of extraordinary situations, the number of victims and the amount of damage can be kept as low as possible.

6.6 Efficient disaster management response to the challenges of climate change

My research is primarily aimed at mapping the responses and solutions to the new types of climate change challenges appearing in disaster management. The most important corrective actions are the following:

- Strengthen skills by improving funding in protection sector organisations, increasing the number and raising the qualification of personnel, providing training and state-of-the-art technical equipment, carrying out management and organisational changes;
- Thorough preparation of the components (organisations, leadership) of protection management for addressing the new (increased) types of risks caused by climate change;
- The changed conditions arising from climate change necessitate a revision of the system of protection-related institutions, with special regard to disaster management specialisations. Society is more and more aware of the consequences of climate change, to which adequate response must be given by providing appropriate disaster management services.

It is recommended to review the Hungarian and broader (regional, international) disaster management environment, particularly the supporting or inhibiting factors arising from the internal and external environment for the development of the system:

Internal supporting factors:

- The problems are scientifically known, there is an established methodology for the measures to be taken;
- Hungary’s disaster exposure is lower than the world average (except floods and inland waters);
- Properly structured and competent protection bodies are working today in Hungary on the elimination of emergency situations.

Internal inhibiting factors:

- Financial difficulties;

- Insufficient number of personnel;
- Lack of state-of-the-art technical equipment;
- Inappropriate dislocation of forces;
- Lack of proper planning and preventive measures;
- The occurrence and chronology of changes can only be guessed based on models, and the lack of experience causes difficulties in preparation and presents the risk that certain consequences are not properly taken into account today.
- Feeling of security in society. The whole of Hungarian society, including the intellectual sphere, does not perceive the risks related to climate change as a real security threat.

External supporting factors:

- Hungary has a well-established network of relationships in the protection sector, and we are members of the largest military (and political) organisation in the world.

External inhibiting factors:

- The natural (and civilisational) disasters, arising as the environmental effects of climate change with an increasing intensity, badly hit certain countries in the region with scarce resources and an underdeveloped economic system.
- Due to its geographical characteristics, Hungary is particularly hit by negative environmental and civilisational effects originating in other countries of the Carpathian Basin, including water and air damage, or potential disasters.
- Our network of cross-border relationships is still insufficient in the area of infrastructure and disaster management, especially regarding micro-regional bilateral assistance agreements.

In this respect, special importance must be attached to the research of the possibilities of emission reduction. In the context of infrastructure and disaster management, the emission of greenhouse gases is particularly problematic because the operation of elements requires a vast amount of energy. The generation of this energy indirectly contributes to the increase of the concentration of greenhouse gases (if it is produced using a fossil energy source). Objectives set [6.29.]:

- Satisfy a higher and higher share of energy demand using renewable energies;
- Reduce energy demand by migrating to more modern and environmentally friendly user technologies;

- Modernise logistic supply systems in order to reduce specific fuel consumption.

6.7 Summary

Research into the process and expected consequences of climate change gives rise to serious scientific debates these days. New studies, analyses and evaluations appear each day worldwide. Some of these sound the alarm bell, others attempt to prove that the process does not represent a long-term threat to mankind.

Findings from the near past definitely confirm tat weather extremities are becoming more and more frequent and intense in Hungary. Taking into consideration the fact that our climate sensitivity at the current socio-economic level of development is a lot higher than, say, a few decades ago, it is obvious that the best thing to do is to prepare for the more efficient management of severe meteorological disasters.

An in-depth review of the increasing negative consequences of climate change is clearly an advantage in terms of establishing a more efficient prevention system and mitigating potential detrimental effects.

The analysis of the natural phenomena, and their consequences, described in this study provides a sound basis for the identification of the areas where protection against such disasters needs to be improved. My proposals in this respect, as well as the review of the corresponding supporting and inhibiting factors are only a first step towards improving the status quo. The further detailed study of the subject may yield important results, which may directly contribute to the better protection of the population, our material assets, and our resources.

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