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Climate Adaptation in Terms of Water Security in the Danube Countries[1]

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In my article, I examine the characteristics of the Danube countries' adaptation to climate change in terms of water security. Among the international strategic documents, I examine the EU Water Framework Directive (WFD, 2000), the Danube River Protection Convention, and the EU Strategy for the Danube Region (EUSDR, 2019). It is a European ambition to create adequate levels of drinking water, outdoor bathing water, and aquatic ecosystem security in EU member states by the end of 2027. Therefore, in my article I examine water safety, not only in terms of drinking water supply security, but also in terms of aquatic ecosystem security for the Danube countries. Based on the examples of recent years in Hungary, I present the damage events caused by high rainfall intensity fluctuations, which occurred from both excess and scarcity of water. I would like to draw your attention to the fact that, as Hungary is a downstream country, upstream interventions can cause more sudden flooding and subsidence in our area on the Danube.

Keywords: *climate adaption, water security, Danube*

The importance of adaptation to climate change in terms of water security

The average temperature of the Earth's surface has increased by almost 1.0°C[3] over the last 150 years, which, according to scientific opinions, is caused by the increase in greenhouse gas emissions typical of the period following the Industrial Revolution. Given that greenhouse gas emissions continue to the present day, depending on the rapidity, this rate will increase by as much as 2–5°C[4] by the end of the 21st century.

Many uncertainties hinder the accurate predictability of the extent and characteristics of climate change. Climate and hydrological models have a limited ability to describe real processes, as several uncertainties play a role in the study of the hydrological effects of

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[3] Hungarian Academy of Sciences, *Magyarország vízgazdálkodása: helyzetkép és stratégiai feladatok* [Water Management in Hungary: Situation Report and Related Strategic Tasks] (Budapest, 2011), 85.

[4] Hungarian Academy of Sciences, *Magyarország vízgazdálkodása,* 86.

climate change like expected output growth related to socio-economic growth; forecasts of climate models – global, regional, hydrological.

Nevertheless, previous experiences have shown that our waters are sensitive to the climate –depending on the type of water, to varying degrees – especially to changes in the characteristics of temperature and precipitation.

As a result of climate change, in the context of global warming, declining rainfall has been predicted for decades by researchers. Nowadays, the process has already begun, and today the global problem is the declining quantity and deterioration of the quality of available water resources.[5]

The global challenge also threatens Europe, thus increases Hungary's vulnerability from the aspect of water security.

In 2019, the main topic of the Budapest Water Summit was the prevention of the water crisis and the promotion of adaptation to the effects, which also indicates the severity of the issue.

As a segment of adaptation to the effects of climate change, such as an increase in the frequency and intensity of droughts, everyone has a role, a right and a responsibility, from citizens, to professional disaster management bodies, to those involved in home security.

There is a tendency for the extremity of precipitation to increase. Precipitation is either too much or too little, which can cause both inland water and drought in the same area, in the same year. One reason for this is extreme intensity precipitation, the other is the moderate useful water storage capacity and underutilisation of the soil.

According to domestic climate change experts, in parallel with the decrease in precipitation, it will be typical that the extremity of precipitation will continue to increase, so the frequency of floods, lightning floods, inland waters and droughts is also expected to increase.

From an environmental safety point of view, it must also be emphasised that fresh water will be a critical area for the future[6] in the context of droughts, as its volume is declining rapidly and its value is rising dramatically.

Atmospheric processes greatly influence the *hydrological processes* taking place in the waters on Earth.

Changes in the state of the atmosphere and the development of the weather directly affect the amount of water flowing from the area, the *water level and discharge of watercourses, the water level of lakes, and the changes in the water level of the soil.*

The *water cycle* is most affected by the evolution in precipitation and temperature over time, as the amount of water flowing from the area rises with increasing precipitation, while it decreases with rising temperature, due to increased evaporation.

Extremely high rainfall causes *inland waters* in the areas and *floods* in watercourses, while extremely low rainfall coupled with high temperatures, results in a decrease in runoff or sometimes a complete absence of it. In the case of a *hydrological drought,* the

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5 László Halász, László Földi and József Padányi, 'Climate change and CBRN defense', *Hadmérnök* 7, no 3 (2012), 42–49.

6 József Padányi, 'Éghajlatváltozás és a biztonság összefüggései' [Correlations between Climate Change and Security], *Hadtudomány* 1–2 (2009), 33–46.

moisture content of the soil, the groundwater level and the amount of water transported in the rivers decrease.

The *runoff* is usually closely related to the weather, while the annual characteristics of the runoff, such as the average annual runoff, the variability of the annual runoff, or the course of the annual runoff within a year are related to the climate.

The runoff fluctuates significantly around the average each year to varying degrees per watercourse. In the Danube region, the minimum annual runoff is 15–75%, the largest is 150–370% of the average, and the ratio between the extremes of the annual runoff reaches 1:10 to 1:15.[7]

Accumulated snow in winter melts and stretches on the watercourses in the late winter–spring months, so the largest monthly runoff is typical for these months. Then the monthly runoff continues to decrease until the autumn months.

In the case of the Danube, the values are different, as the value of the largest monthly runoff occurs in June or July, while the low-water period shifts to November. This is because the melting in the thousands of meters high mountainous part provides a continuous supply for the river, and the feeding resulting from this melting meets the rainfall in June.

Global warming may have an impact on the climate of Hungary and the local catchments of watercourses. Territorial change in climate is reflected in the territorial variability of the average annual runoff of surface waters, and the runoff factor itself is climate-dependent, too.[8]

The statistical analysis shows a decreasing tendency in rainfall in the Carpathian Basin in the 20th century, for almost every month and the winter and summer semester and year.[9] Within rainy days, the number and proportion of snowy days decreased, as did the number of snow- covered days.

According to forecasts, decrease in precipitation and increase in temperature will continue in the coming decades.

If global warming does not reach 1°C by 2035 compared to the current one, mostly in the winter semester[10] twice the temperature rising is expected in these two areas, according to a study done in the Small Hungarian Plain and the Southern Great Hungarian Plain region. It is expected that summer precipitation will decrease, while the amount of precipitation will increase in the winter semester.

Based on the results of the study, warming will be typical also in the cross-border Danube River basins, in both the summer and winter semesters. Regarding precipitation, the expected changes can only be estimated with uncertainty.

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7 Imre Radochay, *Egy éghajlati forgatókönyv hidrológiai hatásának vizsgálata a Dunán, különös tekintettel a kisvízi időszakokra* [Investigation of the Hydrological Impact of a Climatic Scenario on the Danube, with Special Reference to Low Water Periods] (Eötvös Loránd University, Department of Meteorology, 2010).

8 Béla Nováky, ‘Az éghajlatváltozás vízgazdálkodási hatásai’ [Water Management Impacts of Climate Change], *Vízügyi Közlemények* 82, 3–4 (2000), 419–448.

9 János Mika, Péter Ambrózy, Judit Bartholy, Csaba Nemes and Tamás Pálvölgyi, ‘Az Alföld éghajlatának időbeli változékonysága és változásai a hazai szakirodalom tükrében’ [The Temporal Variability and Changes of the Climate of the Great Plain in the Light of the Hungarian Literature], *Vízügyi Közlemények* 77, 3–4 (1995), 261–268.

10 Nováky, ‘Az éghajlatváltozás vízgazdálkodási hatásai’, 423.

No significant change in precipitation is expected in the Danube River basins in Germany and the Czech Republic, but higher precipitation is possible in the Austrian river basin. Thus, except the Austrian river basin, winter precipitation is declining in the Danube River basins.[11]

Climate impact studies show that as a result of the expected climate changes, hydrological characteristics are also changing in Hungary and its cross-border river basins. More water is likely to flow down in the winter semester than in the summer semester compared to the previous water volumes.

As the temperature of the winter semester rises, both the amount of falling snow and the amount of accumulating snow decreases, so the melting of the snow cover occurs earlier. However, in higher catchment areas with cooler climates, warming has less of an effect on melting, so even in the case of increasing warming, melting may be delayed in time, in these areas.

As a result of climate change, it is expected that the mass and peak discharge of the first melting flood wave will rise. Decreasing annual runoff is expected in the period between 2000 and 2030.[12]

As a result of warming, water supplies are declining obviously. This includes stored water supplies. In addition, the supply that is crucial for recovery is also declining.

Due to the expected higher evaporation, both surface runoff and infiltration into groundwater will decrease to a greater extent.

The water use and consumption of the population and the economy will increase significantly if the temperature rises. In the summer period, water consumption will increase by 3–4% in the range of 20–25°C within 1°C rising in temperature.[13]

The temperature-related change in the drinking water demand of the animals shows a similar picture. The average annual water demand of plants is particularly sensitive to the average median temperature of the summer semester (May–October): under current climatic conditions, a 1°C regional variation in temperature causes a 19–89 mm difference in water demand, depending on the plant species.[14] The increase in the frequency of *flash floods* can be significantly facilitated by high-intensity precipitation falling on a small catchment area. Intense rainfall can also increase erosion, so maintenance works should be increased. The expected effects of climate change in our waters can be grouped and summarised as follows:[15]

- with regards to the fact that warming and drought are becoming dominant, the annual runoff may decrease (it can reach up to 30% in Hungary[16])
- the rate of infiltration into groundwater may decrease, the water intake of the lakes may decrease (thus, the water balance of the lakes is expected to deteriorate, their surface area may decrease, some may even dry out)

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11 Ibid. 424.
12 Nováky, ‘Az éghajlatváltozás vízgazdálkodási hatásai’, 424.
13 Ibid. 430.
14 Ibid. 430.
15 Hungarian Academy of Sciences, *Magyarország vízgazdálkodása,* 86.
16 Ibid.

- changes in precipitation characteristics expected in the Danube catchment area (Germany) – decreasing of small waters in homeland river sections during the summer period, and in winter due to increasing rainfall, extended length of winter period is expected
- greater seasonal fluctuations in groundwater levels are expected
- the risk of flash floods increases due to the intensity and frequency of heavy rainfall
- it is likely to occur that rain caused flood waves will become more frequent in the winter semester
- the general warming of the winter months is expected to reduce the risk of icy floods formation
- due to the warming of winter months, an increase in evaporation and a decrease in the number of frosty days may reduce the risk of inland water formation

The above forecasts were formulated in a strategic programme developed by the Section of Engineering Sciences of the Hungarian Academy of Sciences on water management in Hungary, the situation report and related strategic tasks (MTA) study, published in 2011. If we look back at the hydrological characteristics of Hungary in recent years as a kind of success analysis of these forecasts, it can be seen that the forecasts at that time were largely confirmed.

For example in May and June from 2018 every year, at the national level, lots of damage occurred, which was caused by extreme rainfall (flash floods, water flooded part of villages, dilapidations and glissade of flood protection build-ups).

Likewise, from July to November there was such a lack of rainfall that the water level of the Danube was record low.

Challenges of dryness and drought

Climate change is characterised by global warming. Extremely hot periods with higher temperatures, summer heat waves and declining rainfall, such as increasing the length of dry periods, are projected to increase the likelihood of droughts due to the effects of climate change. Drought due to water scarcity and desertification are less of a “spectacular” disaster than damage caused by excess water. They are slow-moving, however, they can cause significant damage and affect the functioning of society in many areas.

In addition to crop production and agriculture, the consequences of drought negatively affect all living organisms, from flora, fauna to humans. As a result of drought impact, the damages hit the natural environment directly and also society and the economy indirectly.

In a kind of disaster categorisation, we distinguish natural and civilisation-related disasters according to their origin. Natural disasters can be further split into meteorological, hydrological, geological and biological damage events.

In my opinion, drought can be approached in several ways in this categorisation and can be assigned into several groups.

If interpreted as a disaster resulting from a lack of extreme rainfall, it is of meteorological origin. If we consider drought as the opposite of disasters caused by excess water (flood, inland water), as a disaster caused by water scarcity, then it is of hydrological origin. While if we look at this damage in terms of the extreme drought of the soil, the earth, it is of geological origin.

Drought differs from other natural disasters in several ways:

- it develops slowly (in Hungary it takes several months to develop)
- neither its exact beginning nor its end, nor its spatial extent are known
- it is more difficult to estimate the extent of the damage caused by drought than in the case of other disasters
- its effects do not cease immediately
- its impact occurs in all areas of life (the load on the human body increases, it causes one of the greatest damages in agriculture, its aspects of water management, transport, industry, water supply and tourism are diverse)

The concept of drought and water scarcity is defined in the 2007 EU Drought Strategy Paper as: “Drought means a temporary reduction in available water resources, for example due to a lack of rain, water scarcity means that water demand exceeds sustainably usable water resources.”

To clarify the concept of drought, the 2012 Drought Strategy distinguishes between meteorological, agricultural, hydrological and socio-economic droughts.

Extremely hot periods with higher temperatures, summer heat waves and declining rainfall, such as increasing the length of dry periods, are projected to increase the likelihood of droughts due to the effects of climate change.

As a result of climate change, summer is characterised by extremely high temperatures and extremely little rainfall.

Territorial differences can be observed in the development of drought in our country. Conditions are favourable for the development of the drought in 90% of the territory of Hungary, primarily in the Great Plain, while in the area of the Sand Ridge between the Danube and the Tisza, signs of desertification have already appeared.

Most drought indicators work with meteorological and hydrological data, e.g. precipitation, river water yield, soil moisture content, reservoir status and groundwater level. Water scarcity indicators most often compare water use with available water resources. Nowadays, it is becoming increasingly important to develop vulnerability indicators for water-related impacts for different climate change and socio-economic scenarios and to assess measures to address possible water scarcity and droughts.

The decrease in precipitation has a negative effect on water resources, so there will be less usable water, which will increase Hungary’s vulnerability and dependence on neighbouring upstream countries in terms of water security. Declining water is in many cases accompanied by a deterioration in water quality.

Climate change is also affecting groundwater resources. Warming can reduce the infiltration that feeds groundwater, especially when warming is accompanied by a decrease in precipitation. As a result, a decrease in groundwater levels as well as greater seasonal fluctuations are likely to occur.

The decrease of the groundwater level has a negative effect on the living organisms and ecosystems living there, and may even cause the dehydration of the vegetation. The level of aquifers and the stratum pressure conditions are significantly affected by the longer dry periods.

Droughts can cause significant damage and affect the functioning of society in many areas (in agriculture, livestock, forestry, tourism, water management, etc.).

Forests play an essential role in the global ecosystem, so the damage caused by drought in the forests is dangerous and serious. A prolonged drought period can cause severe damage to the forest ecosystem. The leaves of trees may fall prematurely, their canopies may deform, their yields may decrease, and pests and infections may multiply in the trees. The risk of wildfires increases during dry, droughty periods. These fires cause serious ecological damages.[17]

Transboundary disasters caused by excess water in Europe

In terms of water management, the biggest challenge in the European Union is preparing for climate change. Since 1998, floods have killed hundreds of people and caused the displacement of hundreds of thousands of people in Europe. In the first years of the 21st century, flood events causing severe damage throughout Europe drew attention to changes in hydrological conditions and shortcomings in existing protection systems. As a result of this, the European Parliament has created a Directive on the assessment and management of flood risks (2007/60/EC) to complement the EU Floods Directive and made its implementation obligatory for all Member States.[18] The aim of the measure is to develop a unified approach to flood risk management for transboundary river basins in the European Union.[19]

Directive 2007/60/EC on the assessment and management of flood risks requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood and to take adequate and coordinated measures to reduce this flood risk. With this, the Directive focuses on risk management.

With the help of risk maps, it becomes possible to see which geographical areas can be flooded by water due to low-, medium- and high-probability floods. It shows the number of citizens concerned and the economic activities affected by the flood.

With the help of these maps, Member States can establish their flood management plans.

The Directive calls for joint planning, rather than separating specific measures, as the risk of floods varies considerably from one river basin to another. These plans should provide assurance that Member States will be prepared for floods in order to protect human lives, ecosystems, cultural heritage and economic activities.

As a result of urbanisation and the intensity of agricultural activity and deforestation, the risk of floods is increasing in many European countries.

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17 *Nemzeti Aszálystratégia tervezet* [Hungarian National Drought Strategy Plan], s. a.

18 Directive 2007/60/EC of the European parliament and of the council of 23 October 2007 on the assessment and management of flood risks.

19 Ildikó Lázár, *Vízrajzi fogalomtár* [Hydrographic Glossary], 2013.

Sustainable flood protection methods intend to use natural and cost-effective tools to reduce risks. Examples include the restoration of mountain forests and wetlands or the restoration of natural river bends. River bends can slow down the flow of water and thus reduce the amount of water that drains from the flood. These methods are also beneficial in other ways, as they also restore natural habitats and biodiversity.

60% of European rivers have *transboundary river basins*.[20] For this reason, EU Member States must draw up a joint plan for international river basins by involving other countries if necessary. Under the Directive, Member States must carry out a public consultation when drawing up flood risk management plans, as it is important for success to raise public awareness of floods and their management.

Mechanisms have been set up in the EU to help take joint action in the event of a disaster.

The Disaster Response Operations Monitoring and Information Centre coordinates the *rapid response* to disasters and also the *training*.[21]

Another tool to support disaster response activities is the *European Union Solidarity Fund*.

In 2013, a massive flood devastated Central Europe, causing huge damages in the Czech Republic, Germany, Austria and Hungary.[22]

A recent report from the European Environment Agency highlighted that two-thirds of *all disaster damage in Europe consist of floods, cloudburst and other hydrometeorological events*. According to the report, this is due to a kind of land use change in which the population is growing in flood-prone areas.

The report finds a correlation between the annual European average median temperature rise and the intensification of the hydrological cycle, which could lead to more frequent and intense floods.[23]

Hungary has assumed a coordinating role with Slovakia in the area of action entitled *Protection and Conservation of Water Quality*. Hungary has also committed to coordinating the *Natural Disaster Management* area with Romania. In the field of water management and flood protection, there is a long tradition of cooperation between Hungary and its neighbouring countries. Demand for clean drinking water, the risk of flooding, water scarcity, or the risk of industrial pollution are frequent problems that affect the lives of citizens in the region.

According to Article 7 of the EU Water Framework Directive, changes in the environment, such as climate change, which is considered to be a relatively new factor, will pose a challenge to water management throughout the European Union in the future.

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[20] WISE (Water Information System Europe), 'Vízügyi jegyzetek a Víz Keretirányelv végrehajtásáról. 10. vízügyi jegyzet: Éghajlatváltozás: Az árvizeket, az aszályokat és a változó vízi ökoszisztémákat célzó intézkedések' [Climate Change: Measures for Floods, Droughts and Changing Aquatic Ecosystems. Water Notes 10], December 2008.

[21] István Simicskó, *Az országvédelem és országmozgósítás szervezeti, hatásköri, irányítási rendszere minősített időszakokban* [Organisation, Authorisation and Command System of the Country's Defence and Mobilisation in Exceptional Periods of Time] (PhD dissertation, Budapest: ZMNE, 2008).

[22] National Geographic Hungary, 'Növekvő árvízi kockázatok' [Emerging Flood Risks], 18 June 2013.

[23] Ibid.

The European Commission's 2007 Communication on addressing the challenge of water scarcity and droughts management establish that the implementation of the Water Framework Directive is a key component.

The *possible consequences of climate change* are assumed by the Water Framework Directive as follows:

- less rain and higher temperatures in the south, which means an increased load on resources
- more rain and increased flood risk in the north

Floods have become more frequent recently. Since 1990, 259 significant river floods have been reported, of which 165 have occurred since 2000.[24]

In the framework of *Directive 2007 on the assessment and management of flood risks*, Member States were obliged to carry out preliminary flood risk management assessments for all river basins by 2011 and to complete them with flood risk maps by 2013.

Member States were required to put in place flood risk management plans by 2015.

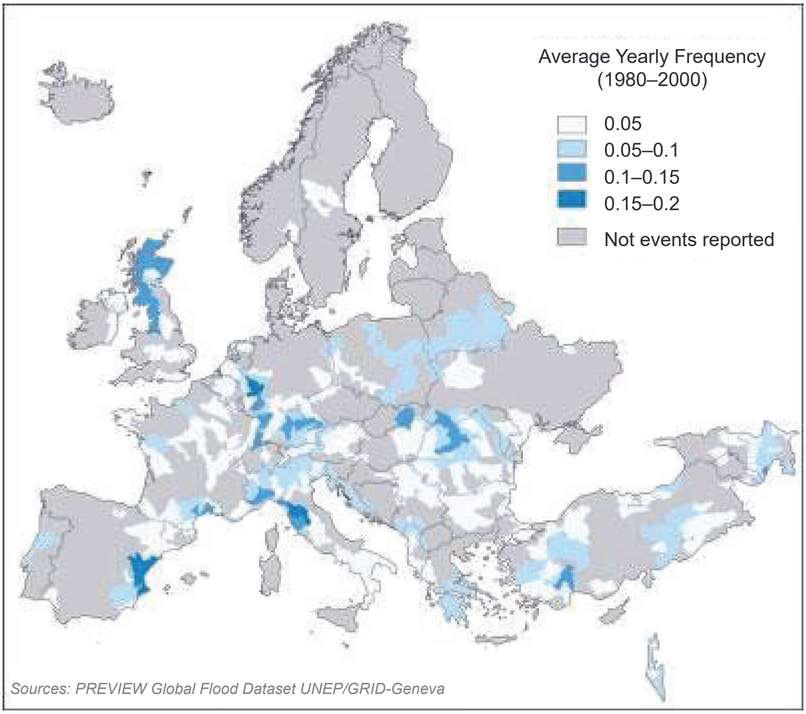

Figure 1: Frequency of floods in Europe

Source: *www.grid.unep.ch/product/publication/freshwater_europe/images/europe_flood_fr.jpg*

[24] European Union Water Framework Directive, 2000.

The Framework Directive states that public involvement will be a key element in achieving the objectives of both the Water Framework Directive and the Flood Risk Assessment and Management Directive. *At the same time, it draws attention to the fact that a significant proportion of European citizens are unaware that they can express an opinion on the future of water. The Directive emphasises the importance of drawing attention to the fact that every effort will help to make progress.*

Flood vulnerability in Hungary

The rivers of the Alps and the Carpathian Mountains flow into the country's two great rivers, the Danube and the Tisza. As a result of this, sudden snowmelt or higher amounts of downpour rushing down the two mountains mentioned above can cause flooding in the country. This is dangerous mostly for the Upper Tisza and its tributaries, as well as for the Körös because there the water level can rise up to 10 meters within 28–36 hours after the rainfall. In addition, flood waves can also be of mixed (combined) origin – as a combined consequence of snowmelt and precipitation. The amount and proportion of precipitation – the runoff factor – can be increased by the following *factors:*

- saturated soil
- frozen soil
- sloping surface of the catchment area
- lack of vegetation cover or sparse vegetation cover
- cool weather which reduces evaporation
- humid air

The following *types* of flood waves can be distinguished on the Danube:[25]

- mutually reinforcing flood waves resulting from precipitation or snowmelt
- cumulative floods of main rivers and tributaries resulting from precipitation or snowmelt
- floods caused by backwater resulting from ice dam
- other floods resulting from backwater
- floods resulting from the effects of artificial interventions

Depending on the hydrographic features of the river basin, two types of floods can occur on the Hungarian section of the Danube. One is the result of snowmelt that occurs in late winter or early spring, and the other is summer flooding caused by extensive, high-intensity precipitation in the highlands of the Alps.

In terms of discharge, summer floods are more dangerous.

[25] Réka Palásty, *Tisza 1970–2000. Rendkívüli árvizek* [Tisza 1970–2000. Extraordinary Floods]. Budapest: BME, 2000.

The Danube as a vital system element in Hungary

The vast majority of the rivers in Hungary – apart from a few small watercourses – originate abroad, so the water cycle of our rivers is basically shaped and influenced not by the waters generated in the catchment area of Hungary, but in other countries. The quantity and quality of water resources are highly dependent on interventions conducted in upstream countries.

The watercourses of Hungary can be divided into the water system of the Danube and the Tisza.

Several of our rivers are accompanied by a detached or cut dead channel, oxbow lake. The number of reservoir lakes is also significant: Lake Tisza, Rakaca and Zámoly reservoirs. The Danube is the main river in the Carpathian Basin (Poprad leads the water to the Baltic Sea via the Dunajec and the Vistula). It is 2,848 km long, making it the longest river in Central Europe. It originates in the Black Forest in Germany and drains into the Black Sea. It crosses 10 countries, making it the "most international" river in the world. There are several major cities along its shores, including 4 capitals – Vienna, Bratislava, Budapest and Belgrade. There are 27 settlements in Hungary on the banks of the Danube River.[26]

The tributaries of the Danube, which flow directly into it: Lajta, Rába, Rábca, Cuha, Sió, Dráva, Ipoly.

Its tributaries, which flow indirectly into it: Répce, which continues in Rábca; Marcal, which flows into the Rába; Koppány, which flows into Kapos, and which flows into Sió; Mura, which flows into the Dráva.

The Hungarian section of the Danube is 417 km and it is a border river in one section. It has a fluctuating water flow. Its flow direction is relatively straight.

The Danube, which crosses Central and Southeastern Europe, is the twenty-first longest river on Earth and the second most water abundant river in Europe. Its average annual discharge is 6,855 m^3/s.

The highest point of its watershed is Piz Bernina, which rises 4,052 m.

The river basin is divided into three main parts, which can be characterised by different hydrographic and geographical features:

- the Upper Danube region from the Black Forest source region to the Dévény gate
- the Middle Danube region to the Iron Gate
- the Lower Danube region to the Danube Delta of the Black Sea

The water of the Danube, the river bed, the surface of the water, the backwaters and the floodplains provide very favourable living conditions for many living creatures.

Backwaters and slower rivers are rich in phytoplankton and seaweeds like floating fern, duckweeds, water lily, water chestnut and wolffia. The shores are characterised by reeds as well as cattails and other sedge species.

[26] Győr, Gönyű, Komárom, Esztergom, Szob, Visegrád, Nagymaros, Kismaros, Verőce, Vác, Göd, Dunakeszi, Szentendre, Budakalász, Budapest, Szigetszentmiklós, Százhalombatta, Ercsi, Dunaharaszti, Ráckeve, Dunaújváros, Dunaföldvár, Solt, Paks, Kalocsa, Baja, Mohács.

In the faster sections, the willow and shrub parts are typical along the river, and further in the groves, white willow and white and black cottonwood are native. It is typical of the Danube that “gallery forests” are created in drier, but water supplied areas. English oak, swamp Spanish oak, elm and ash trees, as well as several creeper plants can be found over here.

In the backwaters, bog forests are forming where the alder is the most characteristic tree and in the undergrowth mosses and bogs can be found. The nettle, which is a protected plant species, is native to the backwaters of the Danube.

The fish stock of the Danube is relatively poor, fifty-two fish species of the Danube are known.[27] Typical fish species are sterlet, carp, pike, catfish, barbel, bream, crucian carp, European bitterling, perch and pikeperch. The Danube salmon and the striped ruffle are unique fish species of the Danube.

The Danube floodplain is home to a wide variety of bird and mammal species. The most typical bird species are the black-headed gull, the mallard, the wild goose, the cormorant, the lapwing, the grey heron, the red heron, the night heron, the great bittern and the European penduline tit. Rose pelicans are inhabitants only of the Danube Delta.

Among the mammals, the most common in the floodplains are the water shrew, the water vole, the harvest mouse, the otter and the beaver. Among predators, foxes and the European polecat live in this area.

In my opinion, critical infrastructure can be interpreted “not only” as one of the living conditions of human society. Even natural habitats that are the living conditions of animals and flora, our environment like the water, floodplain, etc. of the Danube in this article, are considered critical infrastructure. Its absence or the resulting domino-like consequences can also result in basic malfunctions making life impossible for the animals and plants living there. Changes in biodiversity have an impact, directly or indirectly, on people’s daily lives.[28]

One of the typical services of Danube tourism is the offer of event boats on the Danube. In addition to the boats used to host various events, sightseeing cruises and other boat tours also add colour to the tourist programs.

Certain sections of the Danube are suitable for various forms of water tourism. These are spa tourism, water sports, adventure tourism and fishing.

In my opinion, if we define tourism as one of the possibilities for people to relax, rest and recharge, it can be interpreted as critical infrastructure as its absence can cause psychological stress for a wide range of people, which can generate increased problems in society at an individual level.[29]

The importance of Danube shipping and ports also deserve special attention from the topic point of view.

The Danube ports in Hungary are as follows: Port of Csepel, ÁTI DEPO Port in Baja, OKK RO-RO Port in Baja, Dunaferr Port, Port of Dunavecse, Port in Fadd-Dombori,

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[27] *A Duna sokszínű élővilága* [The Varied Ecosystem of the Danube], s. a.

[28] Réka Magdolna Kirovné Rácz, ‘Magyarország folyói – különös tekintettel a Dunára – mint kritikus infrastruktúra vagy létfontosságú rendszer elem’ [Rivers of Hungary – with Special Regard to the Danube – as Elements of Critical Infrastructure or Vital Systems], *Hadtudományi Szemle* 10, no 2 (2017), 437–446.

[29] Ibid. 440.

FERROPORT, Port of Győr–Gönyű, Port of Háros, Port of Mohács, Port of Paks, Port of Százhalombatta, Vigadó Square ship station, Port for small pleasure boats at Kvassay flood gate.

The general characteristics of water transport can be summarised as follows:

- it is suitable for heavy goods transport
- it provides indirect access to the goods
- it has slow transport speed
- it is strongly weather dependent
- it has a high level of transport safety
- it is relatively cheap
- it has relatively gentle environmental effects

If we define the Danube as a shipping route, it can be interpreted as such a "thing" whose destruction, reduced level of operation or services, or its inaccessibility to the water transport process would have a clear negative effect. So it can be considered critical infrastructure. And the Danube ports are essential elements of this critical infrastructure.[30]

The Danube River Basin as a vital component of the European Union

The availability and good quality of fresh water is vital for living creatures. The 800,000 km^2 area of the Danube River Basin covers 19 countries. The Danube River Protection Convention (DRPC) has been signed by 14 of these countries. The Danube catchment area is also affected by the Alps and the Carpathians. As the river knows no boundaries, water management requires serious international cooperation. Regarding the Danube, this coordination is supported, for example, by the International Commission for the Protection of the Danube River (ICPDR). (The countries of the tributaries have also established close international cooperation, e.g. the International Sava River Basin Commission [ISRBC]).

The analyses of the ICPDR[31] provide a complete picture of the water quality and water management situation in the Danube River Basin. These are included in the Danube River Management Plan (DRMP). This document points to significant problems in the catchment area (organic pollution, nutrient pollution – eutrophication, pollution by hazardous substances, hydromorphological changes). These problems are linked to an important issue that the protection of the quality of water flowing into the Black Sea means. The above problems suggest that a significant part of the pollutants flowing into the Black Sea originates from the Danube. Therefore, all efforts aiming to improve the water quality of the Danube will have a positive impact on the Black Sea and its environment.

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30 Ibid. 442.

31 International Commission for the Protection of the Danube River – ICPDR, *Ministerial Meeting 2010: Shared waters – joint responsibilities.*

The national aspirations of the Danube countries

The Action Plan of the European Union Strategy for the Danube Region (Brussels, 8.12.2010 SEC (2010) 1489 final)[32] contains the aspirations and pillars related to environmental protection in the Danube region. The proposals set out in the document will help to achieve the objectives of ensuring sustainable development by resolving the climate change-related problems, and ensuring the sustainability of resources. By doing so, they will contribute to the Europe 2020 strategy, the implementation of the EU's 2050 biodiversity strategy. Restoring and maintaining water quality is one of the pillars to which the proposals apply. Other EU programs also help and support this pillar. In the water sector, for example, to improve the water quality of the Danube River Basin. Wastewater treatment or drinking water-related projects have received financial and technical support.

Water management in the EU must be carried out in accordance with very strict legal requirements, to which national regulations and concrete actions are necessary. They aim to preserve and improve water quality and at the same time help to achieve the objectives of the Water Framework Directive, the Urban Waste Water Treatment (UWWT) Directive and the Nitrates Directive, i.e. to improve water quality. The other pillar is the prevention of natural or civilisation-related disasters on the Danube and preparing for them. Damage to water quality caused by floods or pollutants has a negative impact not only on biodiversity but also on the built environment and endangers people's lives and physical integrity. The countries of the Danube agree – on the basis of water management cooperation – that flood protection is a priority, continuous task, and it cannot be a short-term activity. For this purpose, flood risk management plans are being prepared at a national level. In addition to floods, droughts are also a significant challenge. Water scarcity affects 11% of the European population and 17% of Europe's territory.[33]

Water scarcity is an increasing challenge both in Hungary and in Europe. Domestic strategies on climate change, such as the River Basin Management Plan (2015) or the draft National Drought Strategy (2012), draw attention to the fact of extreme hydrological damage events (e.g. floods, inland water, lightning, frequency and intensity of drought).

The appearance of drought in Hungarian water policy documents – unlike flood – is less pronounced. A separate strategic plan was prepared in 2012 (National Drought Strategy), but was not adopted, 1432/2012 (X.9.). The draft drought strategy had to be integrated into the national water strategy.

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[32] European Commission, *Commission Staff Working Document: Action plan accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning the European Union Strategy for Danube Region,* 13 December 2010.

[33] Ibid.

Summary

In my article, I examined the Danube countries' situation of adaptation to climate change, primarily in terms of water security, and I also pointed out the challenges affecting the aquatic ecosystem security. Based on the relevant hydrological impacts of climate change, I have demonstrated that adaptation to climate change is of unquestionable importance for water security. I presented the challenges of water scarcity, such as dryness and drought, and the problems of excess water in Europe and Hungary. I summarised the national aspirations of the Danube countries through analysis of international conventions and strategies.

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