Zeszyty Naukowe SGSP 2021
2021, Nr 78, s. 127–150
ISSN: 0239-5223

DOI: 10.5604/01.3001.0015.0085

TOMASZ ZWĘGLIŃSKI, PHD
The Main School of Fire Service
e-mail: tzweglinski@sgsp.edu.pl
ORCID 0000-0003-2652-8068

LASZLO BALATONYI, PHD
General Directorate of Water Management
e-mail: balatonyi.laszlo@uni-nke.hu
ORCID 0000-0001-5130-730X

IMPACT OF CLIMATE CHANGE ON HUNGARIAN WATER MANAGEMENT STRATEGY AS A CASE STUDY FOR OTHER EUROPEAN COUNTRIES

ABSTRACT

The European Union is strongly supporting regional integration tailored to build national resilience towards climate change driven hazards. This cooperation is developed by launching and implementation of the EU regional strategies. Poland is deeply involved in execution of the EU Strategy for the Baltic Sea Region while Hungary in EU Strategy for the Danube Region. On one hand both regions have their own problems, however, on the other they face similar challenges arising from climate change phenomena. This argument encourages learning from each other. One of the key problems related to climate change is water management, including flood management and adequate access to fresh water. Nowadays, the southern region of Europe, like the Danube Region including Hungary, is being more and more afflicted by limited access to fresh water. This is not the case in central and northern Europe yet. However, the problem can emerge soon in the Baltic Sea Region if the climate change will be continued. Already first symptoms of such scenario are being noticeable. Therefore, the main aim of the article is to present the Danube Region and Hungarian experiences related to water management in the context of climate change phenomena. The results constitute a lesson learnt from this region that can be easily adapted to the current and future challenges of the Baltic Sea Region.

KEYWORDS

climate change, flood management, water management, flood risk

Received: 29.01.2021; Reviewed: 23.06.2021; Accepted: 25.06.2021

WPŁYW ZMIAN KLIMATYCZNYCH NA WĘGIERSKĄ STRATEGIĘ GOSPODARKI WODNEJ JAKO STUDIUM PRZYPADKU DLA INNYCH PAŃSTW EUROPEJSKICH

ABSTRAKT

Unia Europejska zdecydowanie wspiera integrację regionalną sprzyjającą budowaniu odporności państw członkowskich na zagrożenia związane ze zmianą klimatu. Współpraca ta jest rozwijana poprzez uruchomienie i wdrożenie strategii regionalnych UE. Polska jest silnie zaangażowana w realizację strategii UE na rzecz regionu Morza Bałtyckiego, podczas gdy Węgry strategii na rzecz regionu Dunaju. Z jednej strony oba regiony mają własne problemy, jednak z drugiej stoją przed podobnymi wyzwaniami wynikającymi ze zjawisk związanych ze zmianami klimatycznymi. Zatem państwa zobowiązane są wymieniać się własnymi doświadczeniami szczególnie w zakresie tożsamych wyzwań. Jednym z kluczowych problemów związanych ze zmianą klimatu jest gospodarka wodna, w tym zarządzanie powodziami i dostęp do wystarczającej ilości słodkiej wody. Obecnie południowy region Europy, podobnie jak region Dunaju, w tym Węgry, jest coraz bardziej narażony na ograniczony dostęp do tego zasobu. Nie ma to jeszcze miejsca w Europie Środkowej i Północnej. Problem ten może jednak pojawić się wkrótce również i w regionie Morza Bałtyckiego, jeśli trend niekorzystnych zmian klimatycznych utrzyma się. Niestety pojawiają się już pierwsze symptomy takiego scenariusza. Dlatego głównym celem tego artykułu jest przedstawienie doświadczeń węgierskich w zakresie gospodarki wodnej i zmian klimatycznych w szerszym kontekście regionu Dunaju. Wyniki stanowią lekcję wyciągniętą z tego regionu, którą można stosunkowo łatwo zaadaptować na potrzeby obecnych i przyszłych wyzwań regionu Morza Bałtyckiego.

SŁOWA KLUCZOWE

zmiany klimatyczne, zarządzanie powodziowe, gospodarka wodna, ryzyko powodziowe

Przyjęty: 29.01.2021; Zrecenzowany: 23.06.2021; Zatwierdzony: 25.06.2021

1. INTRODUCTION

"*Water is life's one essential resource and without quality and quantity safety measures the accepted UN Sustainable Development Goals (SDGs) of 2015 cannot be sustained by the year 2030.*"

Climate change has increased the pressure on Hungary's fresh water sources and in many regions the demand and availability are not in balance. For example in Poland there are several programs in place which encourage citizens to invest and promote individual household and local water retention (Państwowe Gospodarstwo Wodne Wody Polskie, 2021).

Moreover, extreme weather conditions, as consequences of climate change, have a negative effect on water resources, environmental safety and the long-term social compatibility of some countries in central Europe, e.g. Hungary. Higher demand and increased challenge of various economic sectors for continuously decreasing water resources can be predicted. Climate change demands more attention and sustainable water usage needs to be a priority.

National and social benefits can only be sustained if water resources are managed based on strict economic and engineering standards and watershed wide planning. Water resources can never be managed only by accepting engineering capacities. Officials need to manage complete watersheds by carefully balancing different economic sectors' financial and social demands.

Future climate predictions have to be taken into account in any scientific research, program or strategy and the completed documents will need to be double checked by dedicated professionals.

Therefore, the European Union (EU) is strongly supporting regional integration, which allows better preparedness and response to safety and security challenges that are triggered by the climate change phenomena (Zwęgliński, 2020; van Duuren and Zwęgliński, 2019). Regional cooperation under the EU umbrella is highly valuable and effective since neighbouring countries are exposed to the same or similar threats, such as floods in 1997 and 2010 on the Oder River, border between Poland and Germany. The adoption of this approach lets them develop cross border cooperation by implementing common operating procedures, prevention programmes or interagency measures (Zwęgliński and Morgado, 2018).

Such cooperation is based on implementing the EU regional strategies. Poland contributes and follows the EU Strategy for the Baltic Sea Region, while Hungary the EU Strategy for the Danube Region. The regions have obviously several differences, as well as similarities. In the context of natural hazards, similarities are mainly driven by climate change. In such a case it is reasonable to learn from each other. Water management, including flood management and sufficient access to fresh water, is one of the commonly shared challenges arising from climate change. Southern region of Europe, and namely the Danube Region including Hungary, is being more severely exposed to the problem of insufficient access to fresh water than central and northern part of the continent. However, climate change phenomena will most probably also constitute a problem for the Baltic Sea Region in the nearest future. The first symptoms of such a scenario are already noticeable in Poland by the increasing importance of water retention.

Consequently, the main aim of the article is to present the Danube Region and Hungarian experiences of water management in the context of climate change phenomena.

2. CLIMATE CHANGE

Nowadays there is no question about a change of the climate, it is happening right now and we can all feel it on our skin. Almost all countries lack the necessary capacity to cope with extreme weather phenomena, such as floods, flash floods, water scarcity, droughts and ice events (Zwęgliński, 2017). In Europe, more frequent and heavier droughts, rainfalls and heatwaves are anticipated or already observable as clear indications of climate change

(IPCC, 2014), and pushing actions based on different levels, such as territorial governance (Macro-regional, Europe, countries, city) as watershed based (Danube basin).

2.1 Macro-regional Strategies

A 'Macro-regional strategy' is an integrated framework endorsed by the European Council to address common challenges faced by a defined geographical area relating to EU Member States and third countries situated in the same geographical area that in such a way benefit from strengthened cooperation that is conducive to achievement of economic, social and territorial cohesion.

Four EU macro-regional strategies, covering several policies, have been already adopted:

- EU Strategy for the Baltic Sea Region (2009)
- EU Strategy for the Danube Region (2010)
- EU Strategy for the Adriatic and Ionian Region (2014)
- EU Strategy for the Alpine Region (2015)

In order to intensify growth and strengthen cooperation at a macro-regional level, the European Union adopted the EU Strategy for the Danube Region (EUSDR) in 2011 with eleven priority areas to harmonise development policies connecting fourteen countries on the Danube basin.

Together with Slovakia, Hungary has been assigned with the task of coordinating the Water Quality Priority Area (PA4) and ensuring integrated water management aimed at reaching the good quality of waters in the Danube River Basin. EUSDR PA4 aiming at maintaining and restoring the quality of waters, to 'safeguard Europe's water resources', furthermore, to assist in the implementation of the EU Water Framework Directive and the Urban Waste Water Treatment Directive. EUSDR PA4 provides its assistance, e.g. in the promotion of measures addressing wastewater treatment measures in non-EU countries, the facilitation of sub-basin activities or the improvement of fish migration.

The coordination of the Environmental Risks Priority Area (PA5) is managed by Hungary and Romania. The main focus of the work is to address the challenges of water scarcity and droughts in line with the Danube River Basin Management Plan, the report on the impacts of droughts in the Danube Basin in 2015 (due in 2016) and the ongoing work in the field of climate adaptation. As a result, in the past few years EUSDR PA5 has contributed to the devising of the ICPDR Climate Change Adaptation Strategy Update 2018, supported project elaboration and implementation in the field of drought management and climate change related spatial planning, dissemination of scientific results to anticipate regional and local impacts of climate change through research. Flood risk management is also a significant target of the priority area. In order to achieve reduction of flood risk events EUSDR PA5 provides and enhances continuous support to the implementation of the Danube Flood Risk Management Plan. Should these prevention measures prove to be insufficiently effective, if disasters occur, EUSDR PA5 is supporting the assessment of disaster risks in the Danube Region, encouraging actions to promote disaster resilience, preparedness and response activities. In 2019 the Disaster Management Working group for the coordination the relevant activities among 14 Danube countries was established.

2.2 Climate change in the Danube basin

An intensification of extreme events, such as floods and droughts, leads to high impacts for agriculture, forestry and industry, as well as built-up areas and infrastructure. As a consequence of decreasing water availability, a shortage in water supply is expected in some areas. There will not be enough water to meet the requirements for irrigation in agriculture and as a consequence the vegetation period will be shortened in large areas in the south of the Danube River basin (hereafter: DRB). In contrast, it seems that in the northern parts there will be enough water for productive farming. Changing climatic conditions are expected to cause a shift in species distribution and an increasing risk of invasive species.

An increase in air and water temperature, combined with changes in precipitation, water availability, water quality and increasing frequency of extreme events, such as floods, low flows and droughts, may lead to changes in ecosystems, life cycles, and biodiversity in the DRB in the long-term. This is frequently mentioned to be one of the most relevant climate change impacts (ICPDR, 2018).

2.3 About Hungary

Hungary is a flatland situated in the Carpathian Basin surrounded by the Alps, the Carpathians and the Dinaric Mountains. The huge volume of water flowing from the mountains slows down on the plains, gets barred, ponded and drifts through the country causing extreme floods. The record floods of the last two decades had the Hungarian experts reconsider their view on flood control. The analyses have proven that the old methods of protection are not adequate anymore. The dykes getting ever higher represent an increasing risk to the population. The constant heightening of the 4.425 km long dyke system would put an enormous economic burden on the country.

Concurrently, expectations of the population have changed significantly as well. While in the 19th century flood control, the protection of arable land, and having as much farmland as possible was demanded, nowadays the protection of natural values, the improvement of ecological services, recreation and nature conscious solutions came into the foreground.

Accordingly flood control often had to fulfil opposing conditions. The citizens expect the government to provide them the European standard in the protection against floods that occur once in a century. However, there is an excessive need to create wetland areas, rehabilitate oxbows, establish recreational opportunities, protect flood plain forests, protect and increase biodiversity. The rising popularity of water sports and hiking requires the creation of natural riverbed sections, the demolition of water control facilities and the focus on natural hydromorphological processes. On the other hand, every activity or development that puts newer and newer obstacles in the way of the flood degrades flood safety.

As the impacts of climate change get more intensified, the situation becomes even more complicated. The three biggest floods on the Danube happened in the last two decades, while the one on the Tisza, the fourth record breaking flood, occurred within 36 month around the millennium.

The floods of the past 20 years made it clear that extreme floods have to be reckoned with in Hungary. In Hungary there were measured extreme flood in 2002 (848 cm), 2006 (860) and the biggest one in 2013 (891), however, during that period the lowest level (33 cm) in 2018 was also recorded (Figure 1). The water level is slowly decreasing ($y=-0.0076x +554.89$ $R^2=0.031$).

During six days of constant precipitation (30.05.–03.06.2013) along the Northern Alps form Bavaria to the Czech Republic a substantial flood event occurred. In total more than 400 mm of precipitation had been measured, which equals approximately to the half-year total, whereas these sums met mainly moist to saturated conditions due to intense rainfalls prior to the event. The individual daily precipitation sums were not exceptionally high

(ICPDR 201). It was the accumulation over the four days from the 31th of May to the 3nd of June that ultimately resulted in extreme flooding (Figure 2).

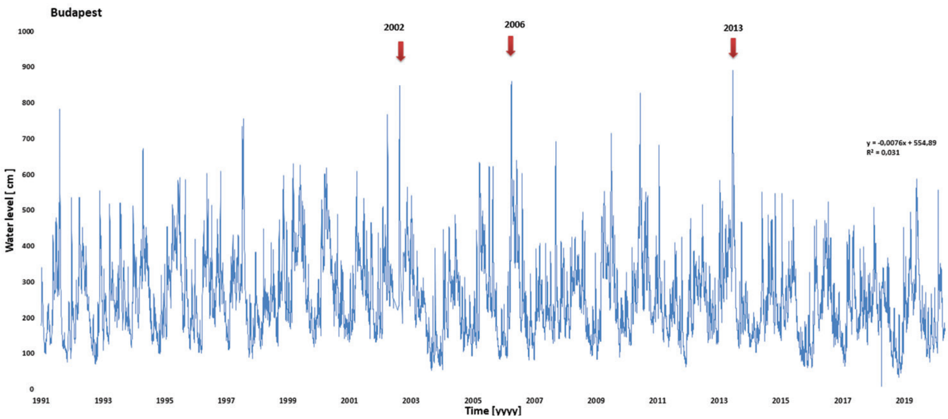

Figure 1. Water levels in the Budapest section of the Danube River
Source: General Directorate of Water Management of Hungary

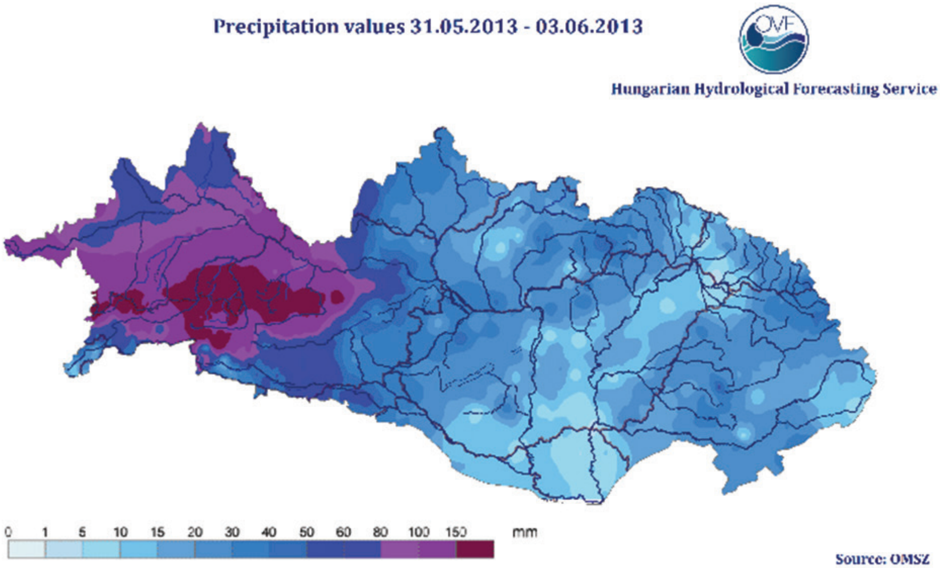

Figure 2. The precipitation during 31.05.2013 – 03.06.2013
Source: General Directorate of Water Management of Hungary

The extreme conditions that affect the economy made the Hungarian water management reforms necessary. Their aim is to ensure the availability of water,

water services (drinking water, irrigation, other water withdrawals), and water damage prevention with measures that are standardized on a river basin level. Within the framework of water damage prevention it is to handle – with an integrated organization:

- excess water and drought protection, with the establishment of dual--operation, water supplementary and drainage system
- flood control against design flood levels with the improvement of the flood plains and the flood protection lines
- extreme water balance situation caused by climate change with the establishment of water reservoir systems.

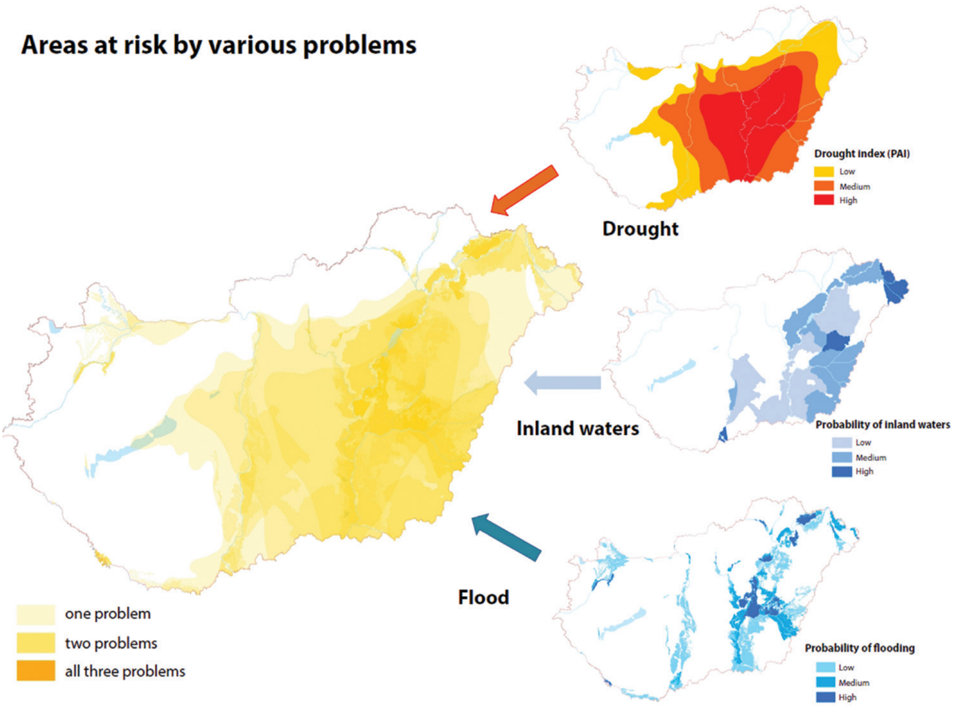

Figure 3. Water related risks in Hungary
Source: General Directorate of Water Management of Hungary

The impacts of climate change are getting more intensified, and the situation becomes further more complicated (Figure 3). The three biggest floods on the Danube took place in the last 10 (15) years, whereas on the Tisza the fourth record breaking flood occurred within 36 month around the millennium.

As regards the damage resulting from the surplus of water, we have to say a few words about the problems caused by the lack of water. 2002, 2003, 2012 were extremely dry years. Although droughts did not cause severe problems in Hungary as in other parts of the world, it is becoming a factor that has to be taken into consideration. The floods of the past 20 years made it clear that extreme floods have to be reckoned with in Hungary.

3. CLIMATE ADAPTATION

Extreme conditions and intense weather events (droughts and floods) test the capacities of the involved institutions (catastrophe protection agencies, local governmental offices and the water sector) and their economies. There is an increasing trend in the formation of local (point source like) extreme storms and precipitation, which demand quick and effective responses. Most likely these situations will force investments in damage prevention measures, but in any case, flash floods (floods within 6 hours) are expected to take place more often in mountainous areas, where people will have to accept much higher risks (Pirkhoffer et al., 2009a, 2009b; Czigány et al., 2010). In the last 10 years, or the last 6 years to be more precise, these extreme rainy days have become more numerous and damage caused by them more serious (Figure 2). Infrastructural and other measures will have to be improved to decrease the potential risks.

Hungary's water management has one primary goal, to retain water in the area, but precipitation is not generally well-managed in our country. Good practices of precipitation as a resource are not well known or accepted. Our towns and cities, the centres of population, infrastructure and industry, are the most vulnerable to climate change and the consequences of extreme weather events, since most of our towns are located directly in the most sensitive geographical areas. Cities' water management systems (safe drinking water, precipitation and sewage management infrastructure) will have to endure the changes of the water cycle (Buzás, 2015).

3.1 Hungarian Water Management Strategy

Hungary's National Water Management Strategy (the 'Kvassay Jenő Plan', hereafter referred to as: KJT) emphasizes the importance of precipitation management, the prevention of contamination and uncontrolled flow of precipitation, to safely maintain surface and ground water resources and to decrease pressure on our infrastructure, while trying to keep most of this unused water resource in place.

The subject of the KJT is water, but not only. That environmental component to which every member of the society relates somehow (starting from the individual through the economic sphere to the state), either as enjoying the benefits or suffering from diverse forms of damage caused by water. The scope extends to the whole territory of the country:

- surface and subsurface waters, their beds, banks and water storing formations;
- all establishments and activities that influence or change the runoff and streaming conditions, quantity, quality, including public water supply and wastewater systems;
- management of water resources, exploration of water use possibilities including conservation and improvement of the role of the water in nature;
- prevention and protection from the damage caused by water;
- survey and exploration of the state of waters, their assessment, research, observation, data collection, processing, dissemination and use;
- the state of water as habitat and activities influencing it as a landscape forming factor.

The KJT is the strategy of the Hungarian water management extending to 2030 and comprises the middle term action plan until 2020. It drafts the activities that need to be executed on the basis of the exploration of the relation between water and society in order to

- enable our country to avoid the water crisis threatening the world, to take necessary measures in time against its already observable signs;
- preserve the water for the next generation, because it is the condition of life, the prime mover of the economy that cannot be substituted by anything else,
- use its benefits efficiently,
- provide sufficient safety from damage it may cause.

The character of the task required the harmonisation of the ecological, technical, social and economic aspects. Methodological assistance was provided in this respect by the DPSIR frame model (driving forces – loads – states – impacts – responses). Most of the measures needed for the execution of the strategy can and should be effectuated in the 2014–2020 programming period. They fit into the EU2020 strategy and the EU cohesion and structural political conception for the period 2014–2020. The strategy has four main elements (Figure 4).

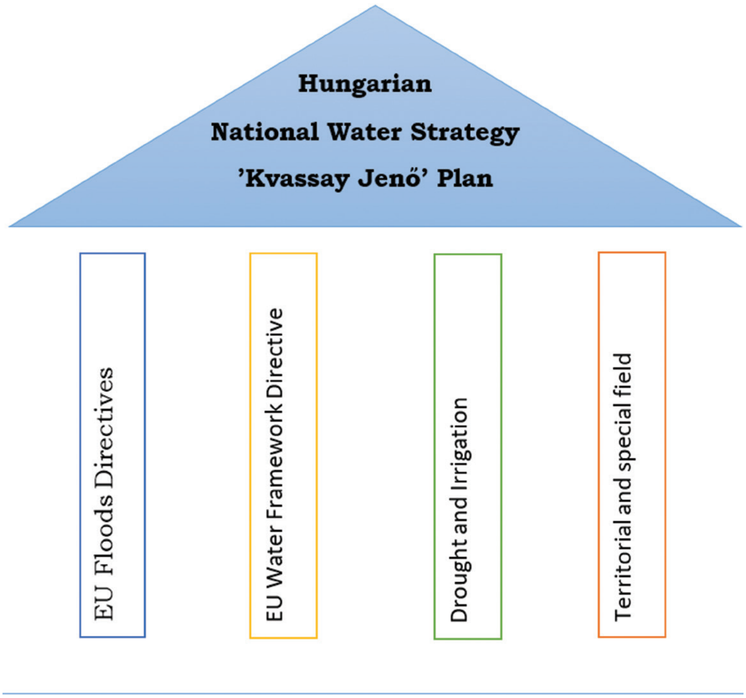

Figure 4. Pillars of the Water Strategy
Source: Author's illustration

3.2 Flood Risk Management in the Danube basin

Directive 2007/60/EC on the assessment and management of flood risks (Flood Directive, FD) requires the EU Member States to assess whether all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. This Directive also reinforces the rights of the public to access information concerning flood risks and related measures, and to influence the planning process. In the rea of the Danube basin the International Commission for the Protection of the Danube River (hereafter: ICPDR) is the coordinating body among particular countries (especially the Flood Protection Expert group). The EU Member

States shall coordinate their own flood risk management practices with all countries sharing an international river basin, including non-Member States, and shall in solidarity not undertake measures that would increase the flood risk in neighbouring countries. In addressing the Directive 2007/60/EC the Member States shall take into consideration long term developments, including climate change and sustainable land use practices.

According to FD the Member States shall, at the level of the river basin district or unit of management, develop flood hazard maps and flood risk maps at the most appropriate scale for areas identified under Article 5(1). The development of flood hazard maps and flood risk maps for areas identified under Article 5 which are shared with other Member States shall be subject to prior exchange of information between the Member States concerned.

Flood hazard maps shall cover the geographical areas that could be flooded according to the following scenarios:

- floods with a low probability, or extreme event scenarios;
- floods with a medium probability (likely return period ≥ 100 years);
- floods with a high probability, where appropriate.
- for each scenario the following elements shall be shown:
  - the flood extent;
  - water depths or water level, as appropriate;
  - where appropriate, the flow velocity or the relevant water flow.

Flood risk maps are to show the potential adverse consequences associated with flood scenarios referred to above and expressed in terms of the following:

- the indicative number of inhabitants potentially affected;
- type of economic activity of the area potentially affected;
- installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control which might cause accidental pollution in case of flooding and potentially affected protected areas identified;
- other information which the Member State considers useful, such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.

For coastal flooding where there is an adequate level of protection in place, and for groundwater flooding, Member States may decide to limit the preparation of flood hazard maps to low probability or extreme events (art 6.6 and 6.7).

3.3 Flood risk management in Hungary

Based on scopes of different scenarios the required risk evaluation was carried out in separate maps (Figure 5) for proper visualization.

- Population affected: estimated number of inhabitants who live in settlements that are spatially overlapping with the inundation (2001 data). The indication of the value is the size of the dot mark.
- Economic activity: the classification is based on the CORINE land cover data set. The important roads and railways, SEVESO objects, power plants, sewage treatment plants, harbours, airports and other industrial facilities were added from the river basin management plans.
- IED installations: the E-PRTR facilities were taken in account on the maps with harmonized classification.
- WFD protected areas: updated data from the river basin management plans were used, such as freshwater sources, recreational areas and protected landscapes. The surface water affected groundwater is also presented.

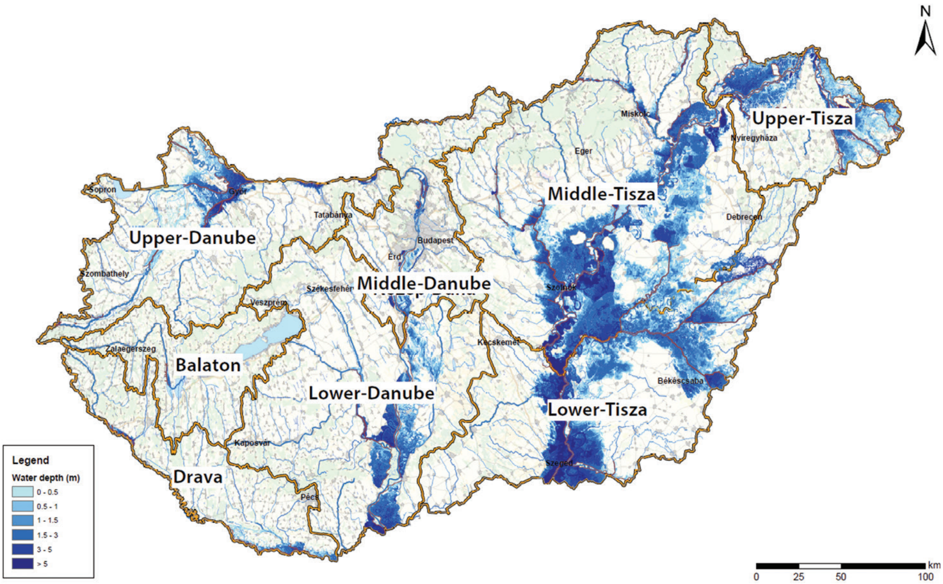

Figure 5. 100 year return period floods affected areas in Hungary
Source: General Directorate of Water Management of Hungary

3.4 Flood Plain Management Plans

Between the periods of 1998–2013 extreme floods exceeding the previous water levels developed with unprecedented rapidity on the rivers of Hungary. While flood discharges are not increasing, water levels are intensely rising (e.g. water level of the river Danube at Budapest broke a record 3 times – 2002, 2006, 2013 – in a period of 10 years), which primarily originates in the continuous reduction of the flood plain's water deliverer ability. That fact pointed out that edifices, wild agricultural territories, proliferation of the forests' underwood located in the flood plain help restrain the natural territory of the river and create a substantial runoff obstacle in case of floods (Figure 6). The negative procedure in the flood plain in addition to the rising of peak water levels results in the persistent remission of safety and consequently the value of the flood protection objects/projects built from the assigned budget. Thus the budget source covered by the tax-payer's money cannot reach its goal.

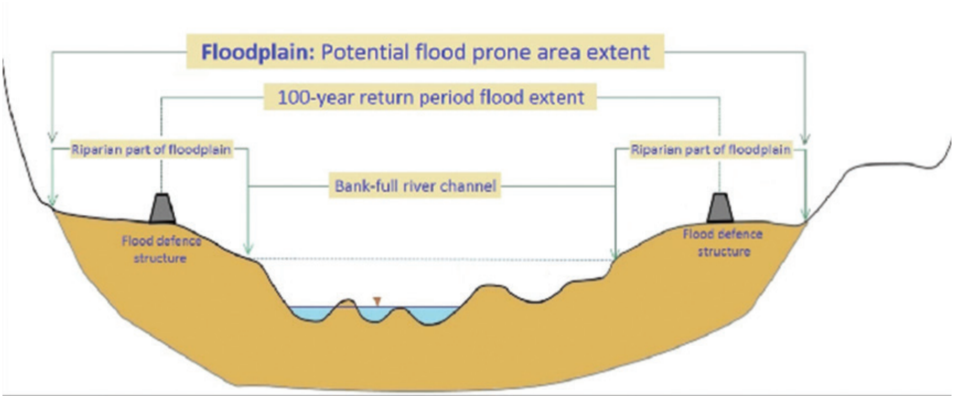

Figure 6. Definition used to characterize the flood plain
Source: Author's illustration

Besides this, the expenses of the further boost of flood protection dykes are exponentially rising, not only because of the size of the dyke, but also because of the amount of salient waters rising due to growing water pressure. This requires the reforming the water system of the protected areas as well. That fact demanded the necessity of stabilising the location of flood and the flood plain, and to avoid its further destruction.

Hungary has developed a special hydro-dynamical modelling process for the safe drainage of floods, which can be used to optimise flood drainage in the flood plain and the economic and public activity in the flood plain. The developed modelling process and the defined measures based on them ensure to stabilize the maintenance and drainage capacity of the flood plain, avoiding the further increase of peak water levels.

3.5 The definition of new design flood levels

The recent flood waves of the Danube – the biggest river of Europe – have recurrently broken the record flood levels of the past 100–150 years. The more frequently occurring flood peaks made it necessary for the water management authorities to generally supervise the earlier defined Design Flood Levels (DFL) that are fundamental for the development and construction of the protection system.

The recently developed methodology is based on scientific foundations – besides the previous system founded on water levels and water level statistics, it defines the DFL levels by statistics of water flow. Furthermore, by generating time series based on feasibly available data it can contribute to widening the database of 50–100 years to several thousand. In such a way, taking the water flow statistics into consideration and their evaluation and making calculations of the riverbed condition, the extended database made it possible to define a professionally sound design flood level for every river in Hungary.

3.6 Differentiated flood control

Based on the water management development strategy, a large number of embankments were built before 2000 with the aim of ensuring safety. However, the flood control experiences of the last 30 years in Hungary have proven that, besides developing dyke systems along rivers and building them to the specified size, it is also necessary to adopt new methods and solutions, and therefore, among others, regional flood control systems have to be deployed.

After 2000 – to prevent the effects of climate change – the development of reservoirs became increasingly important. Due to the high flood levels in 2010, flood bed management plans were completed in 2015 to preserve the necessary protection level.

It is foreseeable that reaching the necessary dyke elevations will not be possible in the next 30 years. This is the reason why the system of differentiated flood control, which is the only solution for the rational management of the ever-increasing floods resulting from climate change, needs to be introduced.

Differentiated flood protection has emerged as a national risk management variant during the preparation of the flood risk management plan.

The alternative, differentiated by basins, contains two significant differences from the current version:

- differentiation between design flood levels;
- heights of dykes are only determined by technical considerations

To introduce differentiation, it is recommended to quantify the technical and economic aspects on the basis of which we can determine the levels of protection. This requires the following aspects:

- protected or affected populations in basins;
- protected economic value or estimated flood damage in basins;
- ranking of affected populations and economic value;
- time advantage for each basin;
- subsoil and cross section problems;
- distances between dykes;
- engineering safety flood level;
- results and impact of developments up to 2020;
- impact of river basin management plans.

4. URBAN WATER MANAGEMENT

In the cities, precipitation management also has other important benefits for the people and for the environment, such as for example microclimate control and higher biodiversity. Precipitation utilization (control, preservation and further usage) is undoubtable one of the main goals of the water management sector, but it is also perhaps the most challenging concept, since all input factors (precipitation intensity and potential maximum in given area and time) shift rapidly, hence the management infrastructure engineering has to cope with these new conditions.

5. PREVENTION, PREPARATION AND RECOVERY

The Hungarian water sectors' approach to damage response has been divided according to the available time scale, to prevention, mitigation and damage repair action plans. Cost and benefit studies have concluded that prevention and mitigation is generally much cheaper than repair (Balatonyi et al., 2018). This is true in general, but also on a local scale, especially for municipal measures, both on a logistic scale and in an informal way as the background principle to influence local peoples' thinking of the problem (either as individuals, or as locals with self-governance, or as part of a larger, regional group).

Either way, the main goal is to prevent problems caused by the water and to protect water quality. This excess water can be utilized as a resource:

- For irrigation,
- For personal household reuse,
- For temporary storage to prevent flood damage,
- For setting important examples in local communities (with sanctioning)

In order to successfully adapt to these new challenging conditions, it is necessary to approach these problems both from a qualitative viewpoint (keeping the water flow in control) and a quantitative perspective (water pollution prevention). Most of the mountainous areas in Hungary already have preventive systems in place, but these are predominantly old and had not been modelled to mitigate the risks of current and future events.

First, we will have to update our risk assessment by carefully studying the previous 30 years' maximum precipitation records (Buzás, 2012). Until new models are generated with updated calculations, we can assume that our safety systems have become outdated, and local floods are going to occur. Furthermore, without updated models, even our new preventive measures will be just as outdated as the old ones.

Climate seems to change as fast as we reconstruct municipal water outlets, so it is possibly the only feasible economical option to focus on local water storage potentials (increasing storm water storage capacities and groundwater inflow).

5.1 Options for Water Storage

The most effective way to prevent flooding in low hill and mountainous areas is to provide storage options around the watershed perimeter, at the source and not where water accumulates. It is also true that the best way is to start retaining water at individual owners' grounds, and only step up as reassurance on the local and national level.

Precipitation events can be categorized by their intensity as follows:

Approximately, below 20 mm hr^{-1} the best option is to use "green tech" to increase ground water recharge at the local grounds. Above this intensity, local governmental infrastructural management is needed, with some designated areas that can be temporarily flooded. The most extreme events might demand regional infrastructure investments.

6. ENGINEERING TASKS FOR FUTURE MUNICIPAL STORM WATER MANAGEMENT

Extreme weather conditions can lead to disagreement and conflict between various dependent groups. People are getting used to constant, reliable improvement of their lives, and they also want the government to provide complete protection from the constantly more and more unpredictable weather. This should not be accepted by the central administration. People will have to be aware of their own responsibility. We might accept and try to control the discourse about the water level control of lake Balaton (a fresh-water lake in the Transdanubian region of Hungary. It is the largest lake in Central Europe), but local problems will have to be solved in situ. Even so, it is inevitable that we will have to develop strict laws for the regional and central governance.

Economics, engineering concepts and laws will all have to be taken into account in order to create a reliable and somewhat flexible but complete strategy for the future. Local resources, the capacities of towns and their people will be the main controlling factors of course, but the concepts should be clear, and these all depend on new, updated calculations and modelss:

- Average precipitation and overflow calculations, based on a reliable, up--to-date data collection system,
- New models, pilot projects and predictions as basic information for everyday practices,
- Informing the general public about challenges and their responsibilities as responsible citizens,
- Scientific studies of previous events and evaluation of their results.

We will need to convert and incorporate international standards and good practice guidelines into our national approach to be able to cope with these new challenges. It will also be necessary to categorize each town and city by their geographic vulnerability into groups and to help the local administration to update their strategic plans by educating them about the new potential risks.

Precipitation can be utilized by individuals as reserve water for gardening in drought periods, or even for household usage. The costs and benefits of those methods are not known too well by people, and so they tend to ignore the issue. We will have to explore the most economic ways that we can promote on a national scale.

7. LAWS AND COORDINATION

It is necessary to identify the most relevant national laws and rules appropriately to each specific situation to be able to decide who is responsible, the individual, or the local or central administration.

Generally speaking, each individual having a property has a direct effect on how precipitation will flow. (Green gardens and concrete grounds have obviously totally different absorption capacities.) Public service providers cannot be "punished" with having to deal with the entire overflow from gardens, when their contracts do not cover issues of rainwater management. Although this should be included in their contracts as basic public utility service (Buzás 2015) it would be unfair to generally ask for a fixed extra price from every citizen. Instead people's payments should be based on the size and condition of their properties.

8. ECONOMIC BACKGROUND OF MUNICIPAL PRECIPITATION MANAGEMENT

As has already been mentioned, people should not rely on the central governance for fixing their own problems, and local administration will have to be responsible for studying and assessing their environmental and economic situation, since they are mostly dependent on long-term local stability. EU sources can be a part of larger investment projects' financial support and the central administration bodies can also help, but local citizens have to realize it is primarily their responsibility.

9. WHERE DO WE STAND NOW

Most people have already realized that climate change is not merely a theoretical concept and that extreme weathers pose real risks. Local actors try to do what they can with limited resources, mainly to keep up the functioning of the existing infrastructure. The central administration's public works program (temporary jobs for unemployed people) helps in maintaining old infrastructure, but new largescale engineering projects require additionally provision of EU resources.

Exploring and sharing experiences, lesson-learned and new ideas on how to increase the resilience for risks triggered by climate change constitute a highly important step forward. The EU is the best possible platform to do so, since it supports such dialog not only with its policies but also financially by way of diverse EU programmes. Thanks to such sources of finances research works on the discussed topic are continued all over Europe, providing and verifying new ideas including the deployment of new technological solutions in order to improve flood management processes (Zwęgliński, 2020).

The aim of the article has been achieved by sufficiently detailed elaboration of the Hungarian system of flood management in the context of climate change. All discussed measures concerning flood prevention, preparedness and response including legal, organizational, economic and engineering aspects valid for Hungary, appear to be the same, or at least similar, to those which are being implemented in Poland. Therefore, continuous monitoring and sharing knowledge and experience are highly important to allow learning from each other. Such approach is a valuable tool for strengthening preparedness in specific state, region and finally entire Europe.

REFERENCES

1. Balatonyi, L., Makay, G., and Tóth, L. (2018): *A közelmúlt globális klímaváltozásai, helyi vízkáreseményei és költségvetési következményei a dél – dunántúli kis vízfolyásokon*.
2. Buzás, K. (2015): *A városi vízrendszerek megújítása, a klímaváltozáshoz való alkalmazkodás növelése.*
3. Buzás, K. (2012): *Települési csapadékvíz gazdálkodás*, Monográfia, Terc kiadó, 2012. 148 old.

4. Czigány, S., Pirkhoffer, E., Balassa, B., Bugya, T., Bötkös, T., Gyenizse, P., Nagyváradi, L., Lóczy, D. and Geresdi, I. (2010): *Villámárvíz, mint természeti veszélyforrás a Dél-Dunántúlon Földrajzi Közlemények* 134(3): 281–298.
5. International Commission for the Protection of the Danube River (2018): Climate Change adaptation strategy, https://www.icpdr.org/flowpaper/app/services/view.php?doc=icpdr_climatechangeadaptationstrategy_2.pdf&format=pdf&page={page}&subfolder=default/files/nodes/documents/ (Access, 15 March, 2021).
6. International Commission for the Protection of the Danube River (2015): 1st DRB Flood Risk Management Plan, https://www.icpdr.org/flowpaper/app/#page=2.
7. International Commission for the Protection of the Danube River (2013): Floods in June 2013 in the Danube River Basin https://www.icpdr.org/main/sites/default/files/nodes/documents/icpdr_floods-report-web_0.pdf.
8. Intergovernmental Panel on Climate Change (2014): Summary for Policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32.
9. Pirkhoffer, E., Czigány, S. and Geresdi, I. (2009a): *Modeling of flash flood events in a small low-mountain watershed in SW Hungary*.
10. Pirkhoffer, E., Czigány S. and Geresdi, I. (2009b): *Occurrence of rainfall pattern on the occurrence of flash floods in Hungary Zeitschrift für Geomorphologie*.
11. van Duuren, C., Zwęgliński, T. (2019): *Analysis of the Dutch Crisis Response System in the Context of the Common European Union Resilience*, Internal Security, 2019, No. 2/2019, pp. 55–64, DOI: 10.5604/01.3001.0013.8205.
12. Państwowe Gospodarstwo Wodne Wody Polskie, https://www.wody.gov.pl (Access: 20 March 2021).
13. Zwęgliński, T. (2017): *Wymiar pomocy międzynarodowej podczas powodzi 2010 roku* [in:] *Bezpieczeństwo w obszarach przygranicznych – Volume I* [ed.] B. Kaczmarczyk, Wydawnictwo Adam Marszałek, Toruń 2017, ISBN 978-83-8019-827-2.
14. Zwęgliński, T., Morgado, C. (2018): *Analytical approach to cooperation of the State Fire Service with the Police in Poland in the context of brief comparison with Portuguese reality*, Internal Security, 2018, Volume 10, Issue 1, Wyższa Szkoła Policji w Szczytnie, DOI: 10.5604/01.3001.0012.7498.

15. Zwęgliński, T. (2020): *An Overview of the European Union Instruments Contributing to the Internal Security of the Organization and its Member States*, Zeszyty Naukowe SGSP, 2020, No. 74/2/2020, pp. 181–196, DOI: 10.5604/01.3001.0014.3178.
16. Zwęgliński, T. (2020): *The Use of Drones in Disaster Aerial Needs Reconnaissance and Damage Assessment – 3D Modelling and Orthophoto Map Study*, Sustainability, 2020, 12(15), 6080, DOI: https://doi.org/10.3390/su12156080.

TOMASZ ZWĘGLIŃSKI – PhD in Security Sciences, Master of Fire Engineering, professional fire officer (Lt. Col.) and a specialist in civil protection and crisis/disaster management.

An academic working in the Internal Security Institute at the Main School of Fire Service (Warsaw, Poland). PhD obtained in a military university (the National Defence Academy in Warsaw, Poland). Fire engineering and disaster management studied at the Main School of Fire Service (Warsaw, Poland) accordingly at the Fire Safety Engineering Faculty and the Civil Safety Engineering Faculty. A disaster environmental expert of the Joint Environmental Unit UNEP/OCHA and high level coordination expert of the European Union Civil Protection Mechanism. EU CBRN Security Manager with completed international post-graduate study in 2018, financed from the EU Internal Security Fund (DG HOME). Occupational safety expert graduated from the Warsaw Technical University and the Central Institute for Labour Protection – National Research Institute (Poland). National and international research and capacity building projects manager (incl. EU funding as well as Official Development Assistance funding). Table-top and field civil protection exercises organizer, trainer and evaluator (incl. UCPM Training Programme).

LASZLO BALATONYI – PhD in Geography.

László BALATONYI MSc in environmental expert who graduated from the Pécs University of Natural Sciences in 2009.

For the past 10 years he has been working for the Hungarian governmental Water Management Service (General Directorate of Water Management, OVF), since 2016 as the head of the unit (Urban Water Management). László Balatonyi is a senior lecturer in the University of Public Service faculty of Water Sciences and teaching the students to practice orientated subjects. In the field of the water diplomacy Mr. Balatonyi is the priority area coordinator (since 2019) of the EU Strategy for Danube Region of the Environmental Risks priority area. When prevention measures are not effective enough, disasters occur, therefore EUSDR PA5 supports the assessment of disaster risks in the Danube Region, encouraging actions to promote disaster resilience, preparedness and response activities.

TOMASZ ZWĘGLIŃSKI – doktor nauk o bezpieczeństwie, magister inżynier pożarnictwa, zawodowy oficer pożarnictwa (ppłk) oraz specjalista w zakresie ochrony ludności i zarządzania kryzysowego/klęsk żywiołowych.

Pracownik naukowy Instytutu Bezpieczeństwa Wewnętrznego Szkoły Głównej Służby Pożarniczej (Warszawa). Doktorat uzyskany w uczelni wojskowej (Akademia Obrony Narodowej w Warszawie). Inżynieria pożarowa i zarządzanie kryzysowe studiowane w Szkole Głównej Służby Pożarniczej (Warszawa), odpowiednio na Wydziale Inżynierii Bezpieczeństwa Pożarowego i Wydziale Inżynierii Bezpieczeństwa Cywilnego. Ekspert ds. środowiska w zakresie katastrof we Wspólnej Jednostce Środowiskowej UNEP/OCHA oraz ekspert wysokiego szczebla ds. koordynacji w ramach Mechanizmu Ochrony Ludności Unii Europejskiej. EU CBRN Security Manager z ukończonymi międzynarodowymi studiami podyplomowymi w 2018 r., finansowanymi ze środków Funduszu Bezpieczeństwa Wewnętrznego UE (DG HOME). Ekspert ds. bezpieczeństwa pracy, absolwent Politechniki Warszawskiej i Centralnego Instytutu Ochrony Pracy – Państwowego Instytutu Badawczego (Polska). Kierownik krajowych i międzynarodowych projektów badawczych oraz projektów budowania potencjału (w tym projektów finansowanych przez UE oraz w ramach Oficjalnej Pomocy Rozwojowej). Organizator, trener i ewaluator ćwiczeń terenowych z zakresu ochrony ludności (m.in. Program szkoleniowy UCPM).

LASZLO BALATONYI – Doktor nauk geograficznych, magister inżynier, ekspert ds. środowiska, który ukończył Uniwersytet Przyrodniczy w Peczu w 2009 r.

Przez ostatnie 10 lat pracuje dla węgierskiej rządowej Służby Gospodarki Wodnej (Generalna Dyrekcja Gospodarki Wodnej, OVF), od 2016 r. jako kierownik jednostki (Miejska Gospodarka Wodna). Jest starszym wykładowcą w University of Public Service na wydziale Nauk o Wodzie i uczy studentów przedmiotów zorientowanych na praktykę. W dziedzinie dyplomacji wodnej jest koordynatorem obszaru priorytetowego (od 2019 r.) Strategii UE dla regionu Dunaju w obszarze priorytetowym Ryzyko środowiskowe. Kiedy środki zapobiegawcze nie są wystarczająco skuteczne, dochodzi do katastrof, dlatego EUSDR PA5 wspiera ocenę ryzyka katastrof w regionie Dunaju, zachęcając do działań promujących odporność na katastrofy, gotowość i działania w zakresie reagowania.