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JOINTISZA

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1 Introduction

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The JOINTISZA project – *Strengthening the Cooperation between River Basin Management Planning and Flood Risk Prevention to Enhance the Status of Waters of the Tisza River Basin* – focuses on interactions of the two key aspects: the river basin management (RBM) and flood protection. The main aims of the project were to further improve the integration of the water management and flood risk prevention planning and actions while elaborating the Updated Integrated Tisza River Basin Management Plan, in line with the relevant EU legislations, as well as to provide improved methods on urban hydrology management procedures through pilot actions on selected cities and also to investigate the climate change issues, taking into account the relevant four types of stakeholder groups, namely the national water administrations, water research institutes, international organisations and other interested stakeholders as well as NGOs, who play a key role in the Tisza River Basin management planning process.

One of the focus themes of the project involved a pilot action on climate change-induced specific water quantity issues, which included the following three major tasks: Task 1: Ad-Hoc Task Group (AHTG) activities; Task 2: Elaboration of the Guidance Paper on Climate Change-Induced Specific Water Quantity Issues to Overcome Challenges; Task 3: Application of the Shared Vision Planning method, a pilot action based on a selected pilot area.

This Guidance paper is a joint product of the AHTG members who were invited by the experts of the Project Partners of the JOINTISZA project to work in the group as well as some internationally recognised external experts who were also invited to join the AHTG.

The AHTG has held three meetings during the project. The Group discussed and determined the aim and content of the Guidance paper, taking into account that the paper was intended to be one of the main outputs of the JOINTISZA project. The AHTG members were also responsible for writing the chapters of the Guidance paper as well as for facilitating the test work on how the Shared Vision Planning method should be used in the selected pilot area.

The Guidance paper aims to provide a practical document for stakeholders who will to be involved in the next term river basin management planning procedures in a river basin significantly influenced by climate change. Firstly, the paper provides an overview on i) the core principles and approaches of the EU policies on climate change adaptation; ii) how the issue is addressed in the Danube River Basin and in the Carpathian Basin and iii) the integrative way of the river basin management.

After setting the scene, Chapter 3 gives a summary on information and monitoring needs on climate change related to water quantity aspects of the river basin management planning.

Chapter 4 discusses how changing climate impacts hydrology and water resources and identifies the induced problems in the Tisza River Basin.

The next chapter is a concise summary of tools that stakeholders engaged in river basin management planning could use to enhance considerations of climate change adaptation.

Chapter 6 introduces a pilot work and experience from the application of the Shared Vision Planning methodology on a selected Tisza River sub-basin located in the middle part of the Tisza Basin. The pilot action focused on modelling and analysing climate change-related drought and flood extremes in a smaller region within the TRB and included testing of the Shared Vision Planning concept.

2 Setting the Scene, Core Principles and Approaches

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2.1 Setting the Scene

2.1.1 Climate change adaptation in Europe

Climate change has significant effects on Europe already. The total reported economic losses caused by weather- and climate-related extremes in the EEA member countries over the period of 1980–2015 amounted to over EUR 433 billion and the impacts will be even more serious in the future. The largest share of the economic impacts is caused by floods (38 %) followed by storms (25 %), droughts (9 %) and heat waves (6 %). The severity and frequency of droughts have increased in some parts of Europe, in particular in southern and south-eastern Europe. Droughts are projected to increase in frequency, duration and severity in most of Europe, with the strongest increase projected for southern Europe. Since 1980, the number of flood events causing large economic losses in Europe has increased, but with a large inter-annual variability *(European Environment Agency, 2017)*. Many catchment areas of the continent – such as the Tisza Basin – have a transboundary feature, therefore risks and challenges need to be coordinated on international scale.

There are several documents, which help the adaptation process and give proposal on how to develop strategy for coordinated climate adaptation activities on the river basin-wide scale. The following documents and information sources serve as helping tools in the preparation of the current guidance paper:

- 2007: EC Communication on water scarcity & droughts in the European Union[1]
- 2009: EC White Paper “Adapting to climate change: Towards a European framework for action”[2]
- 2009: EU CIS Guidance No. 24: River Basin Management in a Changing Climate[3]
- 2009: UNECE Guidance on Water and Adaptation to Climate Change[4]
- 2012: Blueprint to safeguard Europe’s Water resources[5]

In 2012, the European Commission carried out a review of water scarcity and droughts policy (EC, 2012a)[6]. An accompanying report *(Schmidt, G.; C. Benítez-Sanz; 2012)* investigating 73 international RBMPs of the EU concluded that there was a major gap in dealing with water quantity and very few of the international river basins included coordinated measures between the neighbouring countries. The information on transboundary coordination in the field of water scarcity and droughts was not clear in 60% of the plans, no information was found or it could be considered “not relevant”. Only 3% of the plans included co-ordinated measures for the entire international RBD. Joint challenges have been identified by 11% of the plans as the

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[1] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0414:FIN:EN:PDF

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009DC0147&from=EN

[3] https://circabc.europa.eu/sd/a/a88369ef-df4d-43b1-8c8c-306ac7c2d6e1/Guidance_document_n_24_-_River_Basin_Management_in_a_Changing_Climate_FINAL.pdf

[4] https://www.unece.org/index.php?id=11658

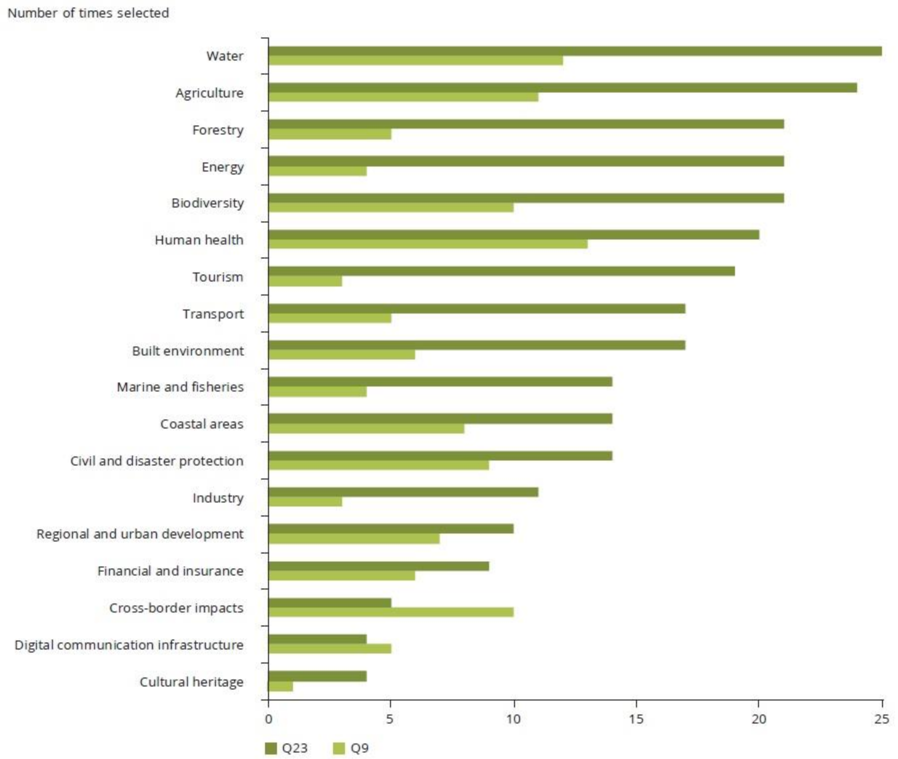
[5] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0673&from=EN

[6] https://climate-adapt.eea.europa.eu/metadata/publications/report-on-the-review-of-the-european-water-scarcity-and-drought-policy/11309505

way to address WS&D issues in shared water bodies and in another 20% the transboundary cooperation was stated as a general coordination issue.

In 2013, the European Commission presented the EU Strategy on Adaptation to Climate Change (EC, 2013)[7] and a number of supporting documents with the overall aim to contribute to a more climate-resilient Europe. This Strategy encourages all Member States to adopt comprehensive adaptation strategies, aims to a mainstream adaptation into relevant EU policies and programmes, provides funding for adaptation actions, promotes action in cities (through the Covenant of Mayors for Climate and Energy), as well as enhances research and knowledge transfer via the European climate adaptation platform (Climate-ADAPT) as 'one-stop shop' for adaptation information.

Since the adoption of the EU CCAS the countries have prepared their national adaptation strategies (NAS) and adaptation plans (NAP). The assessments of current and projected impacts of climate change and of the associated vulnerabilities and risks ('CCIV assessments') are a key element of national adaptation policies *(Figure II.1.)*. They provide crucial information for the development, implementation and revision of adaptation policies and measures, including NASs and NAPs *(European Environment Agency; 2018; p.79)*. The assessments highlight mainly water related issues.



Note: The light green bars are based on the responses from 24 countries, whereas the dark green bars are based on 25 assessments from 23 countries. The absolute length of the two bars cannot be compared, because the survey invited countries to identify up to five priority areas for further information, which is smaller than the number of thematic areas considered in many multi-sectoral CCIV assessments. However, comparison of their relative length is meaningful.

Figure II.1: Coverage of thematic areas in CCIV assessments (dark green bars) and countries stating that more information is required (light green bars) (European Environment Agency; 2018; pp.79).

The European Multiannual Financial Framework (2014–2020) included the objective that a minimum of 20 % of the EU budget contributes to climate-related expenditures (including adaptation). Initial analysis shows that this objective will be achieved, but its effectiveness in terms of enhanced resilience is yet to be evaluated. The proposed EU budget for the future (2021-2027) continues to strengthen the well-established

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[7] https://ec.europa.eu/transparency/regdoc/rep/1/2013/EN/1-2013-216-EN-F1-1.Pdf

programme for the environment and climate action (LIFE). The Commission proposes to set a more ambitious goal for climate mainstreaming across all EU programmes, with a target of 25% of EU expenditures contributing to climate objectives.

In September 2016 the EC started the evaluation of the EU Adaptation Strategy, which terminated at the end of 2018.

2.1.2 Climate change adaptation process in the Danube River Basin (within the ICPDR and EUSDR framework) and in the Carpathian region

The Revision and Update of the Danube Study was initiated by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety to revise the findings of the first Danube study conducted in 2010-2011. The new study elaborated since January 2017 supports a Danube-wide understanding of climate change impact on hydrology and water availability. The outcomes of the study provide an analysis of 73 research and development projects conducted between 2012 and 2016/2017 and a comparison with the findings of the previous document. The study includes suggested adaptation measures in different fields (e.g. water-related climate change impacts, reduced water availability, drought/low flow management, flood management, navigation, etc.). The Danube Study Update was discussed by several experts of the Danube region at the ICPDR Climate Change Adaptation Workshop (March 2018, Belgrade). It was intended to serve as the basis of the Danube Climate Change Adaptation Strategy to be adopted at the end of 2018 by the ICPDR Heads of Delegation.

Within the framework of the EU Strategy for the Danube Region (EUSDR) – as the second macro-regional strategy of the EU founded in 2011 – the challenges of climate change are mostly dedicated to the Priority Area 5 (Environmental risks) dealing partly with floods and drought issues. Thus, the PA5 supports via its three targets the implementation of basin-wide plans and strategies (i.e. Target 2 supporting the implementation of the DFRMP) based on the *Joint Paper on Cooperation and Synergy for the EUSDR Implementation* signed with ICPDR in 2014. Target 1 of EUSDR PA5 (*'To address the challenges of water scarcity and droughts in line with the Danube River Basin Management Plan – Update 2015, 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')* focuses on water scarcity and drought issues. Out of the eight actions of the priority area, two were directly dedicated to climate change. Namely, Action 7 (*'Anticipate regional and local impacts of climate change through research')* and Action 8 (*'To develop spatial planning and construction activities in the context of climate change and increased threats of floods'*) aim to harmonize efforts of the 14 Danube countries in the field of climate adaptation. Furthermore, the harmonization of preventive disaster risk evaluation methods and tools – such as the commonly set standards for risk mapping developed regarding the specific climate and/or extreme weather phenomena, or establishment of the comparability of data/information systems about extreme climatic events – are covered by Action 4 (*'To strengthen operational cooperation among emergency response authorities in the Danube countries and to improve the interoperability of the available assets'*).

Under the EUSDR PA5, several projects received funding since 2011, struggling to reach better preparedness and increased resilience of the region with the improved management of floods or drought events (i.e. SEERISK, JOINTISZA, DriDanube, WateratRisk, EastAvert, RaabFlood4cast, InterFloodCourse, DAREFFORT, DanubeFloodplain).

The *'Strategic agenda on adaptation to climate change in the Carpathian region'* has been elaborated by the 7 Carpathian countries until 2014 and finally the *'Article on Climate Change to the Carpathian Convention'* has been adopted during the Conference of the Parties 5 (COP5) in Hungary 2017. This process was facilitated by the outcomes of the CARPIVIA and CARPATCLIM projects. The latter project prepared a gridded database and climate atlas for the region, since CARPIVIA was the project for integrated assessment of vulnerability of environmental resources and ecosystem-based adaptation measures. The newly adopted article of the Convention obliges its signatories to:

a. pursue policies aimed at climate change mitigation in all sectors relevant to the Convention having in mind their interactions,

b. pursue policies aiming at climate change adaptation by promoting research and scientific cooperation, cross-sectoral integration, transnational cooperation, awareness raising, public participation and cooperation of all stakeholders and fostering local adaptation planning processes and the implementation of actions, especially in the most vulnerable areas and sectors, and

c. undertake integrated measures to reduce the risks and minimise the adverse effects of climate change, especially of extreme weather events.

2.1.3 Climate change adaptation and integrated river basin management in the Tisza River Basin

The Tisza River Basin is unique regarding its nature and biodiversity and due to its geographical characteristics. With a strongly meandering riverbed, the original length of the Tisza River was 1,400 km from its spring in the north-eastern Carpathian Mountains in Ukraine to its mouth at the Danube. During the second half of the 19th century, extensive measures of river training and flood control were undertaken along the river. As a result of these works, the river's total length was shortened by approximately 30% to current 966 km. However, it is still the longest tributary of the Danube River with the second largest discharge after the Sava River. *(ICPDR; 2008)*

The basin faces several problems, such as:

- severe floods,
- drought problems in summer (particularly in Hungary and Serbia),
- landslides and erosion in the uplands (particularly in Ukraine),
- accidental pollution by industrial and mining activities,
- agricultural pollution, affecting the sensitivity of the Danube and the Black Sea by nutrient pollution,
- accidental pollution and nutrient pollution can directly influence aquatic ecosystems and drinking water utilisation, while large-scale land reclamation can damage wetland ecosystems and intensified flooding problems in other areas.

From the above list it is already visible that next to the pressures due to nutrient, organic or hazardous substances pollution, water quantity related problems such as floods, water scarcity and drought are also crucial. The Tisza River Basin countries therefore have been paying special attention to water quantity-related problems since the beginning of cooperation.

As it has been described in the first Integrated Tisza River Basin Management Plan (ITRBMP) *(ICPDR, 2011)*, four significant water management issues (SWMI) were identified at the Danube River Basin District level, having impact on the water quality of surface water and groundwater: organic pollution, nutrient pollution, hazardous substances pollution and hydro-morphological alterations.

In addition to the process described above, the *Tisza countries defined that management issues related to water quantity needed special attention* and are therefore *treated as an additional relevant water* *management issue***.** Water scarcity and droughts, as well as floods and excess water events pose a major challenge for the Tisza River Basin.

Climate change is expected to further influence these challenges.

The ITRBMP already states that an *"overview of the main impacts of climate change on the Tisza River Basin (based on current knowledge) is important to investigate in order to determine whether the Programme of Measures (PoMs) is 'climate-proof' and includes further adaptation measures."*

Floods and droughts have negative side-effects on biodiversity and water quality. In addition, previously existing problems related to water quality could be exacerbated by the effects of these water quantity events. The ITRBMP therefore also focuses on these issues and on how their management can be integrated.

In summary, according to the principles of the Integrated Water Resources Management – *which promote the coordinated development and management of water, land and related resources, to maximise the resulting economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems* – the Tisza countries have developed the Integrated Tisza River Basin Management Plan (ITRBMP) accounting for both water quality and water quantity issues, *to identify measures which will have positive impacts on both water quality and quantity and on aquatic ecosystems in the Tisza River Basin.*

In relation to climate change, the following vision and management objective has been identified to be achieved in the coming management cycles:

- **Climate change related vision** addressed in the ITRBMP: `Climate change and its hydrological impacts (droughts, floods and flash floods) are fully addressed in decision-making to ensure the sustainability of ecosystems`
- **Climate change related management objective** addressed in the ITRBMP: `Identify climate change impacts at the Tisza Basin-wide scale and assess whether and how these impacts affect the Tisza Programme of Measures and vice versa (e.g. are certain measures effective or can certain measures be considered as no-regret measures in relation to climate change adaptation)`

The ITRBMP suggests, as a first step, to get better insight into possible impacts of climate change on the Tisza region, initially achievable through a review and analysis of the many previous and ongoing projects that could lead to the need for any future projects addressing the specific needs of the Tisza River Basin.

Another priority is to ensure that future measures implemented in the Tisza River Basin that might have additional negative impacts on water status are climate-proof or no/low regret measures. Particularly for large infrastructure projects with a long lifetime, possible climate scenarios have to be taken into account.

A further priority is to speed up implementation of some measures of the ITRBMP that increases ecosystem resilience. The examples include floodplain restorations recreating wetlands that can serve as water buffers in times of floods and droughts and fish by-passes that allow fish species to freely adjust their feeding or spawning range when environmental conditions change.

2.2 National climate change adaptation strategies

Since 2014, all five Tisza countries have adopted their own national adaptation strategies (NAS). A revision of NAS has already been done in Hungary and Romania *(Figure II.2).*

Figure II.2: Countries with National Adaptation Strategies in the DRB (LMU, 2018)

In **Hungary,** the report "Climate Change and Hungary: Mitigating the Hazard and Preparing for the Impacts" was published in 2008 as an outcome of the 5-year VAHAVA project. The Climate Change Act 2007 (Act LV) based on the implementation framework of the UNFCCC and its Kyoto Protocol created a framework for building Hungary's ability to adapt to climate change. The National Climate Change Strategy (NCCS) was accepted by the Parliamentary Decree 29/2008 (III. 20.), identifying key objectives and actions to be implemented in the period 2008-2025. The first revision of the NCCS mandated by the Climate Change Act 2007 was finished in 2013 and submitted to the Parliament for adoption in May 2017. The revised version determines the timeline of the strategy from 2014 to 2025, with an outlook to 2050.

The National Adaptation Strategy will be adopted as a part of the second revision of the NCCS *(ITM, 2018)*. This will provide further information on climate change science, observations and sectoral impact assessments (the documents are available through the EEA Climate-Adapt website[8].).

In this regard, a robust metadata base, the National Adaptation Geographical Information System (NAGIS), is currently in progress. This system will be the first comprehensive, countrywide tool to provide high-resolution results of the quantified expected trends and the associated uncertainty of the local and regional exposure, sensitivity and adaptive capacity for different hazards. It will also provide input data for spatial and sectoral vulnerability studies.

Several cities in Hungary have developed their own local climate change strategy. The Hungarian Alliance of Climate-Friendly Cities is a partnership of local governments and NGOs providing technical advice, tools, case studies and information to cities on climate change adaptation and mitigation. Recently, climate change

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[8] https://climate-adapt.eea.europa.eu/countries-regions/countries/hungary

adaptation strategies have been under elaboration on a county level, some of them already adopted as of July 2019.)

In **Romania,** the first National Climate Change Strategy, drawn up in 2005 and approved by the Governmental Decision (no 645/2005) was related to the 2005-2007 period. Climate change adaptation issues were highlighted separately in the chapter "Impact, Vulnerability and Climate Change Adaptation", which briefly detailed the effects of climate change adaptation on the following sectors: agriculture, forestry, water management and human settlements. In 2008, in response to the EU Green Paper "Adapting to climate change in Europe - options for EU action", the Ministry of Environment and Forests developed the Guide on the adaptation to the climate change effects approved by the Ministerial Order (no. 1170/2008).

This guide provides recommendations on measures, which aimed to reduce the risk of the negative effects of climate change in 13 key sectors, e.g. agriculture, biodiversity, water resources, forests, etc. In July 2013, the Romanian Government adopted the *Romania's National Climate Change Strategy (2013-2020)* through the Governmental Decision no. 529/2013 *(MMSC, 2013)*. (Related documents are available through the EEA Climate-Adapt website.[9]) In addition, the *National Strategy on Drought Effects Mitigation*, the *Action Plan for Addressing Nitrate Pollution from Agricultural Sources*, and the *National Plan for Irrigation Rehabilitation and Reform* are among the key plans that are relevant to addressing climate change implications in water related sectors. In 2014, the study "Estimating the impact of climate change on river flow regime in Romania" was elaborated by the NIHWM. In October 2016, the Romanian Government adopted the new strategy approved by the G.D. no. 739/2016.

In **Slovakia,** the High Level Committee for Coordination of the Climate Change Policy was established in 2012. The NAS was adopted by the government (Resolution No. 148/2014) in March 2014. The vulnerability of sectors, i.e. water management, biodiversity, agriculture and forest management was also deeply and on a wider scale of areas assessed in the "Climate change impacts and possible adaptation measures in various sectors in Slovakia" report prepared by the SHMU. This document was the one of basic sources for preparing the NAS. The update of the National adaptation strategy based on the latest available science will be undertaken in 2018. (Related documents are available through the EEA Climate-Adapt website.[10])

Although not having a document on a national climate strategy yet, **Serbia** is involved in the development of such strategies and guidelines under the ICPDR auspices. A climate change adaptation programme was developed under the Initial Nation Communication of the Republic of Serbia (submitted to the UNFCCC in 2010) and basic principles of these issues are included. The Second National Communication, (submitted on the ICPDR Danubius, December 2016), underlined the vulnerability assessment and adaptation in hydrology and water resources, agriculture and forestry, based on the fact that these sectors were identified as the most vulnerable and important in the Initial National Communication. The draft of the First Serbian National Adaptation Plan was published in 2015 and since 2016, the **"Climate Strategy and Action Plan" Project** is funded by the European Union through the Instrument for Pre-Accession Assistance (IPA funds). It will prepare a national cross-sectoral Climate Change Strategy and Action Plan. This will be coordinated by **the Ministry of Environmental Protection.** The Strategy will establish both the strategic and policy framework

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[9] https://climate-adapt.eea.europa.eu/countries-regions/countries/romania

[10] https://climate-adapt.eea.europa.eu/countries-regions/countries/slovakia

for climate action in Serbia in compliance with the international obligations and pledges on greenhouse gas mitigation. (Related documents will be available on the "serbiaclimatestrategy.eu" project website[11]).

In the **Ukraine,** the concept of implementation of the state policy in the field of climate change for the period till 2030 was adopted by the Cabinet of Ministers of the Ukraine in 2017. According to this document, a climate change adaptation strategy should be developed by 2020 and will cover the period from 2021 to 2030.

In the Tisza River Basin, as many as 68 settlements have already joined the **Covenant of Mayors for Climate and Energy Network**[12], representing more than 3 million people *(Table II.2)*. It means these municipalities are not only aware of the challenges of climate change, but are ready to develop their own adaptation strategies and secure funding for local projects in different fields of climate adaptation.

Table II.2: Signatories of the Covenant of Mayors for Climate and Energy in the Tisza countries and settlements covered by the Tisza basin (data

Country	Covenant of Mayors total signatories per country	Population in the country	Covenant of Mayors signatories from the Tisza Basin	Population in the TRB
Hungary	40	3714647	22	951458
Romania	73	4982359	39	1834080
Serbia	1	255518	0	0
Slovakia	13	779985	4	102169
Ukraine	173	15388876	3	137480
TOTAL	**300**	**25121385**	**68**	**3025187**

2.3 Core principles for the WFD implementation in a changing climate

Four water quantity-related management aspects have been specified in the Integrated Tisza River Basin Management Plan in 2011, namely flood and excess water events, drought and water scarcity. Alerting climate scenarios were presented; each of which called for attention since future extreme climate events might further intensify the impacts of flood, drought, excess water and water scarcity in the Tisza River Basin.

The following pages introduce the guiding principles set by the Guidance document no. 24 of the European Communities on the "River Basin Management in a Changing Climate".

The guiding principles set out in the following tables list, on one hand, the guiding principles in relation to the river basin management planning process and provide information on how climate change adaptation should be considered at each step of the river basin management planning.

Guiding principles to be taken into account during drought management, water scarcity and adaptation are listed below in subchapter 2.3.2.

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[11] http://www.serbiaclimatestrategy.eu/about/

[12] https://www.covenantofmayors.eu/about/covenant-community/signatories.html

2.3.1 Guiding principles for the WFD and adaptation

Table II.1: RBM steps and guiding principles for the WFD implementation in a changing climate (source: European Communities, 2009)

RBM steps of WFD	Guiding principle	Summary of the guiding principles for the RBM steps
Assessing pressures and impacts on water bodies	**1**. Assess, over a range of timescales, the direct influences of climate change and indirect influences where pressures are created due to human activities in adapting to climate change	A more integrated approach to risk assessment is needed to counter changes in pressures that may arise from the direct impacts of climate change, as well as from autonomous and/or anticipatory measures taken by different groups to mitigate and adapt to climate change.
Monitoring and status assessment	**2.** Maintain both surface and groundwater surveillance monitoring sites for long time series. Set up an investigative monitoring programme for climate change and for monitoring climate change "hot spots" and try to combine them as much as possible with the results from the operational monitoring programme.	Good monitoring networks will be essential to identifying and reacting to climate change and thus it is important that sites with long time series of data collection are not dropped from surveillance monitoring. In addition, knowledge of when and where climate change might be first detected could be used to target monitoring and reporting of effects in the most vulnerable water bodies, as well as to bring forward adaptation interventions as required. This is important for surface water and groundwater (including groundwater quantity monitoring). In order to detect climate change impacts early, the monitoring frequency needs to be higher than the WFD minimum for surveillance monitoring, as otherwise it will take a long time to gather robust time series.
	3. Include reference sites in long term monitoring programmes to understand the extent and causes of natural variability and impact of climate change	As climate change and human impacts at a catchment scale may affect similarly the quality elements used for status assessment, information on coherent changes at reference sites, which by definition are sites with missing or very minor anthropogenic influence, is the primary proof that would enable disentangling the two kinds of impacts. Therefore concurrent hydro-meteorological data and data on quality elements are needed to better interpret mid and long-term changes in status.

RBM steps of WFD	Guiding principle	Summary of the guiding principles for the RBM steps
Objective setting	**4.** Avoid using climate change as a general justification for relaxing objectives, but follow the steps and conditions set out in the WFD	There is a danger that anthropogenic climate change could be used as an excuse to set lower objectives for water bodies, even though formal attribution of a detected trend to anthropogenic climate change is unlikely at the scale of RBDs for several decades to come. Although the use of exemptions is an integral part of the river basin management planning, applying exemptions without justification in line with the Directive cannot be seen as a general strategy to cope with the consequences of climate change. In addition, there is a need to assess the impacts of using exemptions to making water resources more resilient to climate change.
Economic analysis of water use	**5.** Consider climate change when taking account of long term forecasts of supply and demand and favour options that are robust to the uncertainty in climate projections	Climate change will mean that the value of water will change as the balance between supply and demand is impacted. Economic analysis carried out in order to apply recovery of costs and judge the most cost-effective combination of measures should consider these future conditions. However, uncertainty surrounding projections means that we should look for solutions that will be able to perform over a wide range of climatic conditions.
Adaptation measures related to the WFD		
How to do a climate check of the Programme of Measures?	**6.** Take account of likely or possible future changes in climate when planning measures today, especially when these measures have a long lifetime and are cost-intensive and assess whether these measures are still effective under the likely or possible future climate changes. **7.** Favour measures that are robust and flexible in terms of uncertainty and cater for the range of potential variation related to future climate conditions. Design measures on the basis of the pressures assessment carried out previously including climate projections. **8.** Choose sustainable adaptation measures, especially those with cross-sectoral benefits and that have the least environmental impact, including the GHG emissions.	
What to do if other responses to climate change influence the WFD objective of a good status?	**9.** Avoid measures that are counterproductive to the water environment or that decrease the resilience of water ecosystems **10.** Apply WFD Article 4.7 to adaptation measures that modify the physical characteristics of water bodies (e.g. reservoirs, water abstractions, dykes) and that may cause deterioration in water status **11.** Take all practicable steps to mitigate adverse effects of counterproductive measures	

2.3.2 Guiding principles on "Drought and water scarcity management and adaptation"

Overall guiding principle on drought management, water scarcity and adaptation

1. Use the Water Framework Directive as the basic methodological framework to achieve climate change adaptation in areas of water scarcity and to reduce the impacts of droughts.

River basin management plans as a tool for addressing water scarcity and droughts

2. Make full use of the Water Framework Directive environmental objectives, e.g. the requirement to achieve good groundwater quantitative status helps to ensure a robust water system, which is more resilient to climate change impacts.
3. Determine, on the basis of robust scientific evidence and on a case-by-case basis, whether a prolonged drought allows for the application of the WFD Article 4.6 and take into account climate change predictions in this case-by-case approach.
4. Pay special attention to the requirements of the WFD Article 4.7 when developing measures to tackle water scarcity under a changing climate, which may cause deterioration of water status.

Monitoring and Detecting Climate Change Effects

5. Diagnose the causes that have led to water scarcity in the past and/or may lead to it in the future.
6. Closely monitor water demand and create forecasts based on improved knowledge of demands and trends.
7. Collect as much high quality information as possible to anticipate changes in water supply reliability, which may be incurred by climate change, for early detection of water scarcity.
8. Distinguish climate change signals from natural variability and other human impacts with sufficiently long monitoring time series.

Adaptation measures related to water scarcity & droughts

9. Take additional efforts to prevent water scarcity and be better prepared to tackle the impacts of droughts.
10. Incorporate climate change adaptation in water management by continuing to focus on sustainability (balance between water availability and demand).
11. Follow an integrated approach based on a combination of measures (compared to alternatives based on water supply or economic instruments only).
12. Build adaptive capacity through robust water resource systems.
13. Engage stakeholders in producing decisive measures to tackle water scarcity.
14. Assess other climate change adaptation and mitigation measures by their impact on water scarcity and drought risks."

2.3.3 Potential water management adaptation measures

A toolbox of adaptation measures regarding water management were collected by the UNECE Guidance on Water and Adaptation to Climate Change[13] that could be applied in case of the Tisza River Basin *(Table II.3)*.

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[13] https://www.unece.org/index.php?id=11658

Table II.3: Overview of potential adaptation measures – based on (UNECE, 2009)

TYPE OF MEASURES	FLOOD-PRONE SITUATION	DROUGHT-PRONE SITUATION	IMPAIRED WATER QUALITY	HEALTH EFFECTS
PREVENTION/ IMPROVING RESILIENCE	• restriction of urban development in flood risk zones • measures aiming at maintaining dam safety, afforestation and other structural measures to avoid mudflows • construction of dykes • changes in operation of reservoirs and lakes • land use management • implementation of retention areas • improved drainage possibilities • structural measures (temporary dams, building resilient housing, modifying transport infrastructure) • migration of people away from high-risk areas	• reducing need for water • water conservation measures/effective water use (industrial and other sectors' practices and technologies, recycling/ reusing wastewater) • water saving (e.g. permit systems for water users, education and awareness-raising) • land use management • fostering water efficient technologies and practices (e.g. irrigation) • enhancing the availability of water (e.g. increase of reservoir capacity) • improving the landscape water balance • introduction or strengthening of a sustainable groundwater management strategy • joint operation of water supply and water management networks or building of new networks • identification and evaluation of alternative strategic water resources (surface and groundwater) • identification and evaluation of alternative technological solutions (desalinization; reuse of wastewater) • increase of storage capacity (for surface and ground waters), both natural and artificial • considering additional water supply infrastructure • economic instruments like metering, pricing • water reallocation mechanisms for highly valued uses • reducing leakages in the distribution network • rainwater harvesting and storage • reducing water demand for irrigation by changing crop mix and calendar, irrigation method • promoting indigenous practices for sustainable water use • importing water-intensive agricultural products	• prevention of and cleaning up of dump sites in flood risk zones • improved waste water treatment • regulation of wastewater discharge • improved drinking water intake • safety and effectiveness of waste water systems • isolation of dump sites in flood risk zones • temporary wastewater storage facilities • catchment protection (e.g. enlarging protected areas)	• strengthen capacity for long-term preparation and planning, especially to identify, address and remedy the underlying social and environmental determinants that increase vulnerability • use existing systems and links to general and emergency response systems • ensure effective communication services for use by health officials • regular vector control and vaccination programmes • public education and awareness-raising • measures against heat island effect through physical modification of built environment and improved housing and building standards

Table II.3: Overview of potential adaptation measures (cont.)

TYPE OF MEASURES	FLOOD-PRONE SITUATION	DROUGHT-PRONE SITUATION	IMPAIRED WATER QUALITY	HEALTH EFFECTS
PREPARATION	• flood warning (incl. early warning) • emergency planning (incl. evacuation) • flash-flood risks, (measures taken as prevention, since warning time is too short to react) • flood hazard and risk mapping	• development of drought management plan • monitoring and forecast of drought characteristics • changing reservoir operation rules • prioritization of water use • restrictions of water abstraction for appointed uses • risk communication to the public • training and exercise	• restriction of wastewater discharge and implementation of emergency water storage • regular monitoring of drinking water	• strengthening the mechanism for early warning and action • improved disease/vector surveillance/ monitoring • ensuring well-equipped health stations and availability of communication and transportation facilities • developing water safety plans
RESPONSE	• emergency medical care • safe drinking water distribution • safe sanitation provision • prioritization and type of distribution (bottled water, plastic bags etc.)			
RECOVERY	• clean-up activities • rehabilitation options, such as reconstruction of infrastructures • governance aspects, such as legislation on, inter alia, insurance, a clear policy for rehabilitation, proper institutional settings, rehabilitation plans and capacities and information collection and dissemination • specifically targeted projects: new infrastructures, better schools, hospitals • all kinds of financial and economic support • special tax regimes for investments, companies, people • insurance • evaluation			

2.3.4. Climate and hydrology of the TRB according to TAR, 2007

In connection to climate and hydrology, the following can be summarised based on the Tisza Analysis Report, 2007:

"The Tisza River Basin is influenced by the Atlantic, Mediterranean and Continental climates, which impact regional precipitation. About 60% of the Upper Tisza River Basin gets more than 1,000 mm of precipitation annually. Warm air masses from the Mediterranean Sea and the Atlantic Ocean cause cyclones with heavy rainfall on the southern and western slopes. In general, two-thirds of the precipitation occurs in the warm half of the year. Furthermore, land surface is subdivided into the Carpathian Mountains (70% of the catchment area) and the wide Tisza Lowlands.

The isotherms of the multi-annual mean air temperature vary from less than 3°C (in the Apuseni Mountains) to more than 11°C (along the middle and lower reach of the Tisza itself). The maximum temperatures are observed in July, while the minimum in January (from –1 to –7°C). The annual mean potential evaporation (in RO and HU) is around 700 mm/a and the maximum monthly values (125 - 145 mm) occur in June and July.

The multi-annual mean values of annual precipitation vary within the Tisza River Basin from 500 to 1,600 mm/a. The lowest values (500 mm/a and below) occur in the south-western part of the basin, close to the Tisza River. The highest values (around 1,600 mm/a) occur in the north-western Carpathians and in the Apuseni Mountains. Dry spells (with less than 10 mm/month) are frequent in most areas of the Tisza River Basin in February and March. (**See MAP 3 and Map 7** – Precipitation) The highest maximum depth of snow, measured in various mountains of the Tisza River Basin (including the relatively low Mátra Mountains in Hungary) are above 100 cm, with water equivalents of 250-300 mm. Lower maximum values (40-60 cm with equivalents of 100-200 mm) were registered in the lowland parts of the basin.

The aridity factor (defined as the relation of annual potential evaporation to mean annual precipitation) at the eastern border of the Tisza River Basin (such as in the Carpathian Mountains) is below 0.2 and increases from the northeast to the southwest up to 1.4 in the middle of the Great Hungarian Plain (the mouth of the Körös Rivers).

In the mountainous regions, flash floods are common in the spring and summer. These are further intensified by the low infiltration capacity of the soils in the Carpathian Mountains. The floods cause enormous inundation in the lowland areas.

Flooding is a natural event necessary for riverine ecosystems, but it is also a significant threat to communities settled in the floodplain. Rainfall in the Carpathian Mountains can be substantial and sudden. Extensive runoff, floodplain deforestation and river canalisation reduce the ability of the catchment to attenuate the flood wave. When heavy rains occur, flooding threatens human lives as water levels rise quickly without a sufficient retention capacity."

2.3.5. Climate change-related findings based on the Danube study 2012

An overview will be given based on the outcomes on the projected climate characteristics relevant in the TRB (findings of the Danube study 2012).

Characteristics and scenarios for the TRB based on the Danube study of 2012

For a better assignment, all findings in the Danube Study were classified into statements about the entire Danube River Basin (DRB), the Upper Danube River Basin (UDRB), the Middle Danube River Basin (MDRB) and the Lower Danube River Basin (LDRB), which are based on ten sub-catchments. The separation between the UDRB and MDRB is defined by the Bratislava gauge at the border between Austria and Slovakia, and between the MDRB and LDRB by the Iron Gate gauge at the border between Serbia and Romania. **Since the MDRB covers the Tisza River Basin area, the following chapters introduce the findings of the Danube Study in relation to the MDRB.**

(The Tisza River Basin related outcomes of the Danube Study, first findings of the Carpathian Region related projects)

Uncertainty

Uncertainties can be investigated in two ways: inductive or deductive. Inductive approach means that we estimate the uncertainties at each step of the calculation of the projections. The Danube Adaptation Study used the deductive approach, i.e. the rate of uncertainty was determined according to the standard deviation of the projected values of different climatological elements. For example, the temperature increase is generally accepted and therefore, the temperature has a very high certainty, see below in the figure.

Figure II.3: Uncertainty of climate elements and main impacts due to the four certainty-categories: very high (green), high (yellow), medium (orange) and low (red)

Future scenarios related to temperature

In relation to the already observed changes, the most unified alterations are examined at the temperature. Following the basic idea, global warming is expected all around the world in any season.

The Danube Adaptation Study summarizes the following temperature projections related to the Middle Danube River Basin (MDRB):

For Hungary, an increase of 0.3°C per decade is expected. The expected warming by 2071-2100 is more than 2.5°C and less than 4.8°C for all seasons and for both A2 and B2 scenarios. The smallest difference is expected in spring (0.6°C), while the largest is expected in winter (1°C). The temperature increases in summer for both scenarios with a zonal gradient from north to south and in winter from west to east.

CLAVIER confirms a temperature increase for the Tisza River Basin with an increase of 1.7°C in winter and 1°C in summer (both 2021-2050, A1B).

In general it can be stated that an increase in air temperature is likely and tendencies strengthen in the course of the 21st century. However, regional evaluations are with small spatial resolutions, since differences in temperature patterns on a small scale are not visible in most results.

Less information is available for spring and autumn and winter is characterized by a high uncertainty.

The results are mainly represented by the Hungarian and Romanian studies.

Future scenarios related to precipitation

The situation is more complex in case of precipitation. This variable has a large temporal and spatial variability, which makes modelling and statistical tests difficult (high noise/sign ratio). Furthermore, there are parts of the Earth with increasing and other parts with decreasing annual precipitation sum tendency. Precipitation changes are connected to the circulation types and therefore, the increasing temperature occurs with increasing, another places with decreasing precipitation together.

The situation on a seasonal time scale is more sophisticated. The seasons used to have different tendencies, sometimes even the signs of a change can be opposite. The seasons warm at a different rate, and the seasonal precipitation sums change at different tendencies. Therefore, the hydrological properties of the river flows and their water management can change very strongly. Although we cannot be sure about the quantity of the precipitation in many places of the world, these three properties seems to be quite exact in the future:

1. the precipitation types are expected to change and we should have more rain and less snow, which has a large effect on the water storage capacity and the precipitation/runoff temporal shift;
2. the intensity of precipitation is expected to increase, even where the quantity of precipitation decreases. This means that less precipitation can fall with higher intensity at some regions of the Earth;
3. it is expected that independent from the precipitation tendencies, the extreme events will become more frequent and their strength will increase as well. This conclusion leads directly to the changes in the tendencies of natural disasters, such as floods (in this case river floods, while for in the event of point b. the flash floods) and droughts.

In case of some variables like soil humidity, the deviation among the results of climate models is large, because of unsatisfactory information about other databases, such as pedological data, biomonitoring, etc. These monitoring networks have to be developed and harmonized to produce generally applicable model results for hydrological and water management purposes.

Several climate model results were calculated for the **Tisza catchment**. Despite of the most widely known EU FP research projects such as Prudence, Ensembles, Cecilia and Scenes, many national regional climate model runs are available. Avoiding a long discussion about the uncertainty of the model results, it has to be stated that there are sometimes large differences among the different scenarios. Taking into account that new scenario results are expected (there is a change from the SRES scenarios to the RCP scenarios), the range of the climate projections could increase even more.

Fig. 4 shows large differences among the model results even using the same scenario. From the south of the Carpathian basin, the precipitation will rather decrease and increase to the north, but there is a large uncertainty in the region.

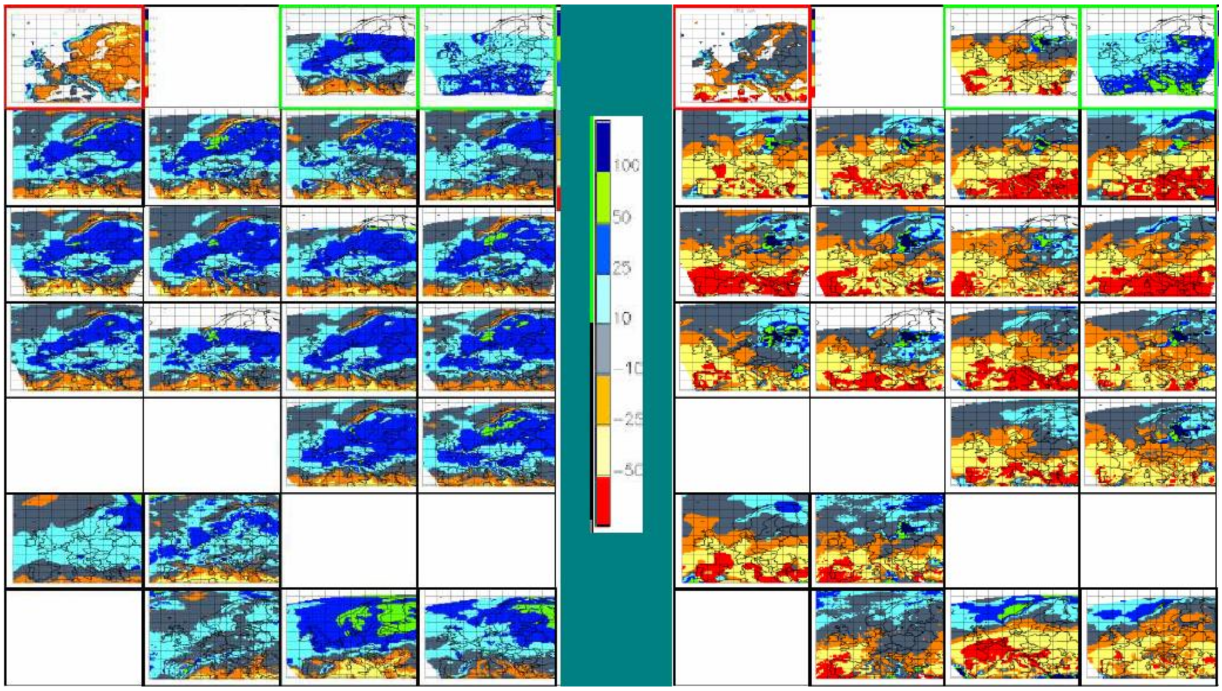

Figure II.4: Expected precipitation changes in 2071-2100, the A2 scenario, the PRUDENCE project (19 model runs, left column for winter, right for summer), Bartholy et al., 2007 [14]

The Danube Adaptation Study summarizes the precipitation related projections for the Middle Danube River Basin (MDRB) as follows:

- Eastern Europe: the decrease of summer precipitation of up to 25-45% (Bulgaria, Hungary, Slovakia, Romania); Precipitation is expected to decrease in summer (-25 up to -45%), while for winter the projections are not uniform, some models show the possibility of an increase and some of a decrease; Hungary and the Carpathian Basin are likely to become drier until 2100. By the end of the century, the annual amount of precipitation in the Carpathian Basin is likely to decrease by about 20% for both A2 and B2 scenarios.
- For the Tisza River Basin, almost no change in the total annual amount of precipitation is modelled. However, the annual cycle of precipitation over Hungary shows that a decreasing summer precipitation is more or less compensated by increasing winter/autumn precipitation. The VAHAVA also projects an increase in winter rainfall (A2: 23-37%, B2: 20-27%) and the results of Bartholy show a slight increase in winter (in spatial average by about 14%), which is significant in case of A2 conditions in the Transdanubium, where the simulated winter precipitation change may exceed 30-40%. The largest change is expected in summer, when a significant drying for the whole country is projected (the simulated precipitation decrease is 43% in case of the B2 scenario conditions and 58% in case of the A2 conditions in spatial average.
- In Hungary, a reversal of seasonal precipitation distribution is expected: summer, which is now the wettest season, will be the driest period (40-50% less rainfall compared with today); winter, which is now very dry, is expected to become a wet season (+14-40%). Winter variability increases significantly. In the recent climate (1961-1990), the wettest months in Hungary are in late spring and early summer (from April to July), when the monthly mean precipitation sum

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[14] https://www.researchgate.net/publication/270408233_Regional_climate_change_expected_in_Hungary_for_2071-2100

exceeds 60 mm. The driest months are January and February with about 30-35 mm of total precipitation on average. The PRECIS simulation outputs suggest that the annual distribution of a monthly precipitation is very likely to be restructured by 2071-2100 in case of both the A2 and B2 scenario. The driest months are expected to be July and August (A2: with less than 20 mm, B2: with about 25-30 mm on average). The wettest month of the A2 scenario runs is April with about 65-70 mm of precipitation on average, while in case of the B2 scenario, the wettest months are April, May and June with about 60 mm of total precipitation on average.

- The IPCC and PRUDENCE projections and some others confirm the results of drier summers and wetter winters for Hungary and the Carpathian Basin with different magnitudes for the near and far future (summer: -3.7 to -8.2% until 2030 and -24 to -33% (A2), and -10 to -20% (B2) until the end of the century, respectively).

In general, it can be summarised that trends show a decreasing summer rainfall and tendency to increasing winter precipitation with high variability. However, it has to be highlighted that

- different GCMs produce partly contrasting patterns of spatial distribution of precipitation
- there are a lot of quantitative uncertainties in the changes of both mean and extreme precipitation amounts.

Future scenarios related to extreme weather events

The Danube Adaptation Study summarizes extreme weather events projections for the Middle Danube River Basin (MDRB) as follows:

In the past three decades, less precipitation occurred in the Carpathian Basin, but heavy or extreme precipitation days increased considerably by the end of the 20th century. The simulation results suggest that the future climate tends to be wetter in winter and drier in summer in the Carpathian Basin. Cold extremes are expected to decrease, while hot extremes tend to increase significantly. Both changes imply regional warming in the Carpathian Basin. With the frequency of summer droughts, on one hand, and increasing heavy precipitation events in autumn and winter on the other, it is suggested that this could indicate a shift of the Hungarian summer climate towards more Mediterranean conditions, where warm and dry summers are followed by rather wet early autumns. Extreme precipitation events in winter will be more intense and more frequent, with a general decrease of extreme precipitation in summer. The spatial patterns of the annual number of heavy precipitation days are similar for the reference period (1961-1990) and the last three decades of the 21st century (2071-2100). Extreme rainfall then occurs on more than 30 days per year in the mountainous regions, while it will not exceed 24 days per year inside the basin. The smallest values are simulated for the southern part of Hungary. The results of the A2/B2-scenarios are similar, but more pronounced than for the A1B-scenarios.

A1B-scenario results for Hungary/CADSES region

- Summer days (Tmax > 25 °C): no changes in the near future (2021-2050); by the end of the century (2071-2100) the annual percentage of summer days is likely to increase by about 7-14% (up to 120 days per year)
- Hot days (Tmax > 30 °C): increase until 2071-2100 by 4-12% (about 62 hot days yearly according to the RegCM simulations)
- Frost days (Tmin < 0 °C): In the future, the frequency of frost days is likely to decrease, by about 3-8% and 8-14% by 2021-2050 and 2071-2100 respectively (less than 55 days, in the lowlands less than 25 days). The decrease is evidently larger in mountainous regions where frost days occurred more frequently in the past.

Heat waves (Tmean > 25-27°C for at least 3 consecutive days): occurrence is clearly projected to increase: the frequency of heat wave warning cases is likely to increase by 2-5 days by 2021-2050 and 10-20 days by 2071-2100 relative to 1961-1990. In the southern parts, the frequency of heat wave warning cases is likely to increase by 24-30 days by 2021-2050, and by 40-50 days by 2071-2100). Heat waves tend to occur earlier and last later in the year. The total length of the possible occurrence of heat waves is likely to extend by about a month by 2071-2100 (approximately 3 days per decade).

In general, it can be summarised that more extreme events, fewer frost days in winter, more summer and hot days in summer can be expected in the basin. Heavy rains become more frequent and an increase in frequency and intensity of storms is also envisaged.

Both possible future developments are projected for Eastern Europe in the scenarios, with less and more intense precipitation in winter.

Further knowledge on seasonal and regional distribution of heavy rainfall would be important to be collected for the basin.[15]

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[15] It has to be noted that from comparing the results of observation and modeling it can be found that there are significant differences between the two information sources. It does not mean that these differences can disappear later (either the climate tendencies can be changed or the climate models can be improved or there will be a convergence between the observations and the modeling).
Unfortunately, many of the adaptation measures and follow up activities are based on these two, unsupported statements. These differences have to be investigated during the preparation of any adaptation strategy in the region.

3 Information and Monitoring Needs on Climate Change and Water Quantity

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3.1 Introduction

Climate is a very complex system with several processes on different temporal and spatial scales. The analysis of climate change consequences is to a large extent dependent on modelling and models rely on the monitoring of climate processes. The monitoring and modelling scales have to be fitted to the process scales, in terms of spatial and temporal resolution. If the monitoring scales are not appropriate to grasp the relevant features of the process, then the network won't be able to collect information adequate to form the basis of the models, including regional climate models or catchment runoff models.

Therefore, it should be realised that the first limiting factor is the monitoring system, the station density, and its output: the time series, their length and the quality of data. We need long series to get solid basis for significant statistical statements, of reasonable quality, because measurements are quite frequently loaded with errors (instrumental and/or human), and a station density needed for good spatial covariance to describe smaller scale, nevertheless important, processes. In case of the modelling, we can neglect a process (assuming not to be important in a given case), parameterize it using statistical connections because of the scarce information and model when we have enough scientific basis and data to calculate the given process.

Models need framework conditions, i.e. information about the surroundings requested for, but not belonging to, the model. In case of climate change studies, the most important conditions are the emissions depending on several factors. To serve the same framework conditions for each model, scenarios are created. We do not know the development of humankind in the future and therefore couple of scenarios are developed to give consistent framework conditions for the models.

Applied models are used to describe climate change impacts in different disciplines. The input scaling requirements of these models usually differ from the ones of climate models causing further problems at the descriptions and clarifications of changes.

There is an ever increasing demand to know more about the future climate. Consequently, all possible climate research methods have to be used and synergized. Even in that case, our results contain smaller or larger errors and uncertainties. The main task is to give as good results as possible about the climate and its impacts, even if our knowledge contains gaps. It is essential to give the best possible information, including the conditions of setting up and uncertainties. A comparison of different uncertainties inherent in climate change projections are shown in *Figures 3.1 and 3.2. (Hawkins, 2013)*. Figure 3.1 shows uncertainties in global mean temperature projection until 2100.

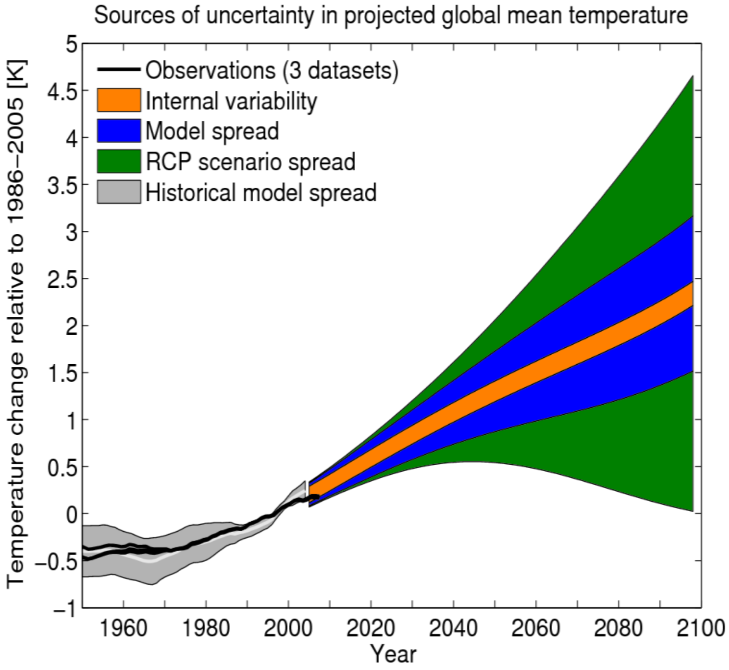


Figure III.1: Sources of uncertainty in global decadal temperature projections, expressed as a 'plume' with the relative contribution to the total uncertainty coloured accordingly. The shaded regions represent 90% confidence intervals.

Figure 3.2 shows that climate variability gives the largest uncertainty in the first decades. The absolute size of variability-caused uncertainty does not change in time, therefore its relative value decreases quite fast and the model uncertainty has the largest impact at about mid-century. In the second half of the 21st century the scenario-caused uncertainties have the largest importance. That is the reason of why the used scenarios have to be given and the latest scenarios are suggested to be used.

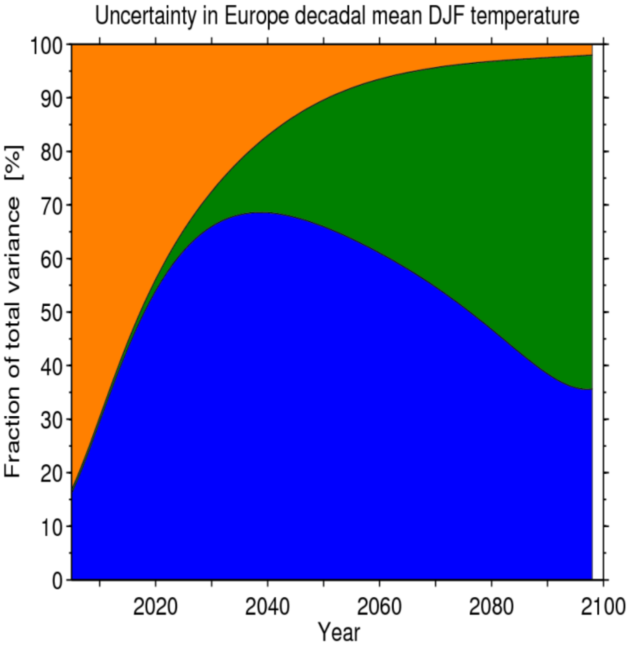


Figure III.2: Sources of uncertainty in the European decadal DJF temperature projections, expressed as a fraction of the total variance.

Monitoring

The meteorological monitoring system is one of the oldest and most global environment monitoring systems. It is an extensive system, with a huge number of monitoring stations on global scale. The Carpathian Region is among the best covered with stations in the world. Nevertheless, reports and studies still emphasize gaps in accessibility of meteorological data as critical. For example, a comparison of 8 global agricultural monitoring (GAM) systems from 2018 showed that meteodata gaps are considered from very to extremely critical by more than half of the systems *(Figure III.3)*.

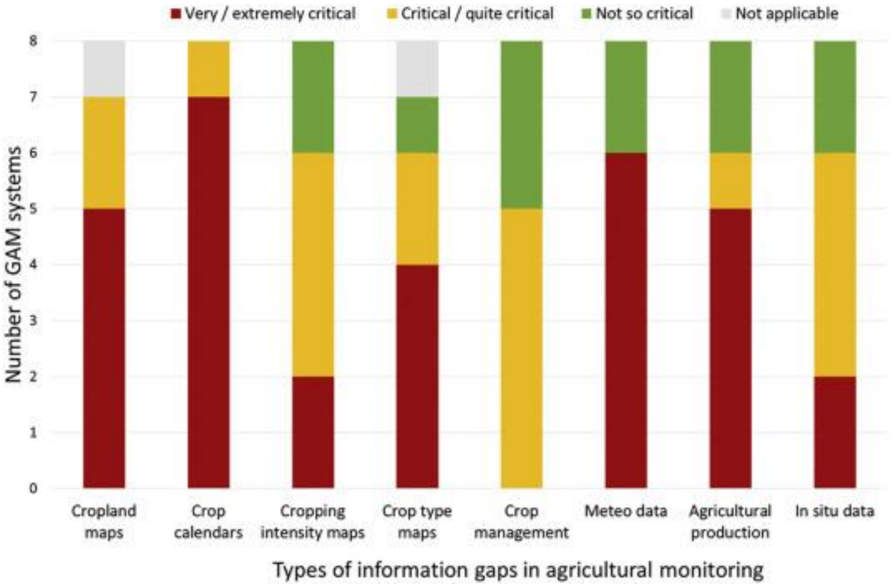


Figure III.3: Different types of data and level of gaps in agricultural monitoring (Fritz et al., Agricultural Systems, 2018.)

Reasons for that can lie in too sparse spatial network of stations, underfunding, costs of operation and maintenance, uncertainties related to measurements, data quality, etc. Solution for these problems was found in the use of numerical models of the climate system, which are nowadays widely used and have, in many cases, a higher priority than the observation due to easier availability and the structured access of data.

Sometimes, the use of numerical models is inevitable - climate investigations, forecasting the climate or climate effects, and analysis of the effects of different developments of humankind are not possible without the models. The problem is that users usually do not take care about the fact that modelling always means simplification. Equations that describe physical processes are not able to describe all components of the processes; a modeller has to decide which components are less important and neglect them while modelling. But a component of the process having less importance in general, can be very important in special cases. In such cases, neglecting can cause large errors in the final result and make derived conclusions, decisions, strategies, or policies wrong, unreliable and less trustful.

Beside simplifications of the model, another issue important to consider during the development of climate models is long-term good quality data. The length of time series depends partly on the variables according to the development of the measurement technology, partly on the cost of the measurement instrument. Also, one should have in mind that the length of time series increases slowly (by one in one year), and if the data quality assurance is not standardized or is not on a necessary level, the data obtained in different countries can be different (sometimes not comparable). These problems are neglected quite frequently in order to increase climate models' resolution in space and time.

Therefore, measurements and modelling should be developed in parallel and in close interaction with each other. The gaps of the model development can be filled by the development of the monitoring system and the modelling requirements need to be followed at the implementation of new observation methods and sites.

Finally, the information on data, model run results, applied data quality (DQ) method, scenario as well as the climate model used, have quite frequently been missing, making the evaluation of results on a good level not possible or less accurate. For example, because of changing scenarios or DQ procedures, different results can be designated with the same name; two homogenisation methods can create different outputs from the same input; or, different models can produce different climate projections (projections can be affected by the hardware as well). Therefore, in order to increase traceability and comparability of results, climate related studies should publish all information used therein.

Scenarios

To make the climate model results consistent, unified emission information is required. (Consistency means that the individual input parameters, such as population, environment, economy etc., are fitting.) *Nakicenovic et al* (2000) published the so-called SRES scenarios (from the publication title: Special Report on Emission Scenarios), where different development possibilities are described in a consistent way. The basic SRES scenarios are as follows:

A1	economic and technological development
A2	heterogeneous world, regional effects
B1	'dematerialised' world, clean technologies
B2	regional sustainability solutions

The A1 scenario was developed into a scenario family (A1B, A1F, A1T), where B means balanced, i.e. the development requested energy increase is supplied by the increase of balanced energy sources (renewable, fossil, nuclear, etc.). The strongest impacts are in the case of A2, the mildest in B1 and the average in the A1B scenario.

The philosophically different, RCP (Reference Concentration Pathway) scenarios, were published in 2013. In this case, the final aim was given first, i.e. how large the anthropogenic greenhouse effect by 2100 in W/m^2 will be Accordingly, we can differentiate RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios. The RCP2.6 seems to be a too optimistic scenario, while the RCP8.5 shows the situation when no action will happen.

3.2 Overview of the climate of the Carpathian Region

To describe the climate of the region, we used the database that has been created within the CarpatClim project (see *Spinoni et al, 2014)*. Additional information on the database can be found on the homepage of the project (www.carpatclim-eu.org). Since the CarpatClim database contains information for the period of 1961-2010, our basic statements are valid for this period.

3.2.1 Temperature

Spatial distribution of temperature is primarily affected by the altitude and latitude. The coldest part of the region is in the Western- and Northern-Carpathian mountains, but the lower mountains in the Eastern- and Southern-Carpathians cannot be detected at the 2 °C resolution of the *Fig III.4*.

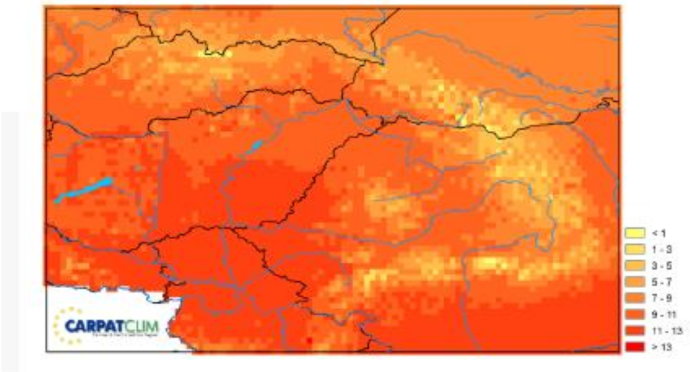


Fig. III.4: Long-term yearly average temperature values for 1981-2010

Because of the basin being open southwards, the warmest part is extended from Serbia up to Budapest and Lake Tisza. The temperature change maps show a much more mosaic-like picture (*Figs III.5 and III.6*). This information was prepared for the period of 1961-2010, i.e. for 50 years. The period starts earlier, but covers much of the present warming period from the mid 70's till 2010.

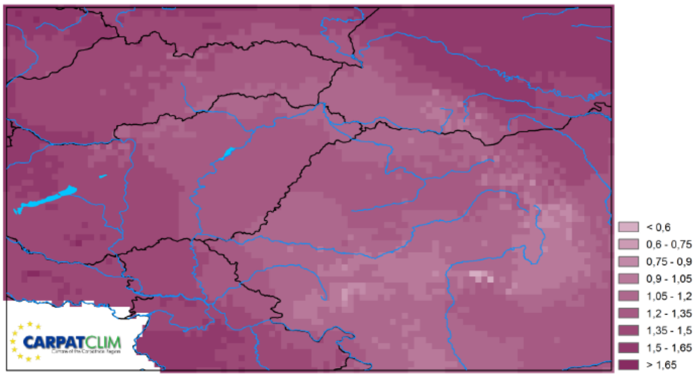


Fig III.5: Change of the annual temperature for the period 1961-2010

The increase of temperature reaches at least 0.6 °C, but can also be more than 1.5 °C. Except for the not very strong altitudinal effect, a clear west-east gradient can be detected. This is probably connected to precipitation changes. For the Tisza catchment, a warming of approximately 1-1.2 °C can be detected in this period.

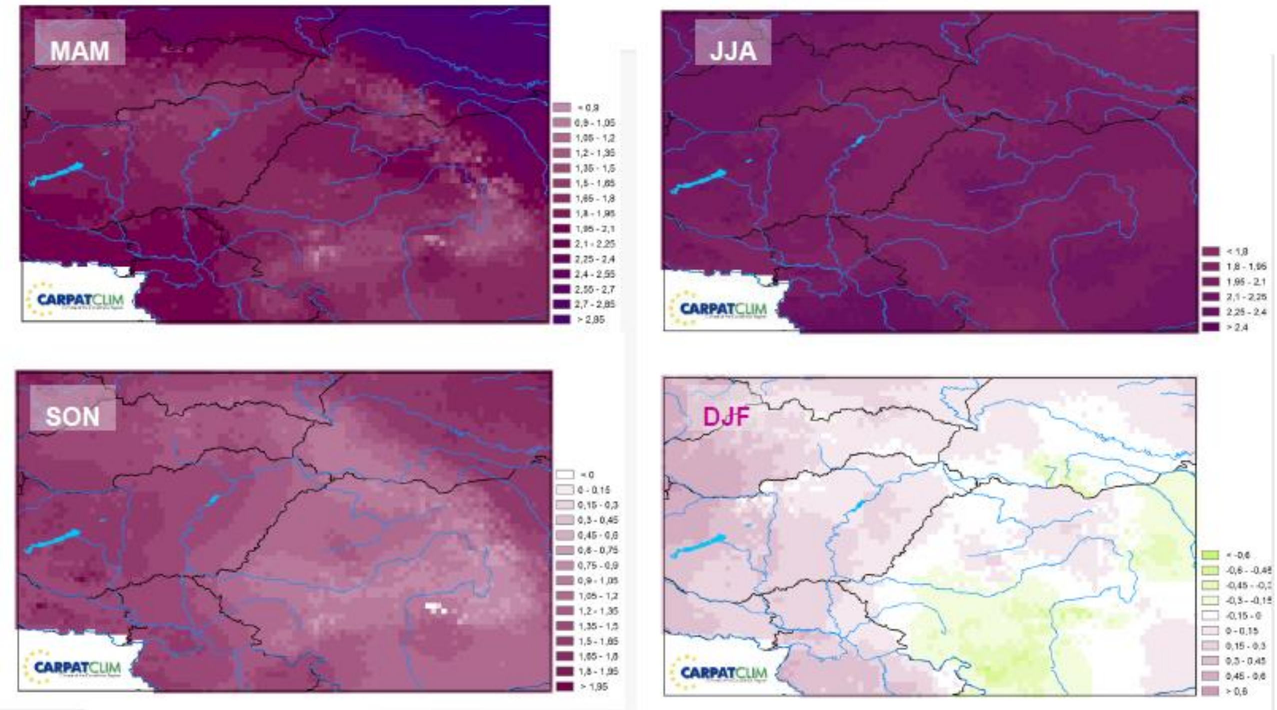


Fig III.6: Changes of seasonal temperature for the period 1961-2010

Note that MAM stands for March, April and May; JJA – Jun, July, August; SON – September, October, November; and DJF – December, January and February.

The largest changes can be recognized in summer with about 2 °C warming, and the smallest in winter, when still decreasing tendencies exist in the South-Transylvania. These negative tendencies are not significant, expected to disappear, but still existing for the given period. The W-E gradient and the altitudinal effect can be detected practically in each season. The large summer warming has several negative effects, like more frequent heat waves and increasing mortality as the consequence, as well as increased potential evapotranspiration, increasing drought frequency, etc.

3.2.2 Precipitation

Precipitation in the Carpathian Basin is characterized by a high spatial and temporal variability. Therefore the maps in connection with precipitation show a fragmented mosaic structure. The changes can be large, but mostly not significant because of the high temporal variability and standard deviation.

Remarkably, the north-northeast part of the Carpathians has larger precipitation values, while the eastern and southern parts have much less humidity. The lowest parts of the Basin used to get 500 mm or even less of precipitation annually.

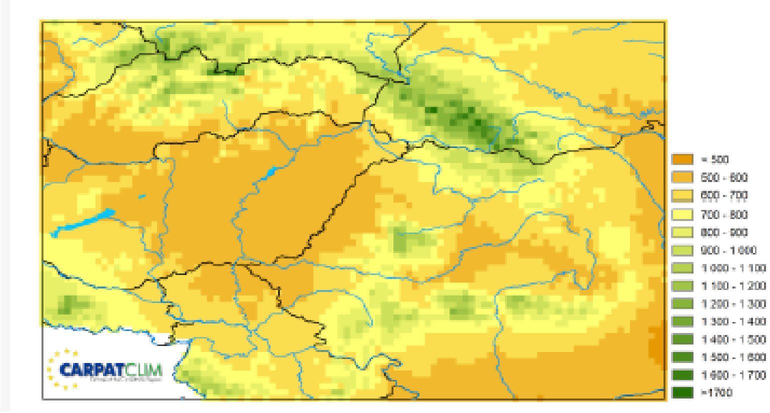


Fig. III.7: Long-term average of the annual precipitation sum for the period 1981-2010

The annual precipitation changes have a clear N-S tendency of increasing towards the north and decreasing towards the south. Less expected is the W-E tendency of a strong decrease towards the west. This makes the basin-wide average less useful, by having a large decrease in a smaller area and a small increase in a larger area. The altitudinal effect can be detected mostly in the northern part of the region. This has an interesting effect on the Tisza River, because the summer precipitation decreases at the headwaters, while downstream it flows through regions with increasing precipitation.

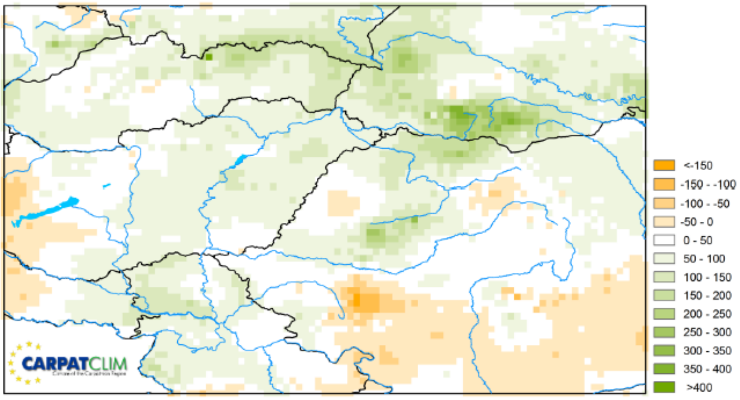


Fig. III.8: Change of the annual precipitation sum for 1961-2010

The climate model results are partly justified and partly not by the observed seasonal precipitation changes that altogether show a better agreement with the RCP than with the SRES scenarios.

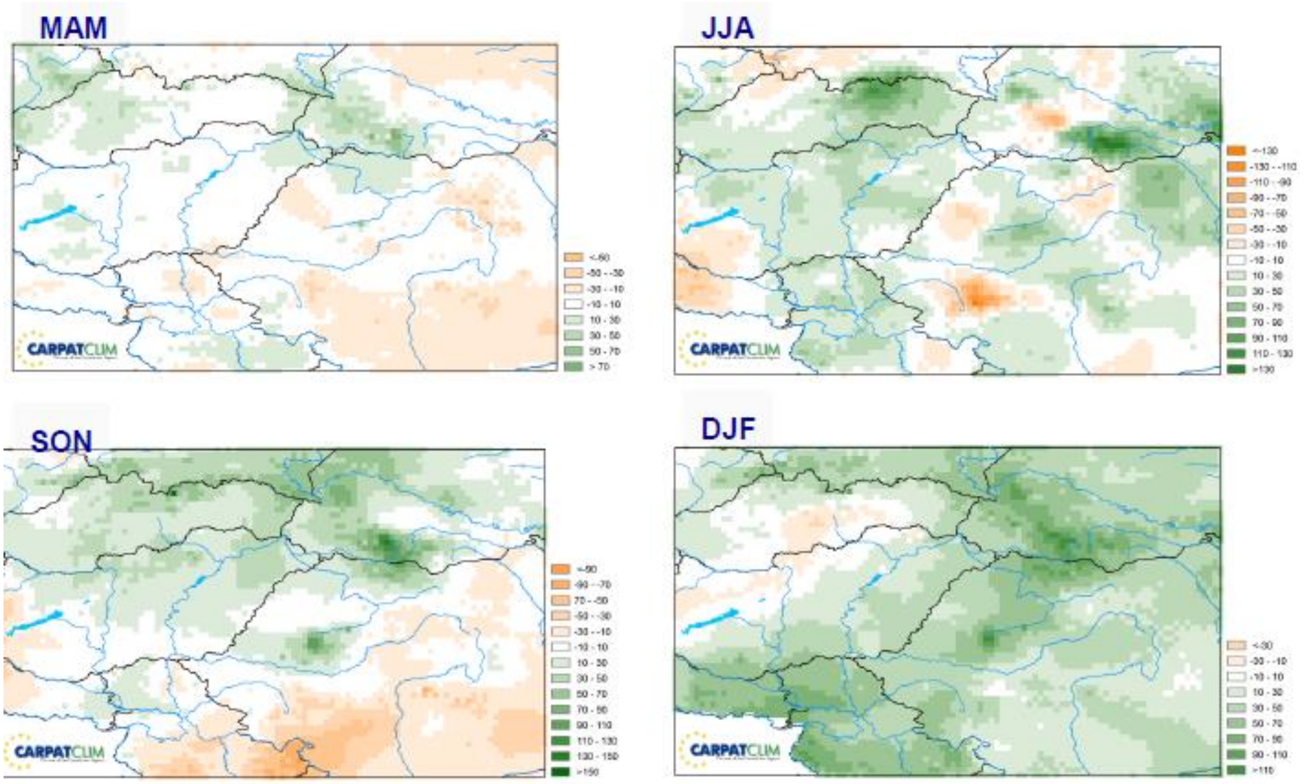


Fig. III.9: Change of the seasonal precipitation sums for 1961-2010

The winter precipitation shows a clear increase, supporting the increase of winter flood events (mostly river floods) by a strong agreement with climate models. Despite the climate model results, the summer precipitation increases in most parts of the territory, as well.

The summer and autumn precipitation show mostly the drying in the western part of the Basin. The unsatisfactory description of the climate in the transient seasons can be the reason for the lack of western drying in the climate models. The quantitative changes can be different in any season. Even in the most wetting season, in winter, drying areas can be found (although such drying is not significant.)

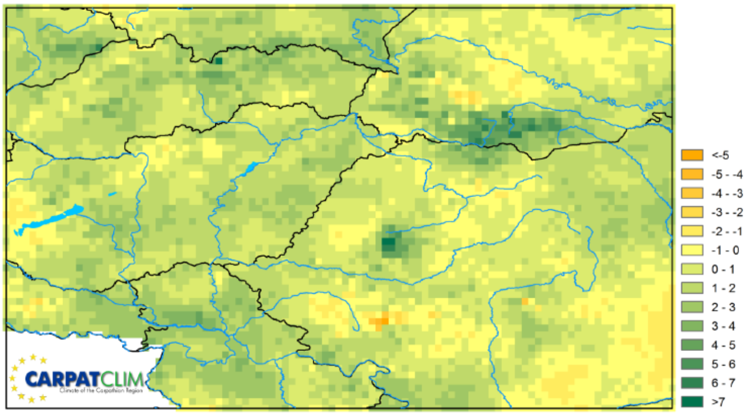


Fig. III.10: Change in the number of days with precipitation above 20 mm, 1961-2010

The most characteristic feature of the changing precipitation is the intensity. Increasing intensity is counted as a sign of climate change as well, but it is much more general than the quantitative changes. *Fig. 3.10* shows that the number of days with precipitation above 20 mm is increasing in the whole region, with small exceptions, and this variable can be taken as an indicator of the intensity.

In 1961-85 only the wind speed (decrease), relative humidity (increase) and sunshine ratio (low decrease) showed significant trends on an annual basis. In 1986-2010, we observed an increase in cloudiness (especially in winter), sunshine ratio (spring and summer), precipitation (summer and autumn) and temperatures (all seasons), whilst wind decreased. In general, the Carpathians show less significant trends than the surrounding plains in 1961-2010, in particular in spring and summer. In the Carpathian region, the solar dimming overcame the global warming in the 60's and the 70's, causing negative temperature anomalies; then, after a transition period in the 80's, a solar brightening period occurred in the 90's and the 2000's, enhancing the temperature rise.

Table 3.1: Annual and seasonal linear trends (per decade) related to 1961-1985 and 1986-2010.

	1961-85					**1986-10**				
	Win	**Spr**	**Sum**	**Aut**	**Year**	**Win**	**Spr**	**Sum**	**Aut**	**Year**
CC	-0.22 (90)					0.25 (90)				0.13 (90)
RS			-0.03 (99)		-0.01 (95)		0.03 (95)	0.02 (90)		
RR								34.26 (95)	21.04 (90)	80.94 (99)
RH			1.63 (99)	1.21 (90)	0.74 (95)		-1.56 (95)			
PA										-0.57 (95)
WS	-0.13 (99)	-0.14 (99)	-0.10 (99)	-0.12 (99)	-0.11 (99)		-0.07 (98)			-0.04 (99)
TN						0.60 (99)	0.43 (90)	0.47 (99)	0.60 (99)	0.45 (99)
TX	-0.52 (98)					0.72 (99)	0.69 (90)	0.79 (98)	0.76 (99)	0.49 (95)
TM	-0.31 (90)					0.66 (99)	0.56 (90)	0.63 (99)	0.68 (68)	0.48 (98)
DTR	-0.42 (98)									

Notations: *In brackets: significance levels. Only trends significant at least of 90% are shown.*
TN, TX and TM: Minimum, maximum and average temperature; DTR: daily temperature range; RR: precipitation; RS: sunshine duration; CC: cloud cover; RH: relative humidity; PA: air pressure; WS: wind speed at 10 meters.

3.3 Present information availability

3.3.1 Information used in the risk assessments

Databases

Many different databases are available, but most of them have not known data quality control and therefore, they are not suggested.

For present climate:

Two main types of the present climate databases are available: a station database and a gridded database. Station databases contain measured data, while gridded databases contain interpolated data. Usually, station data are not available where it is requested in the necessary density, therefore, an interpolation is used. If somebody would like to use their own interpolation and/or data quality control method, or seems to have a methodology (this is mostly not the case in reality), then it is better to use a station data database. In case of a ‘trustful’ user, a gridded database is suggested (the user believes the authors of the gridded database know the meteodata better, and apply better methods than the user could do).

The most-widely used station database is the ECAD (European Climate Assessment and Dataset) in De Bilt, Holland (https://www.ecad.eu/). This database is the climate data regional climate centre of the World Meteorological Organisation. They collect the data from different countries and therefore the database contains regularly updated data. On the other hand, the diversity of sources could cause problems (different DQ methods, border problems) since they cannot use strong DQ in the ECAD database.

The gridded database from the ECAD is the E-OBS database (available on the ECAD homepage). This database is updated regularly, but could have quality problems because of the diversity of data sources.

For the Carpathian (and as it follows, the Tisza) region, a special gridded database was developed with the support of the European Parliament, the CarpatClim database. It has a limited temporal size (because of the lack of financing, it has not been updated yet) of 1961-2010. The benefit of this database in comparison with the E-OBS database is that the authors of the CarpatClim were the data-owning organisations of the countries and that they used a strictly common DQ and homogenisation procedure and a good quality of interpolation (www.carpatclim-eu.org/).

For the future climate:

Based on the model calculations, they are gridded databases. If station information can be requested, they are usually interpolated from the grid to the station.

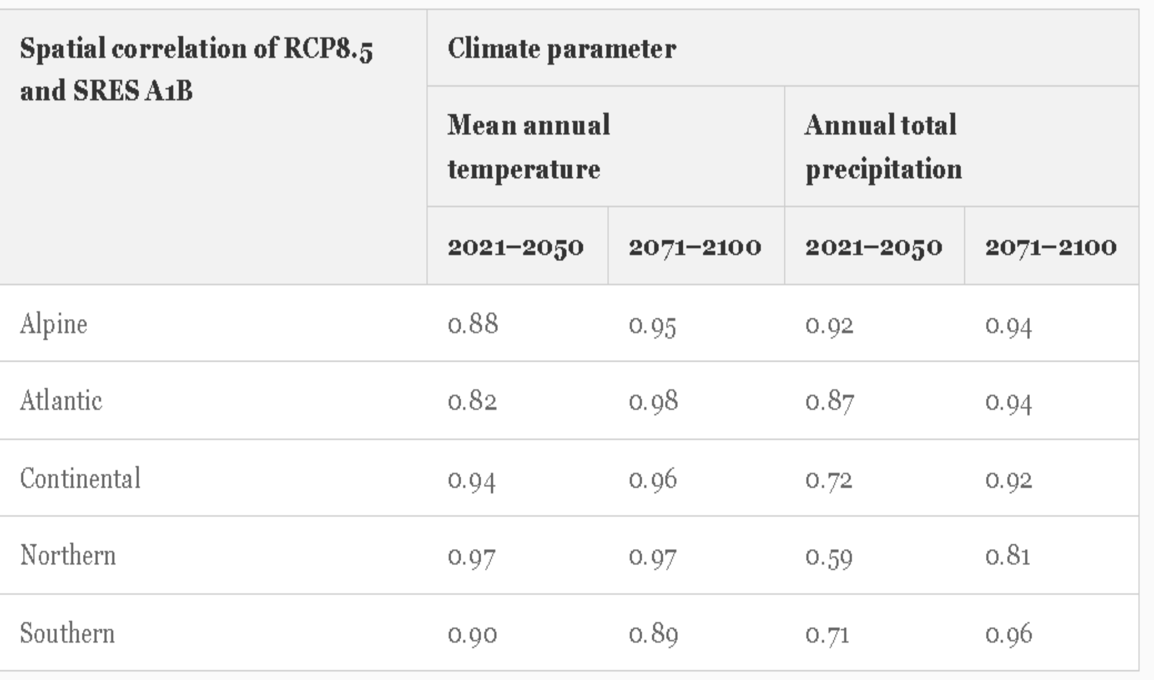
1. SRES scenario calculations are available on the homepage of the Prudence and Ensemle projects. Due to a strongly decreasing interest in SRES scenarios, they have no significance any more.
2. RCP scenario outputs are available on the CORDEX homepage, globally: https://www.cordex.org/
3. For Europe, the CORDEX calculated a special, high resolution dataset: https://www.euro-cordex.net

Comparison of scenarios

Comparison of the SRES and RCP scenarios is important in the present transient period. Many impact studies are based on the SRES scenarios, yet. Jacob et al. (2013) investigated the A1B, RCP4.5 and RCP8.5 scenarios for Europe. The correlation between A1B and RCP8.5 temperatures is higher than 80% in each geographical region with the lowest value of 82% for the Atlantic region in 2021-2050, and the highest of 98% for the Atlantic region but in the long term. Precipitation projections show much larger differences. The lowest values are about 60-70% for the continental, northern and southern part of Europe in a shorter term (the 2021-2050 period).

Based on these results, it can be stated that while the A1B temperature values are different from the RCP8,5 ones, they can be used for researches, since the precipitation data are different enough not to use them to avoid mistakes.

Table 3.2: Spatial correlation of the SRES A1B and RCP8.5 emission scenarios for changes in mean annual temperature and annual total precipitation of the sub-regions for the time periods 2021–2050 and 2071–2100



Spatial correlation of RCP8.5 and SRES A1B	**Climate parameter**			
	Mean annual temperature		**Annual total precipitation**	
	2021–2050	**2071–2100**	**2021–2050**	**2071–2100**
Alpine	0.88	0.95	0.92	0.94
Atlantic	0.82	0.98	0.87	0.94
Continental	0.94	0.96	0.72	0.92
Northern	0.97	0.97	0.59	0.81
Southern	0.90	0.89	0.71	0.96

The spatial distribution of the projections is shown in *Fig. 3.11*. It is even visually clear that precipitation values have large differences and one of these different hot spots is in the Carpathian Basin. A1B shows less precipitation than the RCP scenarios, but there are differences even between RCP scenarios as well. The 'no-change' area is around the Carpathian Basin, in some cases to the north of it, then the projection suggests drier climate, or to the south of it and then wetting is expected. If the model results are compared with the present tendencies calculated from the measurements, it is clear that the RCP scenarios fit better to the observed data than the SRES scenarios.

As it follows from these, the results and applications based on the SRES scenarios using precipitation data have to be revised and modified according to the changes in projections.

The RCP scenarios represent 2.6, 4.5, 6.0 and 8.5 W/m^2 anthropogenic greenhouse effects in 2100. An estimation of the anthropogenic radiation forcing related to 1750 was 2.29 W/m^2 with a confidence interval of 1.13-3.33 W/m^2 in 2011. This means that the present radiative forcing can be already higher than the 2.6 W/m2 scenario for 2100. Therefore, the RCP4.5 scenario used to apply to the mild scenario.

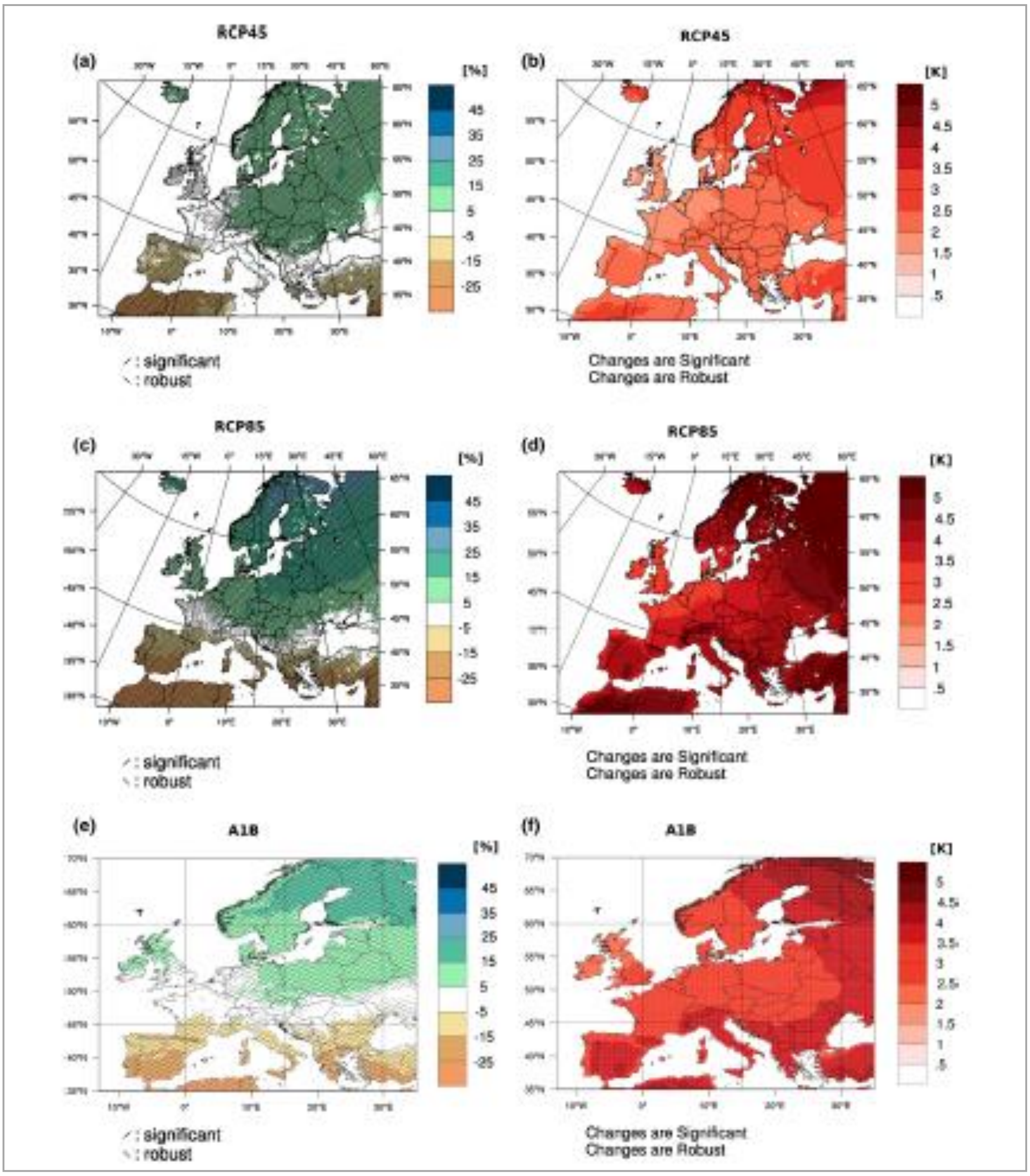


Figure III.11: Future temperature and precipitation changes based on old (SRES) and new (RCP) scenarios (Jacob et. al, 2013)

Application problems

The main characteristics of the modelled and measured fields are different, first of all the covariance. Therefore, it is not suggested to use individual model outputs, but rather distributions for a longer time period and/or area. A statistical analysis may be needed. For example, *Lakatos et al. (2016)* has shown the effect of an intensive thunderstorm on the return periods. The thunderstorm occurred in Budapest, on 17 August, 2015, when 83.3 mm rain fell within 1 hour. The return periods have been changed as in the *Table III.3.*

Table III.3: Return periods of different precipitation sums in Budapest

Return period	**2**	**4**	**5**	**10**	**20**	**50**	**100**	**200**
1998-2014	19.3	25.5	27.4	33	38.7	46.4	52.5	58.9
1998-2015	19.6	28,3	31.4	42.3	55.9	79.9	103.9	134.8

The changes are not very large for shorter return periods, but they increase 2-2.5 times on a longer time scale. Therefore, more detailed analysis is requested in case of higher importance tasks.

Important points at the climate data applications

Summarizing the main factors that should be checked for the use of past or projected climate data:

Past:

1. Data quality and homogeneity. The description of the methods is available in the above suggested databases, but could be lacking in other ones. It has an additional uncertainty.
2. Pay attention to the time periods used. It can have significance in case of the climate variables with a high temporal variability, first of all.
3. Interpolation could cause an additional problem. The applied method has to be checked in the gridded databases. They used to be better than a simple interpolation method at the GIS.

Projection

1. Climate models have a gridded output that makes their application comfortable.
2. Using a model output for a special goal, the management of the special process in the model has to be checked. If the model does not contain the given process (or very simplified), the application of the outputs should be controlled.
3. Distribution of the model outputs is suggested. High resolution temporal and/or spatial data application is misleading. Models cannot describe the high resolution characteristics of the climatological variables.

In the synthesis report, *Tsegai et al. (2015)* described the ‘3 key pillars’ of drought risk reduction, which can be transferred to other risks in connection with water quantity:

1. Implement drought monitoring and early warning systems:
    - Monitor key indicators and indices of precipitation, temperature, soil moisture, vegetation condition, stream flow, snowpack and ground water.
    - Develop reliable seasonal forecasts and develop appropriate decision-supporting tools for impacted sectors.
    - Monitor the consequences of drought, especially the impacts to vulnerable sectors such as agriculture.
    - Communicate reliable warning messages and respond to the risks in a measured and timely fashion

2. Assess drought vulnerability and risk:
    - Identify drought impacts on vulnerable economic sectors including cropping and livestock agriculture, biodiversity and ecosystem, energy, tourism, health sectors.
    - Assess the physical, social, economic and environmental pressures on communities to identify who and what is at risk and why, before, during and shortly after drought.
    - Assess the conditions or situations that increase the resistance or susceptibility to drought and the coping capacity of communities affected by drought.
    - Assess the extent of potential damage or loss in the event of a drought.
3. Implement measures to limit impacts of drought and better response to drought:
    - Implement structural or physical measures, as well as non-structural measures to limit the adverse impacts of a drought, prioritized based on the level of vulnerability (Key Pillar #2).
    - Response includes all efforts, such as the provision of assistance or intervention during or immediately after a drought disaster to meet the life preservation and basic subsistence needs of those communities and sectors that are most vulnerable and impacted.
    - Relevant to sectors affected by drought, based on their vulnerabilities, particularly agriculture, water and the environment, but also health, transport and tourism.
    - Measures can be long-term, medium-term or short-term, depending on their implementation time.
    - e.g. biodiversity, land and ecosystem services play a vital role in reducing vulnerability and mitigating impacts of drought.

Based on the information, we can shortly evaluate the situation in the JOINTISZA area:

Positive features in brief:

- gridded databases exist, covering the whole Tisza catchment
- climate model results are available in a good spatial resolution (nowadays Cordex, Euro-Cordex, earlier Prudence and Ensemble)
- WMO project supports the seasonal forecast in the south-eastern Europe (SEECOF)
- many organizations, commissions support the efforts of a disaster risk reduction
- many monitoring networks operate in different fields of environment in the region.

Some negative features:

- Different databases give different results in the region. For example, the CarpatClim database is stronger in the use of the same DQ methods, but is not updated (finished in 2010), while the E_Obs is up-to-date, but has less effective DQ methods.
- The modelling of the climate of the Carpathian basin has some additional problems in comparison with the neighbouring areas. The unsatisfactory spatial resolution in the models could cause problems in the Basin.
- The accuracy of the seasonal forecast does not reach the level of operability.
- The information flow and even a basic level of cooperation are missing among the countries with some exceptions. The expensive measuring systems, databases could be different (because of the high costs, there is no hope to unify them in the near future, but harmonisation is needed).

- Only the meteorological monitoring can be called satisfactory. In some cases, there are inconsistencies even among national measurements and even more so at the transboundary level. There are significant differences between methodologies, applied techniques, archiving methods and regarding the time the data have become available to a wider auditorium.

3.3.2 Results of climate models for the Tisza River basin

The Tisza-basin is a sophisticated area from a climate change point of view. While models give relatively unified pictures for a temperature change, the precipitation tendencies are very different, depending on a scenario and a model. The reason for that is the zero-change isoline being in the vicinity of this region. If a model shifts this isoline a bit to the north, precipitation increases, if a bit to the south, then a decrease would be forecasted. According to our present knowledge, the quantitative change of annual precipitation will have less impact than its extremity. Independent from the tendency of annual precipitation, the extremeness of precipitation will increase and more frequent and severe drought events and floods can be expected. Management of this situation is extremely important at the adaptation to climate change. In spite of the uncertainties in annual precipitation totals, it seems that the RCP scenarios predict more humid climate future than the SRES scenarios (and it fits better to the present climate tendencies, as well) *(Fig. III.12 and III.13)*. Furthermore, a larger temperature increase will give less precipitation and larger spatial variability than a smaller one among the different RCP scenarios.

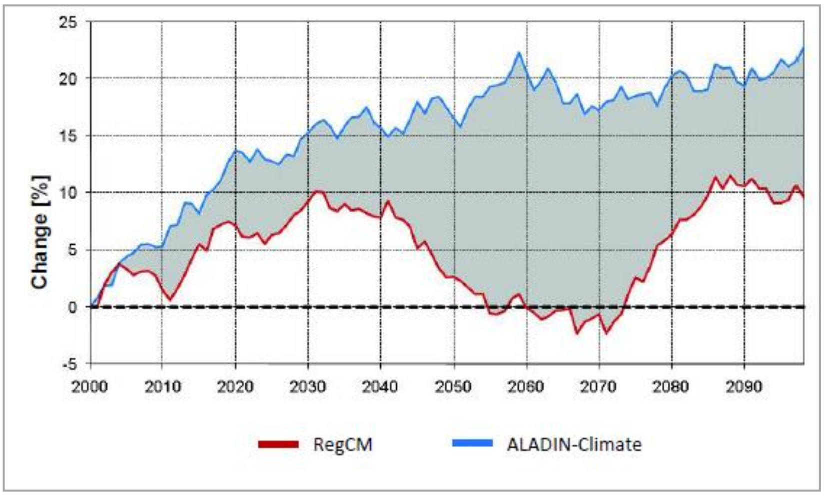


Figure III.12: Change of the annual precipitation sum based on the two scenarios and two models in the 20th century (Sabitz et al., 2017)

Figure III.12 shows that the annual precipitation sum can increase by about 20 % or even decrease. The two regional climate models (RCM) are the RegClim and the Aladin, and the two scenarios are the 8.5 and 4.5. It can be clearly seen that more detailed information about the models and scenarios is needed during the climate projection applications. Furthermore, the global circulation model (GCM) forcing the RCM has an impact on the results as well. Large differences can occur even in same RCM, same scenario, but different GCM. Unfortunately, information about the models, especially about the GCM is frequently missing, making the comparison of climate projections difficult.

The increase of precipitation intensity and the increase of frequency and probably the magnitude of extreme events seem certain.

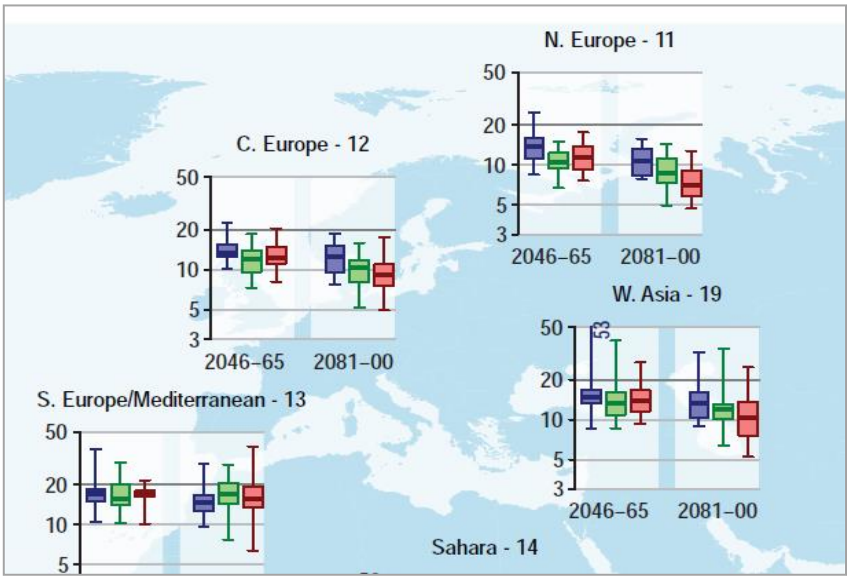


Figure III.13: Changes in the return period of 20-year daily precipitation, Europe

Figure III.13 shows that the daily precipitation intensity will increase in all European regions, perhaps a bit less to the end of the 21th century than in the middle of the century, but the differences are not very large. This change is general in Europe despite the very different precipitation quantity changes.

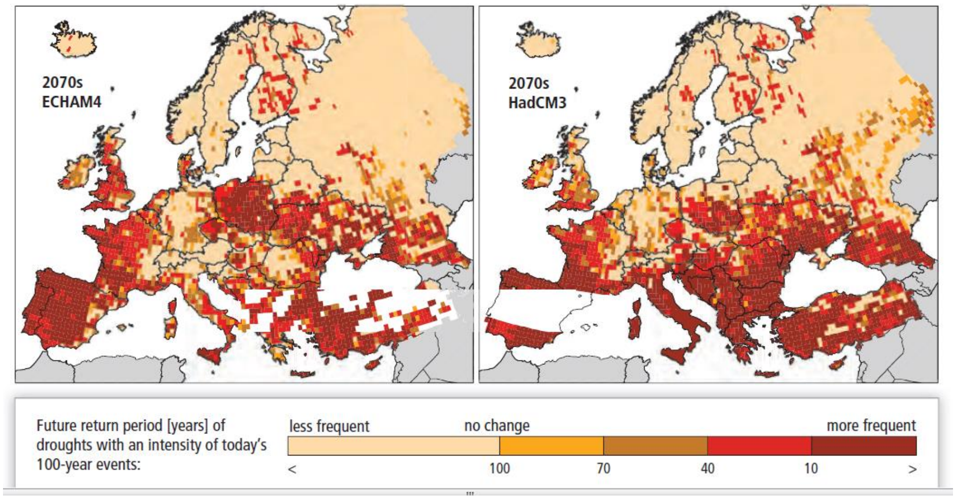


Figure III.14: Changes in the 100-year return period

Figure III.14. shows the drought changes in the return period compared to the today's 100-year events for two models. The similarity is good in the western- Europe (France, Spain, Portugal, UK) and in the northern part of the continent, but weak for Italy, Poland and the SEE region, among others for the Carpathian Basin and the Tisza catchment. While the ECHAM4 model gives less frequent droughts for Transylvania, HadCAM3 suggests more frequent events, some places even with a return period of 10 ye ars or less. As it follows, the uncertainties have to be discussed.

3.3.3 Uncertainties

Climate research is loaded with uncertainties (uc) of a different origin. Basically, uncertainties can be divided into three classes:

- Type 1: aleatoric uc: system inherent, not avoidable
- Type 2: Epistermic uc: model inherent, can be reduced
- Type 3: Forcing uc: conditional on forcing scenario (even if the model would be perfect, it would input uc)

Uncertainties of the past and present are based on the observed/measured data: station distribution and density, length of the time series, accuracy and quality of the time series (including homogeneity) and interpolation tools.

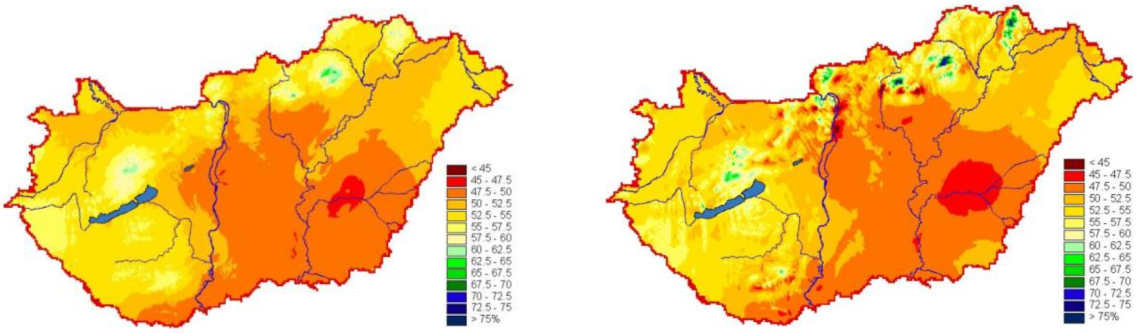


Figure III.15: Comparison of the two maps of an average of the relative humidity on July 13th for Hungary, prepared with two good-quality interpolation methods: Aurelhy is on the left and MISH is on the right.

For example, *Figure III.15* shows maps drawn by two good quality interpolation methods. Nevertheless, large spatial differences can be detected between the two maps. In case of decision-making, these differences can cause problems.

The next level of uncertainty is connected with the climate modelling.

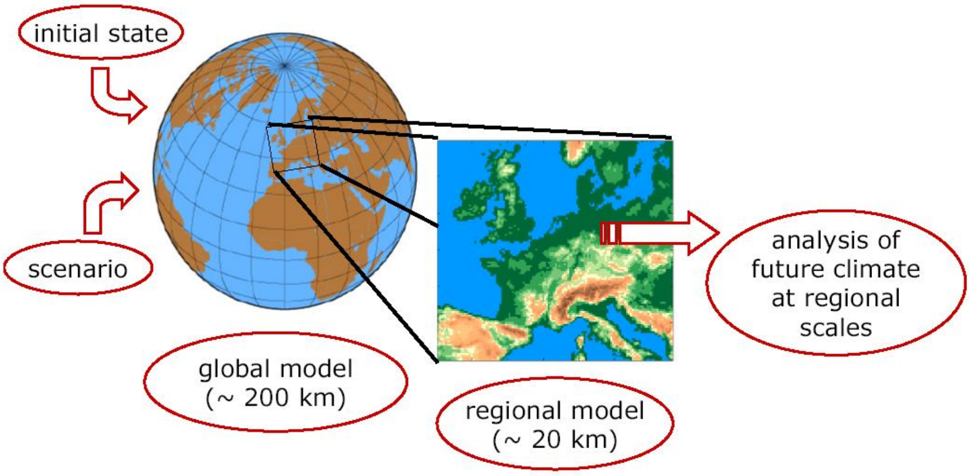


Figure III.16: Uncertainties of the climate modelling

The basic problems associated with the modelling are as follows: Climate is a random system: complex, high-dimensional, non-linear, and realistic climate models attempt to model this random system. But models are always reductions, introducing new uncertainties. Global models have the problems of a spatial resolution which is still about 100 km. The topographical units and processes with a lower resolution cannot be modelled, but parameterized with a higher uncertainty. Frequently, we do not have satisfactory data for the higher resolution with appropriate accuracy. And if we do, we then face the problem of computer capacity and accuracy. The resolution and computer problems are resolved with the help of the regional climate models, but we have another problem of missing coupling of the two models.

Datasets for evaluating the model results can introduce further uncertainties: ones have not strong enough management methods, while others do not have updated data. The comparison of databases for use in climate model evaluations could show spatially large differences.

The spatial and temporal resolutions cause uncertainties in the use of climate model results for applied purposes (applied models). For example, *Fig. III.17* shows the requested scales for different kinds of forest models, which cannot be fulfilled in most cases by the climate models.

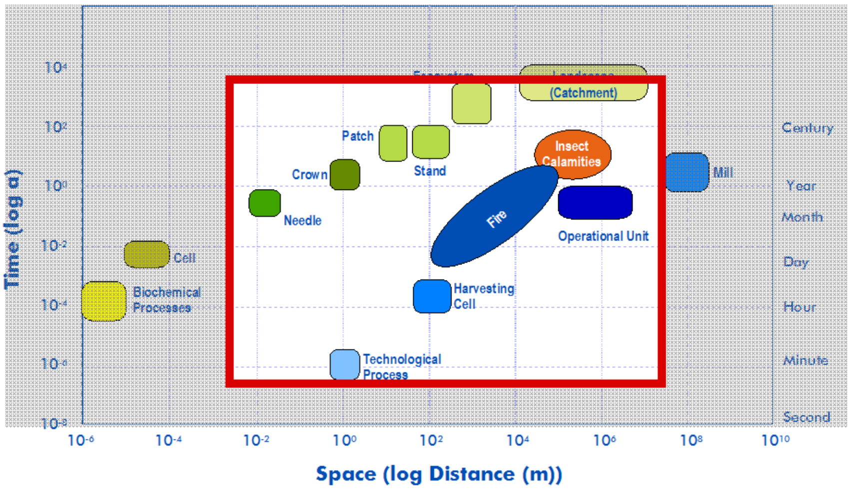


Figure III.17: Requested scales for different kinds of forest models

IPCC (2019) recognised two primary types of uncertainty:

"Uncertainties can be classified in several different ways according to their origin. Two primary types are ‘value uncertainties’ and ‘structural uncertainties’: Value uncertainties arise from the incomplete determination of particular values or results, for example, when data are inaccurate or not fully representative of the phenomenon of interest.

Structural uncertainties arise from an incomplete understanding of the processes that control particular values or results, for example, when the conceptual framework or model used for analysis does not include all the relevant processes or relationships.

Value uncertainties are generally estimated using statistical techniques and expressed probabilistically. Structural uncertainties are generally described by giving the authors’ collective judgment of their confidence in the correctness of a result. In both cases, estimating uncertainties is intrinsically about describing the limits to knowledge and for this reason involves expert judgment about the state of that knowledge. A different type of uncertainty arises in systems that are either chaotic or not fully deterministic in nature and this also limits our ability to project all aspects of climate change".

Furthermore, uncertainties of climate projections for policymaking can be considered in three groups:

- Uncertainties about future climate forcings,

- Uncertainties about how the climate system will respond to past and future forcings,
- Limitations of climate scientists' models and methods for developing climate projections.

The policymaking process has been bogged down in the politics of justice and equity whilst GHG concentrations have been rising at a dangerous rate and climate science has become more uncertain in some respects. Uncertainty in the science and in the methods and tools used by climate scientists has led to the confusion in the policymaking process.

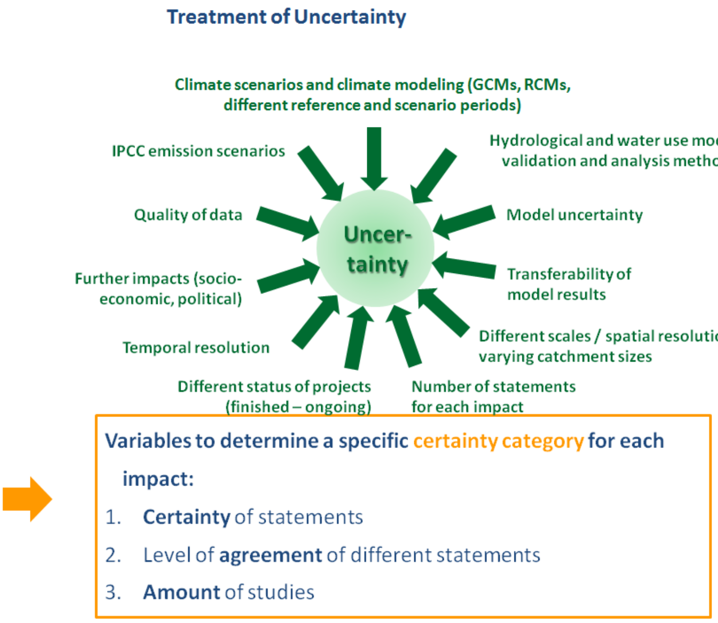


Figure III. 18. Treatment of uncertainty

Figure III.18. gives the theoretical basis for the classification of the certainty categories. One of the practical applications is in the Danube Adaptation Strategy. The changing uncertainties between the first and second version of the Strategy are shown on *Figure III.19*.

Climate elements	Seasonality in precipitation Temperature	Seasonality in precipitation Mean annual precipitation Extreme weather events	Wind	Weather pattern
Water availability		Runoff	Runoff Evapotranspitation	
Extreme hydrological events		Droughts, Waterstress Low flow Flood events	Droughts, Waterstress Low flow	Flood events
Water use		Agriculture, Irrigation, Forestry	Agriculture, Irrigation, Forestry Water related energy production Navigation	
Water quality & ecosystems		Ecosystems	Ecosystems Biodiversity	

Figure III.19. Uncertainties of different hydrological processes (ICPDR, 2018)

3.4 Monitoring systems

The following tables provide the number of surface (in situ) meteorological stations measuring specific parameters in countries participating in the JoinTisza project.

Hungary and Croatia

	number of all stations	number of stations from neighbouring countries
Daily mean temperature	68	19
Minimum air temperature	68	19
Maximum air temperature	68	19
Daily precipitation	233	33
10 m wind direction	66	17
10 m horizontal wind speed	66	17
Sunshine duration	33	17
Cloud cover	66	19
Global radiation	33	17
Relative humidity	68	19
Surface vapour pressure	68	19
Surface air pressure	41	15

Serbia

	number of all stations	number of stations from neighbouring countries
Daily mean temperature	39	12
Minimum air temperature	39	12
Maximum air temperature	39	12
Daily precipitation	114	16
10 m wind direction	40	11
10 m horizontal wind speed	40	11
Sunshine duration	28	10
Cloud cover	39	12
Global radiation	28	10
Relative humidity	35	12
Surface vapour pressure	35	12
Surface air pressure	26	12

Romania

	number of all stations	number of stations from neighbouring countries
Daily mean temperature	140	16
Minimum air temperature	140	16
Maximum air temperature	140	16
Daily precipitation	182	16
10 m wind direction	119	15
10 m horizontal wind speed	119	15
Sunshine duration	112	12
Cloud cover	110	16
Global radiation	112	12
Relative humidity	140	16
Surface vapour pressure	182	16
Surface air pressure	139	15

Ukraine

	number of all stations	number of stations from neighbouring countries
Daily mean temperature	53	14
Minimum air temperature	53	14
Maximum air temperature	53	14
Daily precipitation	57	18
10 m wind direction	53	14
10 m horizontal wind speed	53	14
Sunshine duration	24	12
Cloud cover	53	14
Global radiation	24	12
Relative humidity	53	14
Surface vapour pressure	53	14
Surface air pressure	49	10

Slovakia

	number of all stations	number of stations from neighbouring countries
Daily mean temperature	59	37
Minimum air temperature	59	37
Maximum air temperature	59	37
Daily precipitation	165	102
10 m wind direction	53	31
10 m horizontal wind speed	53	31
Sunshine duration	27	16
Cloud cover	52	30
Global radiation	29	17
Relative humidity	44	22

Surface vapour pressure	52	30
Surface air pressure	26	18

3.5 DriDanube information service project

The following sub-chapter is based on the work of *Susnik et al (2018)*.

The Danube catchment area is characterized by high climate variability, especially in terms of precipitation. A neighbouring region is the Mediterranean region, where climate model projections unanimously show a strong summer precipitation decrease. Observations show a growing frequency and severity of drought events, especially in the middle and lower part of the Danube region.

A growing number of heat waves and temperature increase in summer, the most warming season, cause more frequent summer droughts. High precipitation variability can cause droughts even in wintertime despite a generally increasing precipitation in this season. Growing drought damages directed the interest to this disaster. That was the reason why the Slovenian Environment Agency engaged different institutions across the Danube region to join forces in preparing a proposal for the project entitled Drought Risk in the Danube Region (DriDanube). The project was submitted to the call opened within the Interreg Danube Transnational Programme. It was accepted for financing for the period January 2017 – June 2019. The project's web-page is at http://www.interreg-danube.eu/approved-projects/dridanube.

3.5.1 Project objectives and results

The main objectives of the DriDanube project are as follows:

- to increase the capacity of the Danube region to manage drought related risks;
- to improve drought monitoring by operational innovative service (Drought User Service);
- to unify drought risk assessments based on the Civil Protection Mechanism;
- to improve drought emergency response (to change mainly ad-hoc drought response to pro-active response based on risk management procedures).

The DriDanube's main expected result is an improved drought emergency response and better cooperation among operational services and decision- making authorities in the Danube region. Its primary target groups are the following:

- National Hydrometeorological Services
- Emergency response authorities
- Non-governmental organizations
- Water and farmer communities/chambers
- Industries

Based on the objectives above, the following outputs are foreseen:

- Drought user service
- Methodology for drought risk assessment
- Methodology for drought impact assessment including forecast
- Pilot actions testing the Drought user service and both methodologies
- Capacity building on a national and regional level
- Stakeholders' engagement in development of the DriDanube tools and their use in everyday work.

Being in the second year of the project, some of the results are already available as prototypes. *Figure III.20.* demonstrates how the Soil Water Index will be visualized in the Drought User Service interface. Results of the methodology developed for drought impact assessment including forecast are given in *Figure III.21.*

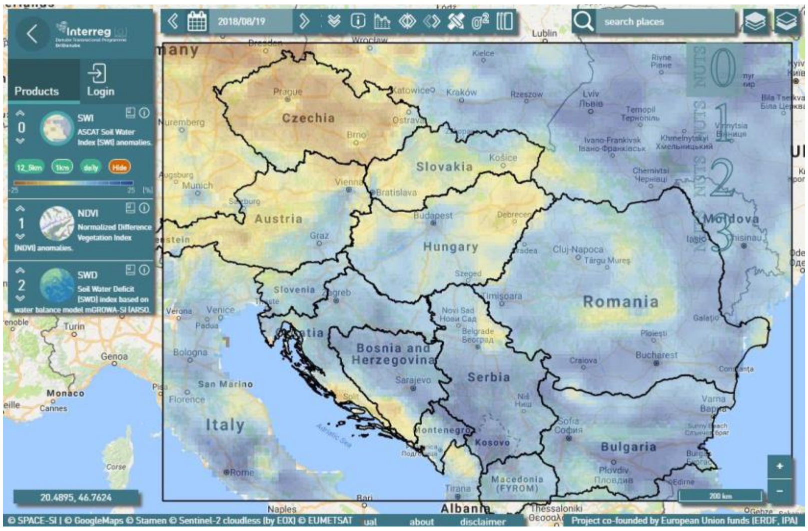


Figure III.20: Soil Water Index on 19 August 2018 across the Danube region as seen in the Drought User Service

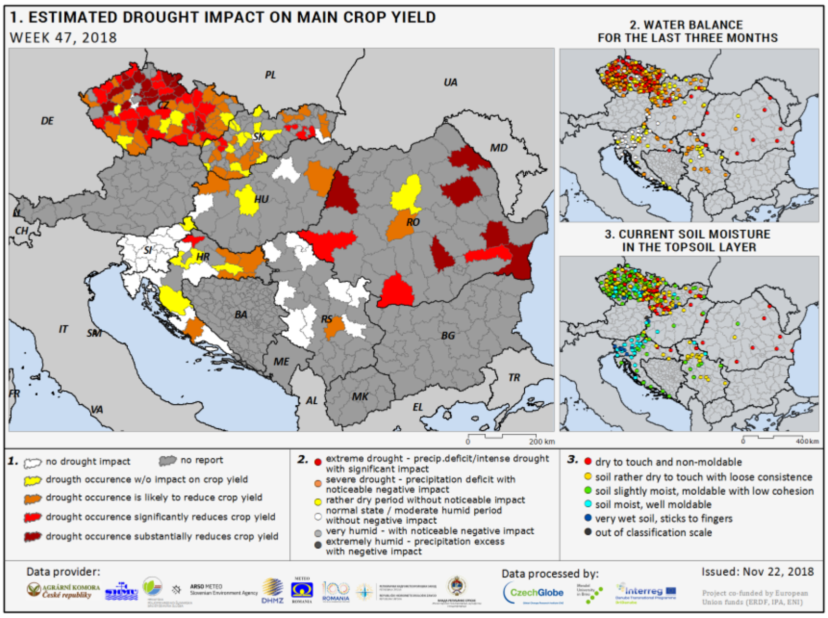


Figure III.21: Drought impact on main crop yield in the Danube Region for the week 47, 2018

3.5.2 Capitalization

The DriDanube project works in close co-operation with other DTP projects having similar topics using synergetic effect of their cooperation. These projects are the following: JOINTISZA, CAMARO-D and DANUBE SEDIMENT.

3.6 Information gaps

The Tisza valley is a relatively highly developed region, with a dense measuring network, existing longer term time series and both remote sensed and in situ measurements. There are quite well developed research activities and several publications.

Despite of these, many problems hinder the higher level regional cooperation:

- Metadata information has to be strengthened: in many cases, more information is needed to reach higher quality results

- Harmonisation problems (measurements, data management): Measuring networks is expensive, therefore it is not expected to unify observing systems, but their harmonisation for regional studies is necessary

- Model results should be managed with care, knowing which processes are described in the model and which are neglected, what is the accuracy, for which problems the results can be used. Climate projections are suggested to be used according to their distribution and not as individual values. Observation data needs quality control and homogenisation; without them their application in the climate change studies is not suggested

- Developing remote sensing (RS) techniques is suggested to improve the point surface measurements. The common use of RS and surface methods increases the accuracy of the data and helps develop better models with more available variables

- Fast data exchange is requested. Information exchange should be faster to improve the quality of common services, such as early warning

- Regional analysis: The countries in the region are not very large, making the near-border problems larger. Most of the water flows are transnational requiring international cooperation.

- Stakeholder connection has to be improved and a dialogue with them can substantially increase the benefits of measurements and models.

3.7 Conclusions

It can be stated that much work has been done, but many further efforts are requested. More and more information will be available and their common and updated application is requested. The Tisza catchment is in a good situation, because a high spatial resolution, daily temporal resolution high-quality climate database, the CarpatClim database, is available. It is a common effort of the national climate services of the countries and provides a solid basis for scientific and practical work for 1961-2010. It should be updated and last years added. A continuous interdisciplinary scientific development needs capacity building developments as well.

Chapter 4 Climate Change-Impacted Hydrology and Water Quantity in the Tisza River Basin – Issues and Adaptation Measures

Chapter authors: Branislava Matic JCI and Miklos Szalay OVF

4.1 Tisza River Basin hydrology

The TRB is the largest sub basin of the DRB, with an area of 157,186 km² (19.5 % of DRB) and 825 m³/s average flow. Together with its tributaries, the Tisza River drains the largest catchment area in the Carpathian Mountains before flowing through the Great Hungarian Plain and joining the Danube River in Serbia. An overview of the basin and its main watercourses is shown in *Figure IV.1.*

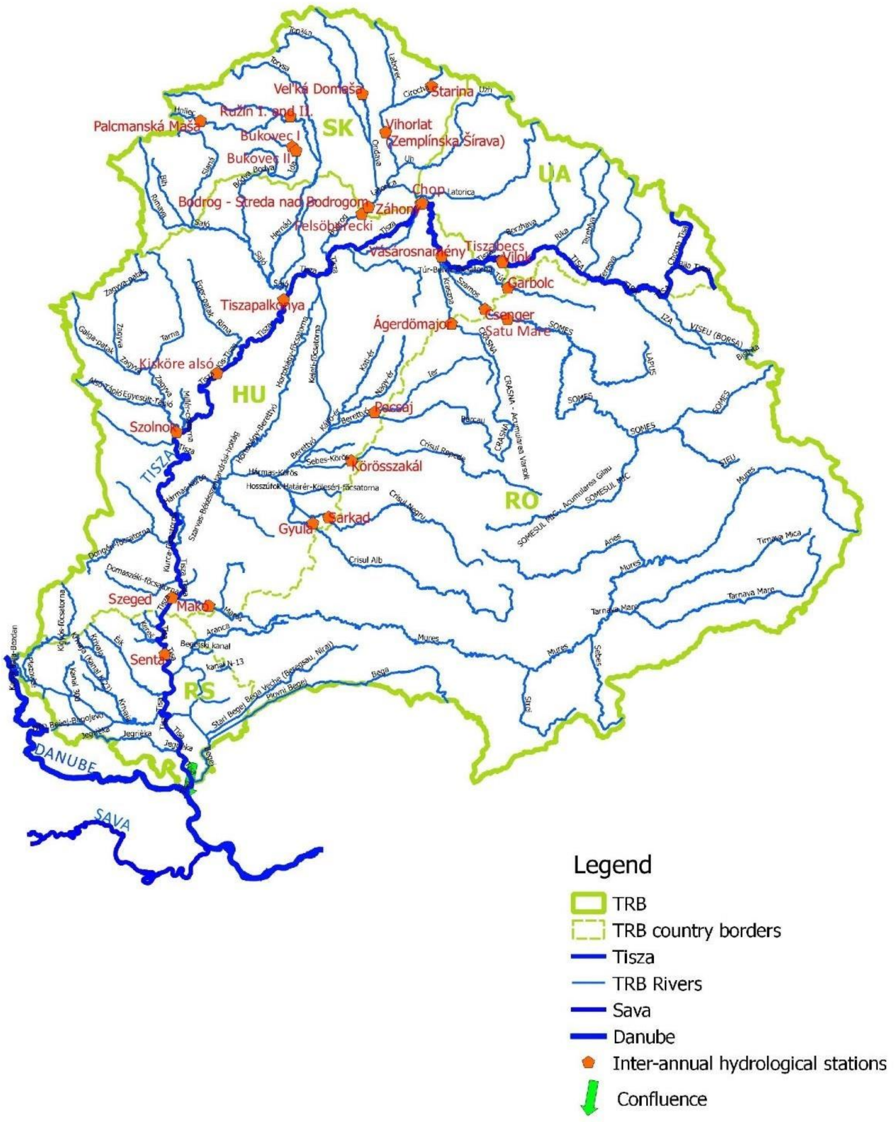


Figure IV.1: Overview map of the Tisza River Basin

There are two parts of the TRB , the mountainous Upper Tisza and its tributaries in Ukraine, Romania and the eastern part of the Slovak Republic, as well as the lowland parts mainly in Hungary and in Serbia surrounded by the East-Slovak Plain, the Transcarpathian Lowland (Ukraine) and the plains in the western borderlands of Romania. On the other hand, the Tisza River itself is divided into three main reaches:

- ***The Upper Tisza***, upstream from the confluence of the Someş/Szamos River;
- ***The Middle Tisza*** in Hungary, which receives the largest left-bank tributaries: the Someş/Szamos River, the Crişul/Körös River System and the Mureş /Maros River draining Transylvania in Romania, moreover the largest right-bank tributaries: the Bodrog and the Slaná/Sajó Rivers together with the Hornád/Hernád River collect water from the Carpathian Mountains in the Slovak Republic and Ukraine, and the Zagyva River that drains the Mátra and the Bükk mountains;
- ***The Lower Tisza*** (downstream from the mouth of the Mureş/Maros River that receives the Bega/Begej River and other tributaries indirectly through the Danube – Tisza – Danube Canal System in Serbia.

Until the middle of the 19th century, the Tisza River had repeatedly inundated some 2 million hectares along its course. The first survey of the river valley was done between 1833 and 1844, and Pál Vásárhelyi issued a plan for riverbed training with 121 short-cuts along the river in 1846. This plan was declined and a new plan with 21 short-cuts was accepted in 1847. River training works finally began after a disastrous flood in 1855 and 112 short-cuts were made by 1875. The length of the Tisza River was shortened from cca. 1,400 km to present-day 966 km.

In the present reporting period (during the implementation of the JOINTISZA project), the Tisza countries provided data for minimum, maximum and average discharge at the hydrological stations exhibited in Figure IV.2 for the period of 1985-2015. More details are presented in Annex 1.

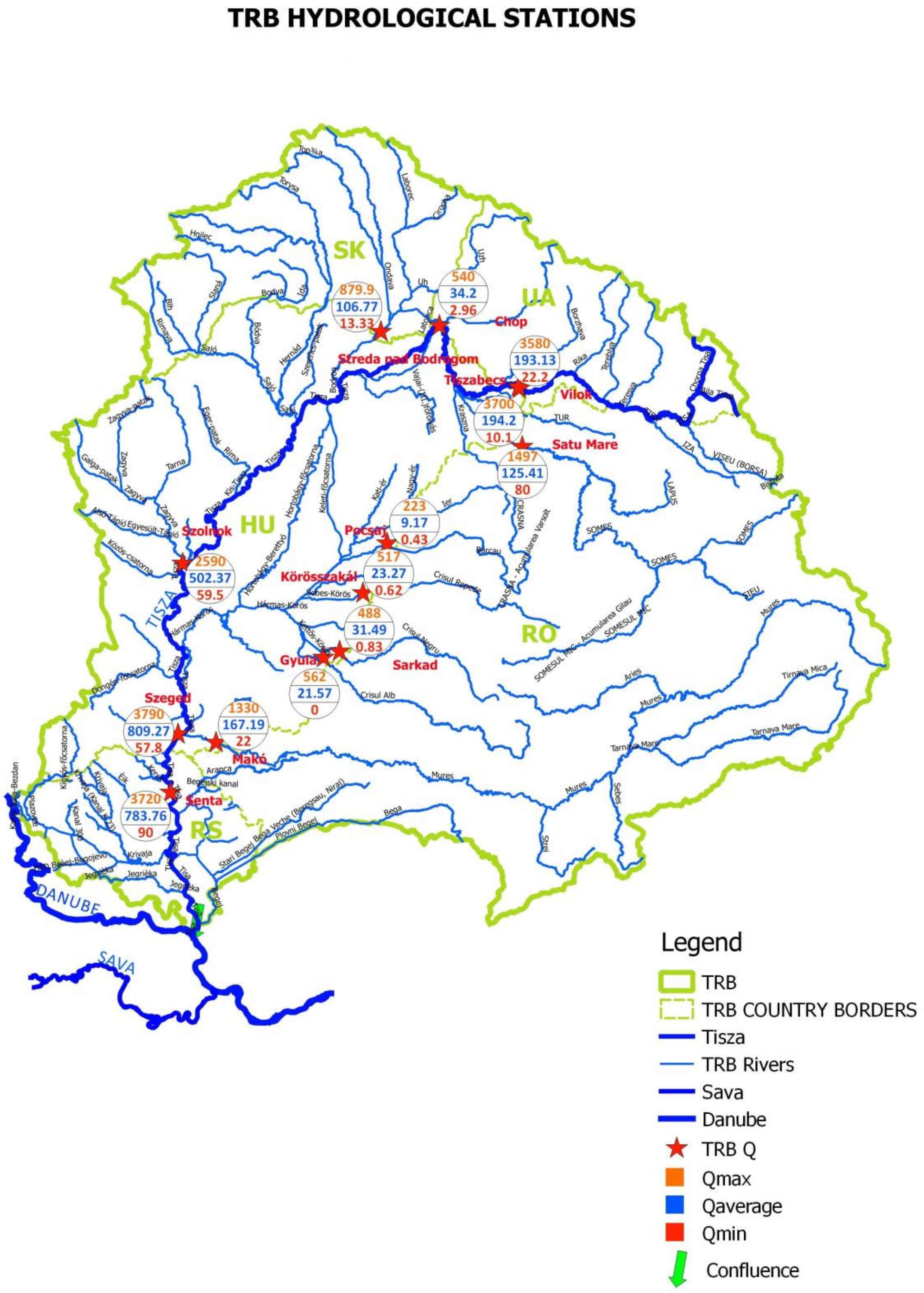


Figure IV.2: Main hydrological stations and observed maximum, average and minimum flows for the years 1986-2015 (Reported by the Tisza countries, JOINTISZA Deliverable 4.2.1: TRB report on water quantity)

4.2 TRB RELEVANT WATER QUANTITY ISSUES AND DPSIR FRAMEWORK

Long term tendencies in runoff provide important information from a climate change point of view. Their causes need to be identified, because this is the background against which the predictions on climate change effects on runoff have to be made. The four main reasons of shifts, upward or downward tendencies in mean annual or semi-annual runoff, are as follows:

- ***changes in catchment runoff conditions***, such as changes in vegetation cover (especially deforestation/reforestation), urbanization (growth of impervious surfaces) or river regulation, excess water drainage, etc..
- ***changes in water use***, e.g. *construction of reservoirs*, thus increasing evaporation losses and the resulting temporal modifications in runoff, *increasing consumptive water use* (especially irrigation).
- **water diversion** into or from the river, river basin or sub-catchments.
- ***climate change***, manifesting itself in changes of rainfall quantity, intensity or temporal distribution, as well as in changes of evaporation and evapotranspiration due to air temperature changes.

High flows

Rainfall in the Carpathian Mountains can be substantial and sudden. Extensive runoff, floodplain deforestation and river canalisation reduce the ability of the catchment to attenuate a flood wave. In the mountainous regions, flash floods are common in spring and summer. These are further intensified by a low infiltration capacity of the soils in the Carpathian Mountains.

These floods might cause inundation in lowland areas. Flooding is a natural event necessary for riverine ecosystems, but it is also a significant threat to communities settled in the floodplain.

When heavy rains occur, flooding threatens human lives as water levels rise quickly without a sufficient retention capacity. Floods generated in Ukraine, Romania and Slovakia are mainly rapid short-lasting floods and last for 2-20 days, with flooded areas situated on the superior Tisza courses or on the tributaries. Large floods on the Tisza in Hungary and in Serbia, in contrast, can last for as long as 100 days or more (the 1970 flood lasted for 180 days). This is due to the very flat characteristic of the river in this region and multi-peak waves that may catch up on the Middle Tisza, causing long flood situations. Also characteristic of the Middle Tisza region is that the Tisza floods often coincide with floods on the Danube and on its tributaries, which is especially dangerous in case of the Someş/Szamos, Crasna/Kraszna, Bodrog, Criş/Körös and Mureş/Maros Rivers.

Mean annual runoff

Runoff in the Tisza river basin is highly variable in both space and time. Spatial differences can be viewed in *Figure IV.2:* areal mean annual runoff is the highest in the Carpathians, especially at the Tisza headwaters, where it reaches above 1000 mm/year, whereas in the Hungarian plain it is only at around 25-50 mm/year.

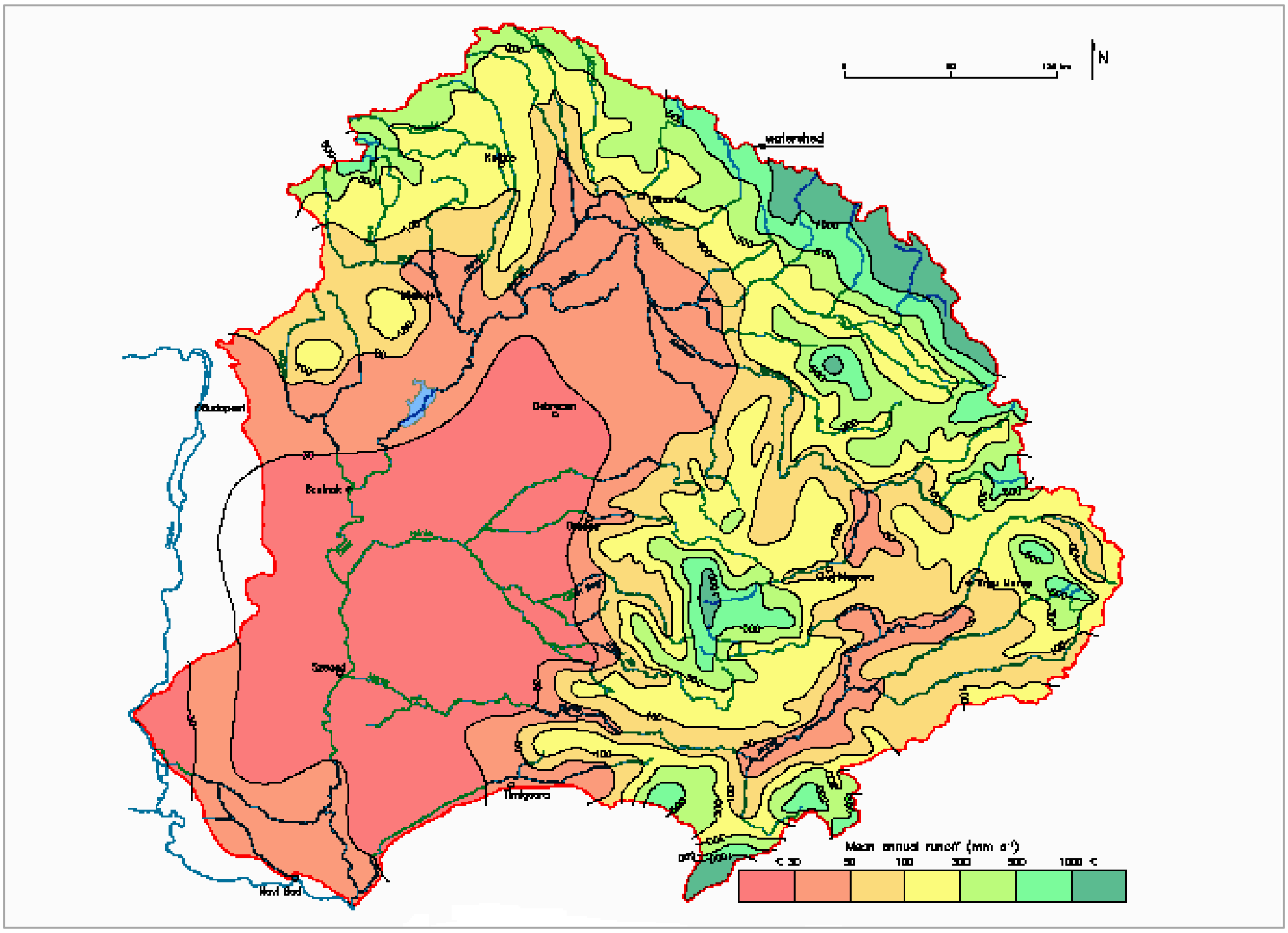


Figure IV.2 Map of the mean annual runoff for the Tisza River Basin, 1931-1970, mm/year (source: RCDC, 1986)

Changes within a 50-year long runoff time series at Záhony on the Tisza River are shown in *Figure IV.3,* for the hydrological year and the summer half-year, including a downward linear trend calculated for the whole period. The Záhony gauging station has been chosen for being upstream of major water uses and diversions. Nevertheless, the annual decrease amounts to 3.85 m^3/s for the summer and 2.40 m^3/s for the hydrological year. The latter mainly reflects the summer decrease since winter flows do not show significant tendencies.

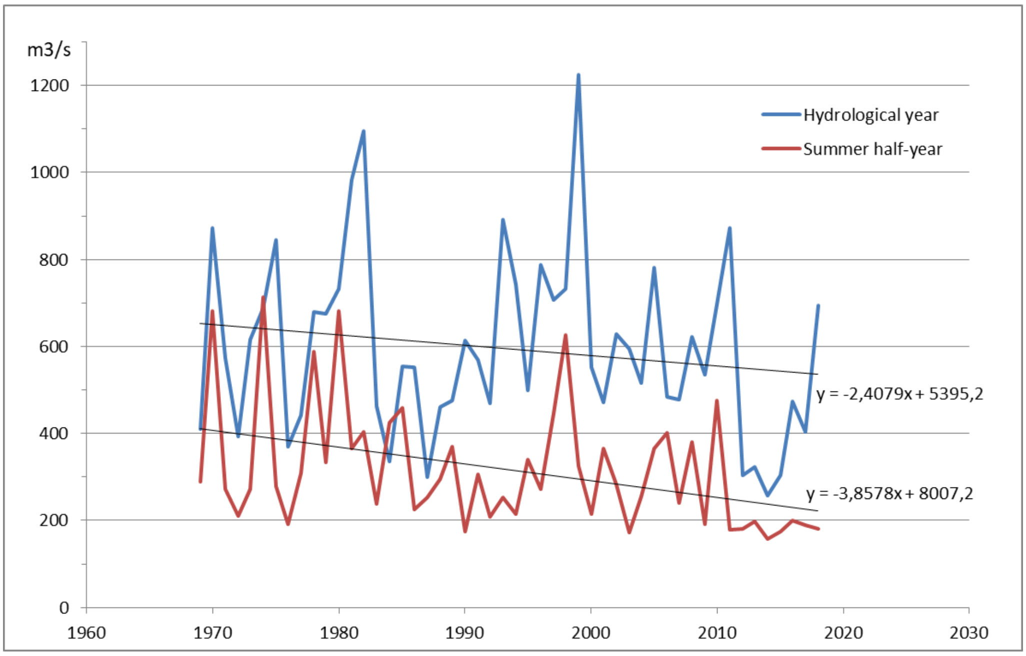


Figure IV.3: Annual and semi-annual runoff time series at the Záhony gauging station on the Tisza, 1969-2018.

Runoff in the summer half-years during the 50-year period of 1969-2018 has receded by a total of 190 m^3/s.

Low flows, water scarcity and drought

Water scarcity is often thought to be a synonym for drought, although these are rather distinct terms. Based on (*MWS&D WG,* 2007), the following definitions can be given:

Water scarcity is an imbalance between demand (water requirement) and an exploitable part of water resources. Water scarcity can be

- *structural*, due to the scarcity of the average resources compared to increasing or excessive demands;
- *random*, due to the failures of water management structures, distribution systems or an unforeseen, temporary increase of demand;
- *socio-economic*, because of a structural or random insufficiency of a system means of use (poverty, lack of finances for maintenance, defect or technical accident) or can even result from excessive demands compared to the needs.

Drought is a normal, recurrent feature of climate, although often erroneously considered an unexpected and extraordinary event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary extremity within the natural variability and can be considered an insidious hazard of nature. (It also differs from aridity, which is a long-term, average feature of climate.) Droughts generally result from a combination of natural factors that can be, in fact, enhanced by anthropogenic influences, including climate change. The primary cause of any drought is a deficiency in rainfall, and, in particular, the timing, distribution and intensity of this deficiency in relation to the existing water storage, demand and use. This deficiency can result in a shortage of water necessary for the functioning of a natural (eco-) system and / or necessary for certain human activities (*MWS&D WG,* 2007).

4.2.1 Water quantity issues

Based on the data and information provided on the TRB meteorology and hydrology in previous chapters, changes in precipitation and temperature (Chapter 3) will very likely generate a change in frequency and magnitude of extreme hydrological events, both floods and droughts. Given that and an increase in water demand and groundwater abstraction, in addition to the TRB Significant Water Management Issues that can directly or indirectly affect the status of ground water and surface water bodies (pollution by organic substances, pollution by nutrients, pollution by hazardous substances, and hydromorphological alterations), the ICPDR TG identified key water quantity issues (floods and excess water, drought and water scarcity and climate change) relevant to the TRB and identified inter-linkages between water quality and quantity related management issues in Figure IV.5.

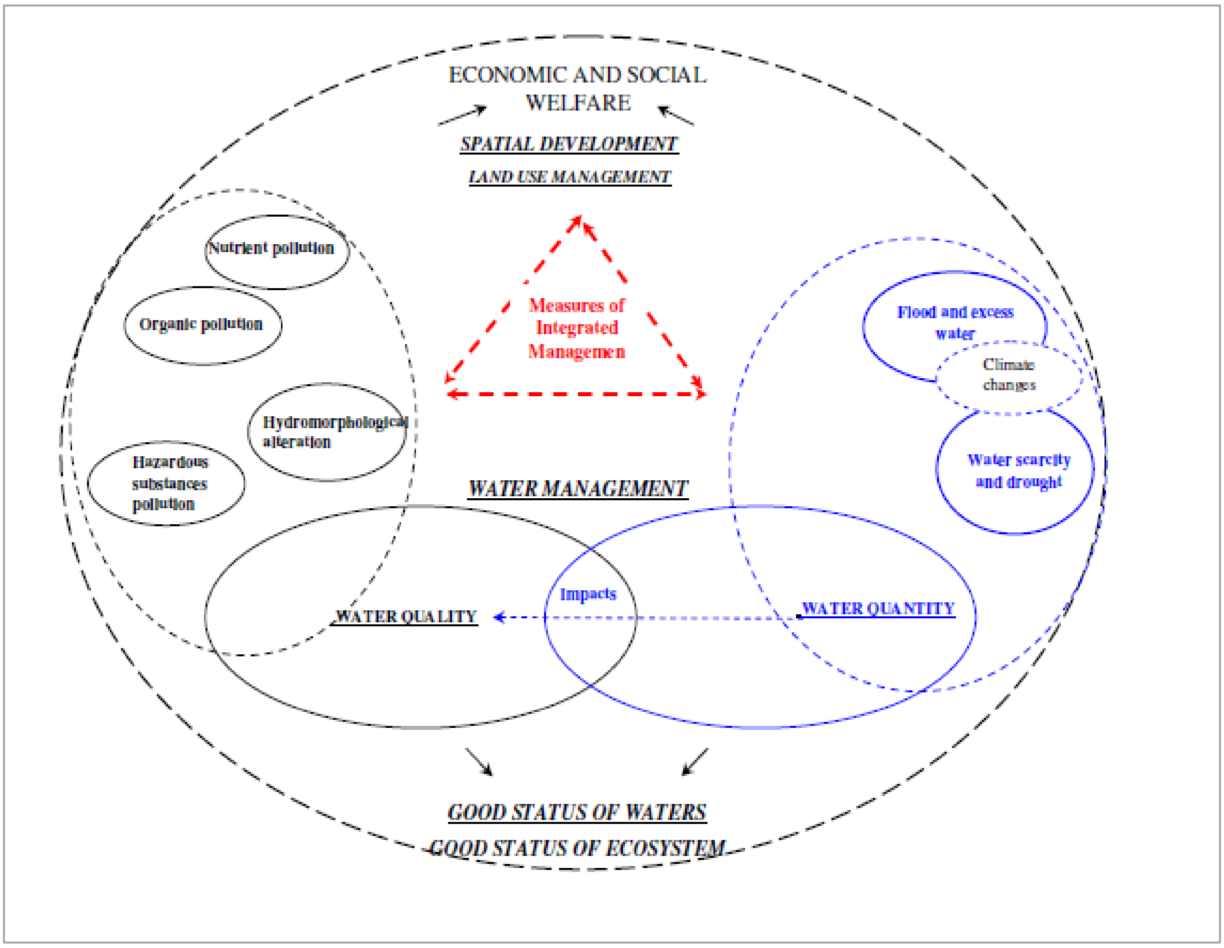


Figure IV.5: ICPDR TG identified Interlinkages between the water quality and water quantity related issue within the TRB (Source: 1st ITRBMP, 2011)

4.2.2 DPSIR Framework

The European Environment Agency (EEA) proposed the use of a framework for describing the interactions between society and the environment, distinguishing driving forces, pressures, states, impacts and responses, known as the DPSIR framework; it has been widely adopted by the EEA, acting as an integrated approach to reporting, e.g. in the EEA's State of the Environment Reports. The Driver-Pressure-State-Impact-Response (DPSIR) Framework provides a structure for the required indicators to enable feedback to decision makers on environmental quality and on the resulting impact of the choices made or to be made in the future (Kristensen, 2004). Figure IV.6 depicts the DPSIR framework overview with causal flows and lines of influence between the driving forces, pressures, states and impacts on ecosystems, human health and functions.

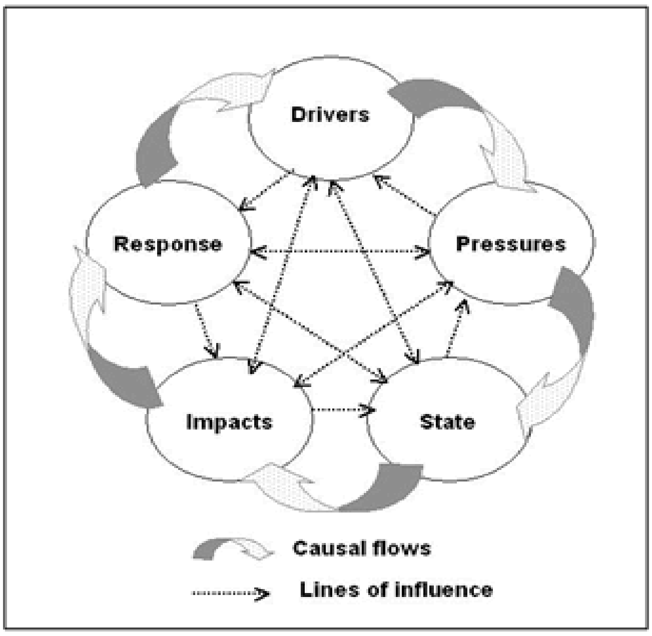


Figure IV.6 DPSIR framework schematic overview. Source (Kristensen P., 2004)

Establishing the DPSIR framework for a particular setting is a complex task as all the various cause-effect relationships have to be carefully described and environmental changes can rarely be attributed to a single cause. When it comes to the River Basin Management Planning (RBMP) at the transboundary level, application of the DPSIR framework is even more challenging, given the RBMP complexity, diversity among the riparian countries, different priorities at the country level, etc. Given the diversity of the TRB, uneven distribution of precipitation and runoff, etc., as well as the visions and management objectives identified in the Integrated Tisza River Basin Management Plan (ITRBM) that reflect the joint approach among all Tisza Basin countries and support the achievement of the EU Water Framework Directive (WFD) and EU Floods Directives objectives, there is a ground for the application of the DPSIR framework in addressing hydrology, water quantity specific issues and measures that contribute to the TRB resilience to water quantity issues.

With respect to the above, the DPSIR framework for the TRB water management and water quantity issues that will overcome challenges due to the CC requires identification of the **driving forces** (what causes the pressures, e.g. irrigation, industry, urban land development, land use changes), **pressures** (e.g., climate change, floods and excess water, droughts and water scarcity), **state** (water quantity, surface and groundwater status, etc.), **impacts** (increase in water demand by different users and flood risks, loss of biodiversity, adverse effects on water status) and **responses** (measures, guidelines, policy measures, etc.).

As a response to the CC and water quantity issues, a number of transboundary and national projects (as mentioned in Chapter 2 (The full list of projects and studies is available in the D 4.2.1, D 4.3.3, and D 5.1.2), strategies, and studies have been developed to comprehensively evaluate the CC impacts on water resources management and to address measures that contribute to the CC adaptation.

In addition to the CC adverse impacts within the TRB on floods and droughts, analyses and comparison between present water use and future water demand (by 2021) for selected indicators (JOINTISZA deliverable 4.2.1), i.e., the value of 1,409.84 Mm^3, regardless of the source of water, is significantly lower than the water demand planned by the end of the next planning period of 2,585.67 Mm^3, e.g., at approximately 54 %. Additional pressures that should not be neglected are the so-called priority pressures and resulting impacts (ITRBMP) linked with floods and excess water and droughts and water scarcity. For floods the following pressures apply:

- Hydro-morphological alteration due to flood protection measures
- Accidental pollution due to floods
- Disconnection of adjacent wetlands/floodplains
- Solid waste

In addressing drought and water scarcity, the following priority pressures should be considered:

- Groundwater over abstraction
- Increased irrigation and related surface water abstraction

4.3 Adaptation measures relevant to water quantity and CC within the TRB

The measures proposed for adaptation to climate change for water quantity issues are in line with visions and management objectives relevant to water quantity within the TRB (ITRBMP, 2011). In addition, these measures are in line with the TRB countries national policies and legal framework.

4.3.1 Flood protection measures

IV.1 Flood risk management proposed measures in the Tisza River Basin

Field of action	Measure category	Type of measure	Countries				
			RO	SK	HU	RS	UK
Prevention	Organizational measures (legislative, institutional ...)	The definition of a legislative, organizational and technical framework for the Floods Directive implementation	x	x	x	x	x
		Reviewing and updating plans for flood risk management	x	x	x	x	x
		Coordination of territorial planning strategies (plans for development of planning at national, county and regional level) and urban plans (Regional/Urban/Zonal/Plans) with plans for flood risk management	x	x	x	x	x

Protection	Natural water retention measures – associated to watercourses, wetlands, natural lakes, in accordance with the Directive 2000/60 /EC	Measures to restore retention areas (flood plains, wetlands, etc.)	x	x	x	x	-
	Change or adapt land use practices (partial recovery of ecosystem functions or structures modified by changing or adapting land use practices) in urban areas	Natural water retention measures in urban areas	-	-	-	x	-
	Change or adapt land use practices (partial recovery of ecosystem functions or structures modified by changing or adapting land use practices) for forest management	Natural water retention measures by changing or adapting land use practices in forest management	x	-	-	-	-
	Other water retention measures	Other measures to reduce water levels	x	-	x	x	-
		Measures to improve retention capacity at the river basin level by a construction of polders and small retention reservoirs (made in the upper part of the river basin)	x	x	x	x	x
		Measures to improve retention capacity at the river basin level by increasing the safety of existing large dams / increasing the attenuation capacity of reservoirs towards the projected capacity	x	x	-	-	x
		Structural protection measures (planning and accomplishing)	x	x	-	-	x
	Measures for increasing population resilience	Measures for increasing resilience of population (Implementation and adaptation of protection measures at multiple objectives – buildings, constructions)	-	x	-	-	-
Protection	Inspection measures and maintenance of watercourses and of the hydraulic flood defence infrastructure	Surveillance, behaviour monitoring, expertise, strengthening interventions, rehabilitation and maintenance of watercourses and hydraulic flood defence infrastructure	x	x	x	x	x
	Adapting of the existing defence structures to climate change conditions	Adaptation of the construction, infrastructure and existing defence structures in terms of climate change	x	x	-	-	-
Public awareness	Measures to increase community awareness	Activities regarding adequate public information and promotion of the public participation	x	x	-	x	x
		Education / training activities of the population	x	x	-	x	x
Preparedness	Preparedness measures /Improvement of preparedness to reduce the adverse effects of floods	Measures for monitoring, forecasting and flood warning	x	x	x	x	x
		Development / reviewing of the flood defence plans in correlation with other emergency situation management plans (GIES- General Inspectorate for Emergency Situations)	x	x	-	x	-

		Simulation exercise activities involving interinstitutional parties	-	x	-	x	x
		Providing personnel, funding and materials needed in emergency situations and stimulation of voluntary actions	-	x	-	x	x
Response and Recovery/ Reconstruction	Post-event recovery measures	Response actions in case of emergency situations	-	x	-	x	x
		Damage assessment and restoration	-	x	-	x	x
		Documentation and Analysis	-	x	-	x	x

Common synergies of the proposed measures

Analysing the measures proposed by each Tisza country, it is noticeable that there is already a common thinking to reduce the flood risk and to increase the level of population protection. Thus, they aim to reach the following common goals:

- increase the storage of capacity in the Tisza river basin – by creating polders and small retention reservoirs made in the upper part of the tributary river basin, increasing the safety of existing large dams and increasing the attenuation capacity of reservoirs towards projected capacity in the upper Tisza river basin,
- involve the public in elaboration of different plans,
- increase the degree of monitoring, forecasting and flood warning, etc.

Also, the potential measures proposed by each country have taken into account the link with the EUSDR targets[16] that have been validated at the meeting of National Coordinators and Priority Area Coordinators held in Bratislava on 23 May 2016. These measures contribute to the achievement of the EUSDR targets, but due to the fact that the present document is a report dedicated to potential measures that will contribute to flood risk mitigation at the Tisza river basin level, not all of the targets can benefit from the proposed measures and the link between them is presented in the table below (Table VII.2.).

Table IV.2: Link between the proposed measures for flood risk management and EUSDR targets

Priority Area of EUSDR	Targets of EUSDR	Field of action	Type of measure for flood risk management
Priority Area 5 "To manage environmental risks"	Provide and enhance continuous support to the implementation of the Danube Flood Risk Management Plan – adopted in 2015 in line with the EU Floods Directive – to achieve significant reductions of flood risk events by 2021, also taking into account potential impacts of climate change and adaption strategies	Prevention	The definition of a legislative, organizational and technical framework for the Floods Directive implementation
			Reviewing and updating plans for flood risk management
Priority Area 6 "To preserve biodiversity, landscapes and quality of air and soils"	Enhance the work on establishing green infrastructure and the process of restoration of at least 15% of the degraded ecosystems, including soil, in order to maintain and enhance ecosystems and their services by 2020 in the Danube Region and to improve air quality	Protection	Measures to restore retention areas (flood plains, wetlands, etc.)
			Natural water retention measures in urban areas
			Natural water retention measures by changing or adapting land use practices in forest management
			Other measures to reduce water levels
			Measures to improve retention capacity at the river basin level by creating polders and small retention reservoirs (made in the upper part of the river basin)

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[16] http://www.danube-region.eu/about/our-targets

Priority Area of EUSDR	Targets of EUSDR	Field of action	Type of measure for flood risk management
			Measures to improve retention capacity at the river basin level by increasing the safety of existing large dams / increasing the attenuation capacity of reservoirs towards the projected capacity
Priority Area 9 "To invest in people and skills"	Contribution to ensuring inclusive education, training and promoting inclusive labour markets, equal opportunities and non-discrimination as well as the promotion of civic competences and lifelong learning opportunities for all	Protection	Education / training activities of the population
	Contribution to an increased quality and efficiency of education, training and labour market systems	Protection	Providing personnel, funding and materials needed in emergency situations and stimulating the voluntary actions
Priority Area 10 "To step up institutional capacity and cooperation"	The UPDR helps generate, through the exchange of information and support, at all levels of cooperation, for 25% of the UPDR stakeholder organisations, at least one Urban Danube Project, furthering the aim of better spending	Protection	Development / reviewing of the flood defence plans in correlation with other emergency situation management plans (GIES- General Inspectorate for Emergency Situations)

4.3.2 Draught and water scarcity measures

There is an indication that current water use in the Tisza Basin will increase in the near future, with a very significant increase in water use for irrigation. However, there is a need for better knowledge of the spatial distribution of water use and future demands relevant to the Tisza River Basin. One element is the establishment of common indices to define droughts and to get a better insight of water scarcity across the Tisza Basin.

Table IV.3: TRB Drought and water scarcity measures implementation

Title of a proposed measure	Status of the measures estimated towards the end of 2021				
	UA	**RO**	**SK**	**HU**	**RS**
Establishment of common indices to define droughts and to get a better insight of water scarcity across the Tisza Basin	**NS**	**IG**	**IG**	**IG**	**IG**
Maps with water scarce areas identified for the Tisza Basin.	**NS**	**CO**	**IG**	**IG**	**NS**
Collection of more precise information on irrigation and groundwater depletion is needed for the future uses.	**PG**	**CO**	**CO**	**IG, CO**	**IG**
Changes in agricultural practices	**PG**	**CO**	**IG**	**IG**	**PG**
Reduction of leakage rates	**PG**	**IG**	**NS**	**IG**	**NS**
Improving irrigation efficiency	**PG**	**IG**		**IG**	**PG**
Development of an agreed-upon groundwater model to assess depletion	**NS**	**N/A**	**N/A**	**N/A**	**NS**

Title of a proposed measure	Status of the measures estimated towards the end of 2021				
	UA	RO	SK	HU	RS
Coordinated approach to water allocation and application of economic incentives or tools such as water pricing	PG	CO	CO	IG	PG
Overview of the methodologies used for establishing minimum national ecological flows to be prepared (to lead to an agreement on comparable limits and approaches to managing low-flow situations)	NS	CO	IG	IG	PG
Establishment of comparable national approaches to monitor and report groundwater abstraction to ensure better management and regulation of groundwater resources	NS	CO	CO	CO	IG
Any other					IG

For drought and water scarcity measures, the criteria for their implementation is based on an approach agreed by the EU Water Directors, i.e., **NS** (not started), **PG** (planning ongoing), **OG** (ongoing) and **CO** (completed) for different types of measures.

4.3.3 Climate Change measures

Based on the ICPDR Climate Change Adaptation Strategy (2012, 2018), climate change is scientifically confirmed worldwide, *inter alia*, by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[1]. Despite ambitious international climate protection objectives and activities, adaptation to climate change impacts is urgently needed. Water, together with temperature, is in the centre of the expected changes. Due to the fact that water is a cross-cutting issue with major relevance for different sectors, water is key to taking the required adaptation steps. In the Danube River Basin, climate change is likely to cause significant impacts on water resources and can develop into a significant threat if a reduction of greenhouse gas emissions is not complemented by climate adaptation measures. There are no studies that address the whole TRB level. The framework for the CC adaptation integration in the Danube River Basin Management Plans and Integrated Tisza River Basin Management Plans, are the EU WFD (and its daughter directives) and the EU Floods Directive (2007/60/EC). However, other policies such as the Water Scarcity and Droughts EU Policy and the EC's White Paper on Adaptation are important building blocks for adaptation. A short overview of the CC adaptation measures provided by the Tisza countries is presented below. The measures that include strategies, action plans and other relevant issues are elaborated in Chapter 2 herein.

Romania

The strategies and action plan include adaptation orientation and type of measures on water sector at the national, regional and local level, such as:

- Re-assessment of water resources for all river basins and sub-basins in the context of climate changes:
    - Increasing the multi-annual regulating capacity of the river basins;
    - Limitation of the groundwater uses to water supply for households in the zones where the over-exploitations of ground waters can lead to high drying up of the aquifers;

- Increasing the water use efficiency in agriculture and implementation of technological measures for crop adaptation to drought and water scarcity;
- Optimizing the land use management;
- Extending the national forests fund (including forest buffers) and afforestation of the ve rsants against propagation of the floods;
- Reduction of the leakages in the drinking water distribution network and in the sewage network (from 50 % to 20 % in 2025) by developing and regionalizing the drinking water supply and sewerage systems, rehabilitation and re-design of the water and waste-water infrastructures;
- Planning of the activities at local and regional level in order to cope with the periods of heat waves, etc.;
- Promoting the integrated informational system on climate change adaptation;
- Development of the specific researches on climate change adaptation as a technical support for decision planning.

In the National Action Plan to implement the National Strategy on Climate Change 2016-2020, the prioritization of the adaptation and mitigation measures included in the National Strategy of Climate Change was done according to the analysis of the benefits, costs and associated risks. Thus, the priority mitigation actions focus on planning and implementation of the measures to reduce greenhouse gases from the water and wastewaters sectors and on increasing the energetic efficiency of the systems. Also, the priority adaptation actions are oriented towards the reduction of flood risk and water scarcity.

Slovakia

Adaptation planned in the field of water management includes the following:

- for floods – measures to: reduce runoff from the river basin, reduce the maximum flood discharge, risk assessment;
- for droughts – measures for reasonable use of water resources;
- monitoring.

Hungary

The second National Climate Change Strategy contains, among others, the National Adaptation Strategy, which aims to reduce risks related to climate change and climate security, to mitigate damages and to present potential awareness-raising activities concerning climate change preparation and adaptation.
Water-related action lines in the Strategy:

- Short-term: water retention measures, actions resulted from the WFD, review of land use, water-saving irrigation and water uses, reduction of flash flood risk, in-depth analyses of a changing water regime and hydrology, risk mapping of flooding, waste water management, development of adaptation measures, indicator systems;
- Mid-term: water retention in water management, flood plain landscape management, navigation under a changing climate, prediction of water demands, developing monitoring systems, reaching good qualitative and quantitative status of waters;
- Long-term: full integration of the CC-adjusted water management in international cooperation and foreign policy.

Serbia

Climate change measures relevant to water sector included in the Second National Communication, Table 6.8 (Submitted on the ICPDR Danubius, December 2016) are based on vulnerability assessment. The proposed measures are divided into the following four main categories:

- *Risk reduction* –more specific groups of adaptation measures that address water use measures (e.g., application of best available techniques in irrigation and cooperation with upstream countries - bilateral commissions, ICPDR, etc., with respect to water quantity), water quality (e.g., best available techniques applied to diffuse sources of pollution that mainly originate from the agriculture), protection against the adverse effects of water (e.g. the development of flood protection plans for international rivers and large river basins – Danube, Tisza, etc.) and multipurpose measures (e.g. an increase in water storage capacity);

- ***Policy and legal framework*** (e.g., water management strategy, RBMPs, other planning documents);
- ***Monitoring and research*** (e.g., improving monitoring and other non-structural measures to combat droughts, etc.); and
- ***Capacity building and public awareness*** (e.g., improvement of coordination/harmonized activities of institutions and organizations in charge at a local, regional and national level, etc.).

For all proposed adaptation measures, the classes are assigned in the following way:

- No regrets – NR;
- Low regrets – LR; and
- Techno-economic analyses required – TEAR.

In relation to the time required for implementation. the measures are classified based on the following criteria:

- Short term-ST;
- Medium term-MT;
- Long term-LT; and
- Continuous long term – CLT.

4.3.4 Horizontal measures

The horizontal measures relevant to the TRB are reported, based on the following categories:

- **International coordination**: ICPDR -Egs, further engagement with bilateral commissions addressing water management in the Tisza River Basin, etc.;
- **Incentives:** Development of appropriate long-term compensation schemes for land owners in the event that their land is used for wider water management purposes, such as flood protection, improving natural values, water retention;
- **Communication and consultation:** To identify measures that integrate different objectives and benefits, it is necessary that the relevant competent authorities work together from the early stages of development onwards. Therefore, inter-ministerial (and/or inter-sectorial) committees or work groups could be established that prepare decisions and coordinate implementation.
- **Any other**

Table IV.4: TRB Drought and water scarcity measures implementation

Title of a proposed measure	Status of the measures estimated towards the end of 2021				
	UA	RO	SK	HU	RS
International coordination	IG	CO	IG	IG	IG
Incentives	NS	CO	NS	PG, IG CO *	NS

Title of a proposed measure	Status of the measures estimated towards the end of 2021				
	UA	RO	SK	HU	RS
Communication and consultation	PG	CO	IG	IG	PG

4.3.4 Groundwater quantity measures

Available groundwater resources must not be exceeded by the long-term annual average rate of abstraction to maintain good quantitative status according to the WFD Annex V (2). Furthermore, any damage to groundwater-dependent terrestrial ecosystems must be prevented. According to the Water Framework Directive (ANNEX VI, Part A and Part B), the measures to be included within the programmes of measures for groundwater are basic measures (BM), supplementary measures (SM) and other basic measures (OBM). Slow and insufficiently recharging deep aquifers in some parts of the Tisza River Basin, followed by several decades of intensive public water supply, have resulted in over-abstraction. Sustainable solutions for future water supplies in such cases include measures to investigate alternative water sources.

Table IV.5: TRB summary measures for groundwater quantity

Country	0BM		BM+SM		OBM+SM		BM+OBM+SM		No measures	
Year	2010	2017	2010	2017	2010	2017	2010	2017	2010	2017
Ukraine	-	-	-	-	-	-	-	-	9	9
Romania	-	-	-	-	-	-	-	11	11	0
Slovakia	-	-	-	-	-	-	-	-	7	8
Hungary	1	26	-	-	7	19	4	2	32	4
Serbia	-	-	7	7	-	-	-	-	7	7

5. Tools for Stakeholder Engagement to Enhance River Basin Management and Climate Change Adaptation

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5.1 Introduction

Clear signals from the scientific community show that river basin management planning will require adaptive approaches to cope with climate change. In this process, stakeholders will be important actors. The notion of "**stakeholder**" in general refers to affected and interested individuals, groups and organizations, both public and private[17]. Stakeholders can provide information on climate change impacts and adaptations; they can also assess the viability of the proposed adaptive measures.

Engagement (sometimes called "stakeholder participation") means opening up official organizational processes to include relevant and interested stakeholders to take part in decision-making and problem solving[18].

Most agree that stakeholder involvement in the planning processes is highly beneficial. What remains unclear is how effectively the measures that needed to be adopted could be communicated and understood by the stakeholders[19]. The stakeholder involvement in water resource planning is complex and includes diverse fields such as economics, agriculture, public health, pollution prevention, business and education. Several scholars expressed a dilemma that for the water sector, the issue of stakeholder involvement is "either a necessity for sustainable water management, or a luxury to be used to complement traditional approaches"[20].
The stakeholder involvement is not "just another step" in the river basin management planning process. It is highly unlikely that any plan can be implemented successfully if it does not meet public acceptance and if it is not supported by key stakeholder groups.

This chapter deals with the description of the purpose and tools of stakeholders' involvement. It responds to the questions of why, how and when to involve the stakeholders.

5.2 Stakeholder involvement justification

Two basic European Union directives set out the **legal and policy framework** for the information and involvement of the stakeholders and the public in the development of river basin plans: The Water Framework Directive (WFD) (Directive 2000/60/EC) and the Floods Directive (Directive 2007/60/EC).

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[17] EC (2003): Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No 8

[18] EC (2008): Water Note 12. A Common Task: Public Participation in River Basin Management Planning

[19] Kankaanpää, S., Carter, T.R. and Liski, J. (2005). Stakeholder perceptions of climate change and the need to adapt. FINADAPT Working Paper 14, Finnish Environment Institute Mimeographs 344, Helsinki, 36 pp.

[20] Morrison, K. (2003): Stakeholder involvement in water management: necessity or luxury? Water Sci Technol. 2003;47(6):43-51.

Specifically, the Article 14 of the WFD determines that the EU Member States shall encourage active involvement of all interested parties in the implementation of the Directive and development of river basin management plans. The Floods Directive also uses the terms "active involvement of all interested parties" along with similar other terms in the WFD. In Article 9.3 the FD requires a coordination of the active involvement process under the Floods Directive, with active involvement of interested parties under the Article 14 of the WFD.

The Tisza River Basin countries are parties to various international agreements, such as the UNECE Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention)[21], the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki Convention)[22]. The Tisza River Basin countries have also signed the Convention on Co-operation for the Protection and Sustainable Use of the River Danube (Danube River Protection Convention), which forms the overall legal instrument for cooperation and transboundary water management in the Danube River Basin.

International commitments were translated into the national legislations of all Tisza River Basin countries. Even though the EU water-related legislation is legally binding for the EU Member States, the non-EU countries sharing the Tisza and Danube River Basins (Ukraine and Serbia) agreed to make all efforts to implement the EU WFD and the WU FD[23].

The **JOINTISZA project** highlights the stakeholder involvement; the partners committed to "*ensure better embedding of flood risk management planning into the RBM planning process, and to encourage the involvement of relevant sectors (such as flood risk management, water resource management, urban hydrology management, drought management) and interested stakeholders*"[24].

In the context of the Activity 6.5, the JOINTISZA project partners agreed to conduct activities that will identify who, when and how to involve in the preparation of the updated International Tisza River Basin Management Plan (ITRBM Plan). The Output 6.3 "Public Involvement and Participation Strategy" was elaborated to guide the project partners to the following:

- to identify key stakeholders using the Stakeholder Analysis methodology,
- to set up the plan of participation processes, and
- to select tools and techniques for the participation.

While there is some experience in stakeholder engagement in river basin planning in general (the start of public participation in the 1st cycle of the river basin planning according to the EU WFD was launched in 2006), there are **specific reasons** to engage with stakeholders for "planning for adaptation". Decision-making in a changing climate requires new areas of expertise and wider consultation than might typically be involved in traditional "decision-making". The reasons of carefully planning and conducting the stakeholder

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[21] The UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention) adopted on 25 June 1998, entered into force on 30 October 2001.

[22] The UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki Convention), adopted on 17 March 1992, entered into force on 6 October 1996.

[23] ICPDR (2015). Danube River Basin District Management Plan – update 2015

[24] Application Form JOINTISZA (DTP1-1-152-2.1) Interreg project

engagement include both the cross-sectoral nature of climate change impacts and the uncertainty regarding the level of climate change and climate variability. Climate change requires decision-making authorities, societies and communities to change (adapt), sometimes quickly, with widening extremes of weather, greater variability in climate patterns and long-term changes in the local setting.

There are several features of climate change that make it difficult for people to connect with or respond to. These features present substantial challenges that engagement processes will have to overcome, and include the following[25]:

- Climate change is a “global” problem, with negative impacts that will occur many years in the future, often in distant locations rather than locally (substantial scepticism);
- Lack of understanding of climate change projections;
- Adaptation to the potential impacts of climate change requires a strong focus on long-term, “strategic” thinking, and many people, groups and businesses tend to use much shorter planning horizons and more “tactical” responses;
- Stakeholders may not feel personally responsible for climate change and/or they may expect outside agencies and other stakeholders (typically other countries or the government) to take responsibility for a solution.

A variety of benefits of engaging stakeholders is often a topic for both academia and project leaders. Facilitating clear communication and exchange of information, with all parties involved, will bring a better **understanding of issues**, potential solutions and alternative perspectives. By gaining better insight into potential outcomes, solutions to conflicts will improve the **effectiveness of decision-making processes.**

In general, it is anticipated that stakeholder involvement will increase the **quality of decisions** and their acceptance amongst stakeholders. The report on the Public Involvement and Participation Strategy (Outcome 6.3 of the JOINTISZA project) highlighted numerous benefits of stakeholder involvement as indicated in *Table V.1.*

Table V.1: Benefits of stakeholder involvement and public participation (adapted from Outcome 6.3)

Benefits for decision-makers	Benefits for stakeholders and the public
- *Improving credibility within the community and gaining their support for the decisions;* - Gaining new (local) knowledge, obtaining information and data; - *Better understanding of expectations;* - *Improving* decisions by perceiving *a broader range of perspectives and opinions;*	- Better understanding of the decision-makers’ responsibilities and plans; - Opportunity to inform the decision-makers on local conditions and issues of concern; - Better understanding and acceptance of decisions when concerns of the public were considered;

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[25] Gardner, J, Dowd, A-M., Mason, C. and Ashworth, P. (2009). A framework for stakeholder engagement on climate adaptation. CSIRO Climate Adaptation Flagship Working paper No.3. http://www.csiro.au/resources/CAF-working-papers.html

- Better *outcomes* – plans and their implementation as the community contributed to *identifying problems, alternatives and solutions.*	- Improvement of local conditions by implementing outcomes – plans which considered local knowledge; - Gaining knowledge and skills that may be used in solving other community issues.

Participation can lead to – but does not directly result in – **accountability**. Participation can increase transparency and make clear to stakeholders the lines of decision-making, but on its own it cannot guarantee that officials hold themselves accountable to the decisions they make.

This list of benefits seems compelling; however, the use of engagement is by no means a norm in decision-making processes. Particularly important are the facts that engagement requires a lot of time, resources (both human and financial) and skills. It also means to give up a degree of control to people beyond the instigating group or organization, which can threaten the adoption of a preferred outcome.

Engagement processes are unlikely to be able to change pre-existing values or to generate social influence; at a minimum, they may be able to increase awareness of existing expectations of interested parties. It is important to note that a fundamental precondition of all engagement is a level of willingness to be involved amongst the stakeholders[26].

5.3 Specific issues for climate-related engagement in the Tisza River basin

The stakeholder involvement in the framework of the JOINTISZA project started from the beginning of the project in 2017. The project partners organized the training and numerous follow-up national consultations to assess the Joint program of measures (draft) with a specific consideration of climate change impacts.

The stakeholder involvement activities included

- 15 stakeholder group meetings;
- 11 individual interviews with more than 400 stakeholders participating in these events basin-wide;
- Dissemination of materials and presentations about the relevant significant water management issues of the Tisza River and the 1st ITRBM Plan;
- more than 500 stakeholders in two countries (Hungary and Romania) were targeted with online questionnaires;
- more than 200 active stakeholders expressed their willingness to contribute to further steps.

In general, four methods were used: group meetings for stakeholders, face-to-face meetings (interviews), online questionnaires and mass emails.

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[26] Moser, S. C. 2007. More bad news: The risk of neglecting emotional responses to climate change information. (pp. 64-80). In: Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change. Eds. S.C. Moser and L. Dilling, Cambridge: Cambridge University Press.

Table V.2: Types of methods of stakeholder involvement in the Tisza River Basin countries (in the period of June 2017 – October 2018)

Country	SH method used
Hungary	SH group meetings, face-to-face meetings, mass email
Romania	Online questionnaire
Serbia	SH group meeting, fa-to-face meetings, online questionnaire
Slovakia	SH group meetings, online questionnaire
Ukraine	SH group meetings, online questionnaire

Based upon a feedback from national consultations, the stakeholders have listed all significant water management issues (SWMI) as defined in the 1st ITRBM Plan. In addition, a few new SWMIs were identified.

The summary of priority issues tested in consultation processes for the development of the ITRBM Plan update includes:

- organic pollution,
- nutrients,
- hazardous substances, and
- hydro-morphological alterations
- quality of groundwater
- quantity of groundwater
- climate change impacts including floods, drought and water scarcity

Some other issues included

- plastic waste
- biodiversity and ecosystem protection
- lakes management
- need for better cooperation among different economic sectors at the national level
- enhancement of an international cooperation among countries sharing the Tisza River Basin.

Stakeholders also identified the issues relevant to climate change impacts. Some of the issues overlap with the issues defined in the 1st ITRBM Plan (and in the draft of the updated ITRBM Plan). The priorities taking into account climate change adaptation include

- flood management
- water supply and demand by each and every water user group (agriculture, industry, households)
- drought and water scarcity
- water quality (both ground and surface water)
- soil erosion/sedimentation
- forest management favourable to water resources protection
- biodiversity and ecosystem

- water related energy generation
- navigation
- human health aspects
- water temperature.

Based upon the consultation conclusions, the stakeholders agreed that river basin management planning itself is an "adaptation" measure. In other words, adaptation measures are seldom undertaken in response to climate change alone.

5.4 Groups of stakeholders

The first step in facilitating the stakeholder involvement process is to identify all potential stakeholders. It does not mean that all stakeholders are to be involved in everything all the time. Methods suggest identifying primary and secondary stakeholders[27]. **Primary stakeholders** are affected either positively or negatively by the project/decision. **Secondary stakeholders** generally include governmental, non-governmental and private sector institutions; however, this can vary depending on the subject matter being consulted. It is important to indicate which stakeholders will be beneficiaries and which will be negatively affected. This helps gauge which parties will support the project as advocates and which may impede the project, acting as opponents. A typology of possible stakeholders according to the EU Common Implementation Strategy[1] is shown in Table 3.

Table V.3: Typology of stakeholders

Stakeholders	Examples
Professionals	Public and private sector organizations, professional voluntary groups and professional NGOs (social, economic and environmental). This also includes statutory agencies, conservation groups, business, industry, insurance groups and academia.
Authorities and elected people	Government departments, statutory agencies, municipalities, local authorities
Local Groups	Non-professional-organized entities operating at a local level, usually breaking down into the following: - Communities centred on place – attachment centred on place, which includes groups like residents' associations and local councils. - Communities centred on interest – e.g. farmers' groups, fishermen, birdwatchers.
Individuals	Individual citizens, farmers and companies representing themselves. Key individual landowners or local individual residents.

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[27] GWP (2015): IWRM ToolBox Teaching Manual

5.5 Meaningful stakeholder engagement

When working with a large group of stakeholders, it is important to facilitate **strong communication channels** and appoint trustworthy moderators. Through these channels, moderators can encourage consensus building in order to resolve a difference in opinions, and conflict management when appropriate in order to reach a compromise between the stakeholders. One communication tool to avoid disputes over water resources is a shared vision planning, which facilitates communication throughout a project or decision-making process. Shared vision planning combines traditional water resource planning approaches with public participation and collaborative computer modelling in order to identify problems, determine objectives and criteria for evaluation, and analyse trade-offs between alternative options[28].

It should be noted that there is a difference between stakeholder participation and conflict management. Participation is driven by articulation of interests and access, but this can increase as well as reduce the level of conflict. Conflict management is driven by the aggregation of interests and refers to the suite of tools available to deal with conflicts over interests and values. Both concepts may, however, use similar techniques at different times.

Meaningful stakeholder involvement is about clarifying the purpose of the involvement. The purpose of the involvement will help to develop an involvement strategy. The following table summarizes different purposes and respective strategies of involving stakeholders.

Table V.4: Aims and related strategies of involving stakeholders

Reason to involve	**Involvement strategy**
Can a stakeholder contribute to decision – making?	Involvement to improve the quality of plans and projects
Is a stakeholder needed for implementation?	Involvement to improve implementation of plans
Can a stakeholder block decision – making or implementation?	Involvement to prevent litigation and delays
Is Involvement legally required?	Involvement to meet legal requirements

The following table highlights **steps in wise stakeholders' engagement**

Table V.5: Steps in stakeholder engagement

Step	What
Prior to engagement	- Clarifying what is necessary to achieve from the engagement process. - Ensure adequate and realistic funding (or co-funding) for engagement is available - Define the stakeholders

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[28] GWP (2017) Collaborative Modelling – engaging stakeholders in solving complex problems of water management

	- Stakeholders mapping and analysis ○ assessment of interests ○ assessment of influence and importance
Engagement process	- Time consuming phase that requires adequate financial backup - Essential role of a team that is in charge to run a participation process
Follow up and evaluation	- As a minimum, all stakeholders should have an access to the final decisions made

Whatever method of the stakeholder engagement is used (ranging from one-to-one consultation, newsletters, open houses, seminars, training, study tours to interactive web portal) it is necessary to ensure the following[29]:

- **Appropriateness** of information provided; information must be applicable to the type of problem and technical ability of the stakeholder. If capacity is lacking, special efforts will be needed to facilitate information exchange
- **Accessibility;** building on the current capacity of stakeholders rather than requiring major upgrades in individual and institutional or technical ability
- **Equity**: information exchange must respect cultural needs and should not discriminate specific stakeholders

In addition, **adaptation planning** itself requires a capacity for strategic planning, which is not present in all groups. Groups with previous experience in strategic planning and those with a longer planning horizon are more likely to be willing to apply this experience in adaptation planning. Where groups do not have such an experience, part of the engagement process will require a development of this capacity.

The most important **lessons learned** during the national stakeholders` involvement conducted under the JOINTISZA project are as follows (Deliverable 6.5.2 report of the JOINTISZA project):

- During the consultations it became clear, that the 1st ITRBMP is generally not known by the stakeholders. One reason for that is a language barrier (the full version is only available in English) and the other might be a relative novelty of the Plan (known only since 2010-2011) compared to other Plans and Directives;
- Some sectors were contacted and involved, however, they have sent no significant comments so far: industry and chambers in Hungary, agriculture, aquaculture, industry in Slovakia, forestry in Ukraine;
- It is easier to reach governmental institutions then private ones; the water management sector dominates;
- Personal or sectoral connections are highly important: without these it is difficult to effectively reach some stakeholders;
- Some stakeholders are already overloaded with different consultations from different projects, while others face this opportunity for the very first time (e.g. Ukraine);
- The „quality" of the comments is mixed, many of those focus on local issues or have not searched for exact connections with the existing ITRBMP;
- Many stakeholders proposed to have more detailed or exact comments after they would receive new drafts of the plan or its elements. On the other hand, it took time to make them understood

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[29] GWP (2006): Sharing knowledge for equitable, efficient and sustainable water resources management; IWRM ToolBox, Version 2

that during the preparation phase, gathering their inputs is useful and their inputs will be considered during the compilation of the 1st draft of the 2nd ITRMP

- There is a need to focus on the stakeholders' role in the implementation of the Plan in the future („not only blaming water sector or others") – however, it is very important to build partnerships.

5.6 Tools relevant to the Tisza River Basin planning

Stakeholder participation can employ a broad range of participatory tools at various stages of the decision-making process. Each format is suited differently to disseminating information, gathering information and making decisions. Additionally, many formats are appropriate only for a particular scale of participation.

Stakeholders in a **trans-boundary basin** – the Tisza River Basin is the case, belong to different countries with national legislations governing the water management. But these countries share a resource – and this sharing can be expressed through similar activities (agriculture, fishing, tourism) or by the same sensitivity to risk and phenomena (drought and water scarcity, floods, impacts of dams, pollution or invasive species). One of the main difficulties in relation to the scale of a trans-boundary basin is obtaining a true representativeness of the stakeholders.

One solution is to identify representatives by theme (agriculture, fishery, drinking water supply and sanitation, environment, dams, etc.), while making sure that each country is represented. The representatives' legitimacy should also be gained and accepted. Cultural aspects should not be overlooked in this kind of approach and can provide enabling conditions for participation.

Another difficulty is the need to move up and down from the local level, through the national level to the international basin level. The solution is to establish a cooperation mechanism – that exists at the ICPDR level with the Tisza Group. In 2004, The Tisza Group has been established by the ICPDR and it is a good foundation for strengthening coordination and information exchange related to international, regional and national activities[30].

Tools to be applied for the RBMP in general (or for individual projects) are summarized below.

Consultation

- Written consultation, people (representing organizations) are asked to comment in writing on the proposed analysis or measures. The EU WFD directive requires such commenting process to be employed at each stage of a planning cycle.
- Oral or active consultation, people are invited to meetings and workshops with designated topics and issues to be presented and consulted. There are several obstacles in this type of consultation:
- Invited people are not prepared (or do not have a mandate from the organization) to present statements
- Consultation is dominated by a few loud speakers that might even not be "primary" stakeholders
- Purpose of the meeting/workshop is not well defined - "how, who, when to solve the issue"; it is rather a generic workshop on "what is the problem".

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[30] ICPDR (2004): Tisza Memorandum of Understanding; Strengthening the Tisza River Basin Cooperation

Active consultation – workshops, seminars, meetings – are an excellent opportunity to bring together people that "show interest" as they accepted an invitation to attend. A facilitator of such consultation has an excellent opportunity to recognize supporters/opponents in the planning (or project) process. It also gives an opportunity to define co-thinkers, co-knowers and co-operators.

Surveys and public opinion pools

These are relatively cheap tools of stakeholders' involvement. When the questions are open (rather than yes/no or multiple choice), the competent authority might receive responses that will illustrate local knowledge not known to the authority. It also might encourage diverse perspectives.

Advisory Boards

Solutions are likely to be more sustainable and equitable through the input of a wider range of knowledge and perspectives. Designation of a pool of experts plays a role in advising the competent authorities. Advisory Boards might be established to use knowledge and experience. The most common mistakes in establishing the Boards are as follows:

- Board members are asked to conduct tasks that should be done/known by the competent authority
- Board members do not represent a broad spectrum of economic sectors (agriculture, industry, energy) or government/non-government/private sectors
- Board members are formally designated by a competent authority without clarifying their roles.

An advisory body can advise in all stages of the policy making process and signalize issues to be put on the agenda or fulfil a canalizing or sounding board function. However, the advisory board members should not be used directly in the project implementation (if the advice generates such a project).

Expert groups

Mobilizing several experts and finding a date for the meeting can be difficult. Thus, this tool requires a good preparation. Usually, the participating experts are asked to contribute to technical studies that serve for future decisions. A study also takes time and resources (technical and financial) that need to be accounted for prior to such an assignment.

Specific studies that require the input from experts include

- risk assessment (e.g. flood: to evaluate the level of flood risk in each river basin district or unit of management and to select those areas in which to undertake flood mapping and flood risk management plans)
- vulnerability assessment (e.g. floods/drought: assessment of environmental vulnerability)
- economic assessments (e.g. assessing the economic impact of the proposed programmes of measures aimed at improving water status - i.e. who are the losers, who are the gainers).
- environmental assessments (e.g. the Strategic Environmental Assessment that concerns the impacts of policies, plans and programmes and the Environmental Impact Assessment dealing with the project level anticipating the environmental effects of a project intervention).

When expert groups are assigned a specific task (project), the competent authority might decide to make a review of the study in thematic roundtables, expert meetings, written commenting – these all are a combination of tools for stakeholders' involvement.

Interactive e-platforms

Computer infrastructure and people´s ability to use IT is growing fast and the e-platforms are not a limiting factor anymore. E-platforms give the possibility to inform and provide data, knowledge resources, documents, maps, photo galleries and any other information. Participation is made easier. The most important principle is to keep the e-platform "interactive" – to allow users have an access to it. It also means that the e-platform must be maintained and kept up-to-date.

5.7 Shared Vision Planning methodology

5.7.1 The Shared Vision Planning methodology

Analytical models become to have an increasing role in the complex world of water resources under climate change. They support key decision-making for managing flood risk, building dams, managing groundwater and bringing together social, economic, and environmental issues. But models only provide us with one view of the world. The Shared Vision Planning (SVP) is a tool that helps involving stakeholders in all phases of model development and decision-making. SVP combines more traditional water resource planning approaches with public participation and collaborative computer modelling. These jointly developed models are used for identifying problems, determining objectives and criteria for evaluation as well as to analyse trade-offs and alternative options.

By involving participants from the outset, they can develop a common understanding of the natural water system and gain insights into how the different parts of the system are interlinked. This way, SVP helps to build a common language of the water resource issues among the parties. Stakeholders take part in developing the tools that are later used for evaluating the alternatives and generating alternatives themselves, which can be tested by using the model. This ensures that the results from the models will be credible to all stakeholders and decisions based on them will be accepted.

Shared Vision Planning follows seven steps, the first five of which can be repeated as more information becomes available for evaluation[31].

1. Build a team and identify stakeholders, decision makers, and experts;
2. Develop objectives and categories for evaluation;
3. Describe the status quo by using the collaboratively built model;
4. Jointly formulate alternatives;
5. Evaluate alternatives and develop recommendations using the model;
6. Synthesize results in a plan and implement it;
7. Update the plan.

Shared Vision Planning is best suited for multi-stakeholder, multi-issue situations. As parties begin to confront the need to plan for growing scarcity of water under competing demands, it is highly useful to bring sectors together. It is also useful where there is no common database and data sharing is difficult and with little shared knowledge of the resources.

Shared Vision Planning (SVP) is a cooperative approach that integrates traditional planning principles, system modelling and stakeholder collaboration into a practical forum for developing water management solutions.

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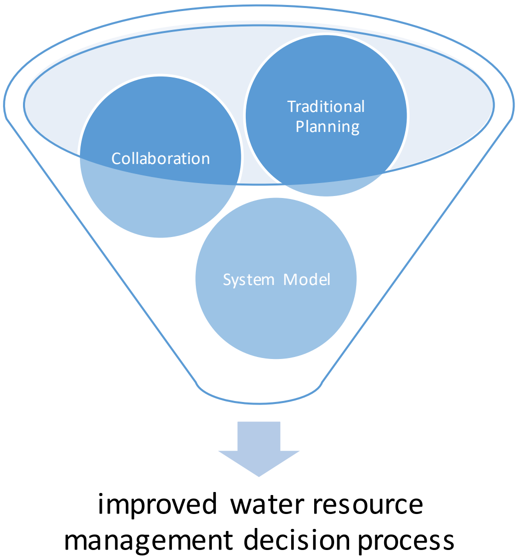
[31] Full details including knowledge resources are accessible at the US Army Corps of Engineers web site

SVP builds an understanding of the system, confidence in the analysis and trust between the stakeholders. The goal of the Shared Vision Planning is to improve the economic, environmental and social outcomes of water management decisions. Shared Vision Planning facilitates a common understanding of a natural resource system and provides a consensus-based forum for stakeholders to identify trade-offs and new management options. Shared Vision Planning creates user-friendly and understandable computer models that are relevant to stakeholder interests and adaptable to changing conditions. [32]

SVP differs from the traditional planning processes in that a great emphasis is placed on technical analysis. SVP differs from the traditional technical analysis in that stakeholders are active participants in developing and validating the analysis. The SVP technical analysis is integrated in that it brings together all issues; it is user friendly and usable by non-technical parties; it is understandable and transparent with all assumptions, input, relationships and output clearly stated; it is relevant to the issues important to stakeholders and decision makers; and it is flexible in adapting to changing conditions or evolving processes.



The Shared Vision Planning approach employs a specific method for creating collaborative discussions and computer models. The first five steps are performed iteratively; that is, the sequence of steps is repeated as more information becomes available for evaluation.

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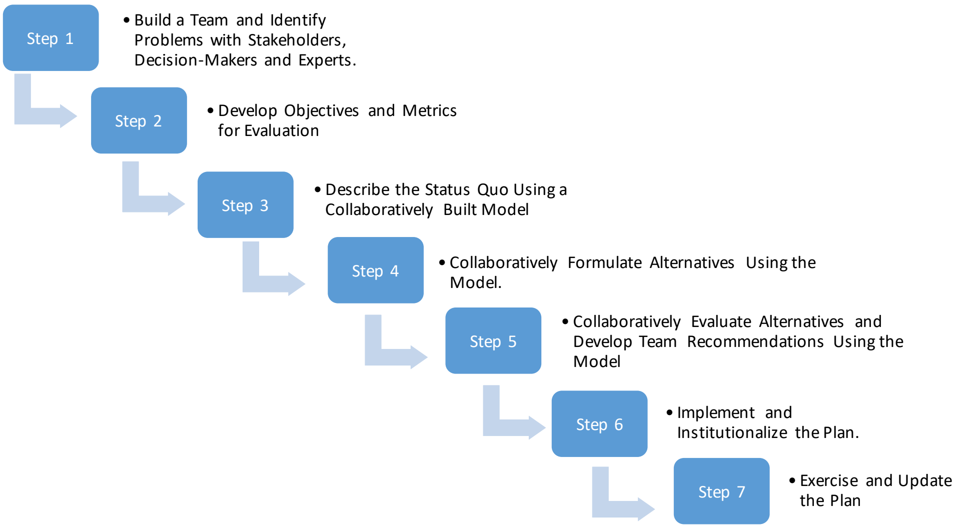
[32] https://www.iwr.usace.army.mil/Missions/Collaboration-and-Conflict-Resolution/Shared-Vision-Planning/



In Step 1 of the SVP, a team is formed that comprises stakeholders that can affect or are affected by the decision, decision makers who can make the decision and experts who can inform the decision. It is important during team formation to develop a good understanding of the anticipated level of involvement for each team member. Once formed, the team works together to develop problem or opportunity statements. Ideally, these statements are broad enough to include all potential solutions, while also taking current and future conditions into consideration.

In Step 2 of the SVP, the planning objectives directly related to the problem or opportunity statements from Step 1 are developed. The objectives specify the desired end result of the planning process and may differ for each stakeholder group. A team then develops performance indicators or metrics for each planning object. Performance indicators allow planners to compare the current system performance with the proposed system performance. Performance indicators measure the progress towards meeting the planning objectives.

In Step 3 of the SVP, a model of the current system is developed. The model is built in collaboration with stakeholders and is tied directly to the planning objectives and performance indicators. The current system model shows what the outcome without any change in management or activity in the system will be (status quo). This model serves as the base case which the models of alternatives will be evaluated against.

In Step 4 of the SVP, the team brainstorms alternatives to the status quo. The alternatives put into the model and the results are evaluated in Step 5. The formation and evaluation of alternatives is an iterative process that often requires a number of iterations to meet the performance metrics. Once the team has alternatives that meet the established performance metrics, they find consensus on specific recommendations for the decision makers.

In Step 6, the decision makers' decisions are implemented and the plan is institutionalized. The SVP process allows for this step to occur more rapidly that in a traditional planning process, because of the decision makers' and multiple stakeholders' involvement throughout the process.

In Step 7 of the SVP, the models are updated based on the changes to the system and through the use of the SVP process the plan is updated to keep the system on track to meet the established performance criteria.

5.7.2 WFD approach and the JOINTISZA stakeholder involvement

The legal framework for this was based on Article 14 of the EU Water Framework Directive.
The JOINTISZA project consulted stakeholders in the entire cycle of its activities. The public participation consisted of two parts during the development of the Updated Integrated Tisza River Basin Management Plan. The first part was to improve the knowledge about the stakeholder involvement and the role of this approach during the preparation of the ITRBMP (train the planners' seminar and one follow-up meeting in each Tisza country.). The second part is represented by the concrete public involvement actions (stakeholder and public consultations).

5.8 Stakeholder involvement example: The Krivaja River case study

The following case study provides short information on the identification of stakeholders with regard to the water management issues of the Krivaja watershed in Serbia *(Bajčetić R. et al, 2015; Srdjevic Z. et al, 2017).*

The Krivaja River is a transboundary river between Serbia and Hungary, with a length of 115.1 km (out of 124.38 km of total length) and with the river basin coverage area of 115.884 hectares in Serbia. Around 40.000 people live in this agricultural area, with a usual farm size of less than 10 hectares. There are 6 reservoirs in the basin; the biggest one is Zobnatica, mostly used for irrigation and outdoor activities. Most important water uses are irrigation, industry, fishing and outdoor activities (sport and recreation).

The Krivaja River basin is selected as a case study because of its multifunctional and multipurpose system, with complex decision-making process characterized by the conflicting interests of different parties: government, local authorities in municipalities, responsible water management companies, ecologists, public bodies, etc. The conflicts are presently sharpened because of the lack of funding, improper legislation or the absence of precise water policies, low efficiency in collecting water taxes, difficulties in motivating societal delegates to participate in management, low water quality, etc.

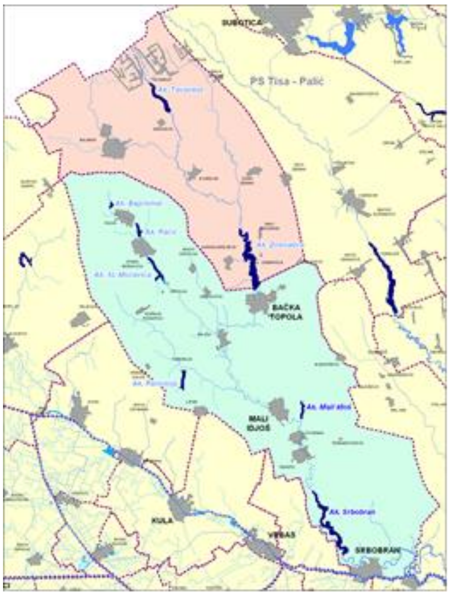


Figure V.7: Krivaja River basin, Serbia, with reservoirs (existing and planned)

A decision-making framework was created to enable

(1) identification of stakeholders and importance of each stakeholder group (by stakeholders);
(2) ranking the uses of waters in watershed by stakeholders and reaching the group decision;
(3) performing spatial multi-criteria analysis of land suitability for irrigation (stakeholders/experts);
(4) simulating multi-year scenarios of water allocation within the watershed based on the stakeholder preferences.

Eight major stakeholders' groups and their sub-groups were identified for the Krivaja River basin *(Bajčetić et al. 2015)*:

1. users (irrigation, industry, fishing ponds, tourism),
2. government (ministries and provincial secretariats),
3. water sector (public water management company and regional water management companies),

4. scientific community (university and research institutes),
5. local authorities,
6. non-governmental organizations,
7. citizen's associations, and
8. general public.

Semi-structured and informal interviews, regular mail and e-mail were used to distribute questionnaires to

- 110 legal entities (20 responses received)
- 30 individuals (5 responses)
- public institutions: state institutions, ministries, provincial secretariats, local governments, water management companies, academic bodies, etc. (35 responses).

5.8 Conclusions

The methods and approaches are summarized in the following principles:

- Ensure key stakeholders are represented in the basin management
- Distinguish between information, consultation, participation and empowerment
- Ensure administrative processes do not jeopardize real participation
- Boost ownership of the basin action plans by establishing and maintaining community participation
- Ensure financing for involving stakeholders is adequate
- Ensure communication between those managing local action plans, heads of governmental water agencies and heads of basin organizations
- Develop the capacity of vulnerable groups so they can participate in planning and implementation at appropriate levels

The **recommendations** include

At the Tisza River Basin, there are multiple levels of stakeholders' involvement: international, national and the River Basin District. The key stakeholders for trans-boundary basin organizations are usually very different from the key stakeholders in a national and basin authority. While competent authorities at basin level normally interact with various groups, including water users, at the trans-boundary level there is almost never any direct link or interaction with actual water users. At the Tisza River – the interaction will almost always be with the national water authorities of the riparian states.

1. The Tisza Group under the ICPDR is an appropriate platform to strengthen coordination and information exchange. It should be fully supported by national authorities.

Stakeholders' involvement is not just another step in river basin management and it should be an integral part (rather than appendix) of the full planning process. This is impossible without designation of a "stakeholder involvement team". In addition, involvement requires time, funds and full back-up by expert teams. Organizational adjustments together with changing attitudes of authorities should go hand by hand with valuing knowledge of others. This is especially relevant to "post-socialist" countries, where the involvement of stakeholders was not practiced or was largely formal. It should also be noted that water managers might not have skills that are expected of a communication practitioner. Whatever communication technique and tool is applied, it should be in hands of professionals and thus it is worth to hire such "communication person" internally or request external expertise to support the stakeholder involvement process.

2. Competent authorities are encouraged to understand involvement of stakeholders being a valuable part of the planning process. Strong communication channels and trustworthy moderators should be designated at all levels (international, sub-basin and local).

There are “traditional” tools (workshops, seminars and commenting processes) that work well. For the Tisza River Basin – an innovative tool of the Shared Vision Planning was tested.

6. SVP Application – Experience from Pilot Actions

Dávid Béla Vizi, Middle Tisza District Water Directorate

6.1 Introduction

The pilot actions of the project within the WP6 Activity 6.4 focus on climate change-induced drought and flood related issues. The main goal of this pilot activity is to investigate the impacts of climate change-induced drought and flood on a smaller region within the TRB. The task is to test the Shared Vision Planning (SVP) concept in a smaller region of the basin focusing on the middle part of the TRB and to investigate the drought periods and how to optimize the available water resources according to the ecological and irrigation water demands. The overall process is tested via the SVP methodology and as a tool via the part of the TIKEVIR System, which was built-up and operated by Hungary.

The Tisza River Basin (TRB) can be considered unique in several aspects among the river basins of Europe. In certain hydro-meteorological situations, the chance of extraordinary floods is high. This was especially true at the beginning of the 2000s, when the flood waves set new record high water levels along the Hungarian section of the Tisza River. Over the last decades, drought has also brought more and more challenges to the experts of the local Water Directorates. The occasional extreme low water flow of the river is a problem especially in the flat areas of the Tisza River Basin. The climate change plays a major role in the emergence of these hydro-meteorological situations (*Lehner et al, 2006*). In the JOINTISZA project, a pilot area was selected in the Middle Tisza which is endangered by both extreme situations - floods as well as droughts.

Regarding a spatial and temporal distribution of drought in Europe, the major European droughts also had an impact on Hungary. Hungary has a high risk of developing a drought period, especially typical in the Great Hungarian Plain region (*Tamás, 2016*). The drought phenomenon can significantly increase because of the man activity and ineffective water management. It is expected that the extremely long, dry weather conditions will occur more regularly for several years in Hungary (*Szalai, 2009*). The prevalence of droughts has increased over the past decades and especially the rolling drought phenomena have become critical when consecutive years of drought multiply the adverse effects of the previous years (*Pálfai, 1992*). According to the final report of the Danube River Basin Climate Adaptation Study from *Mauser et al (2018),* the possibility of more intense and more harmful droughts is expected in the Middle Tisza region.

Water demand is also expected to increase in the Great Hungarian Plain, causing new challenges in water management (*Somlyódy, 2011*). The local Water Directorate is responsible for providing adequate amount of water to satisfy the water needs. This requires river basin planning and proper water management.

We used the forecasts of climate models produced by the Joint Research Centre. The data sets they generated – according to the predicted hydrological, meteorological, economic and social conditions – were used in modelling as a boundary condition (*Bisselink et al. 2018*). With the help of these time-series, we aimed to explore possible medium and long-term conflict situations in water resources and to make recommendations for possible measures, thereby helping the water management planning of river basins with similar problems.

The detailed description of the SVP application is described in the background document of the Deliverable 6.4.2 titled *SVP Application – Experience from Pilot Actions*. The background document presents the results of the pilot action, such as the application of the SVP method and the results of the hydrodynamic modelling.

6.1.1 Pilot area

The selected pilot area is located in the flat region of the TRB in the middle of the Hungarian Great Plain *(Figure VI.1)*. The pilot area gets water from Lake Tisza, the water intake of which is controlled by the local Water Directorate. This pilot area is selected because only a proper water management work could satisfy the water demands.

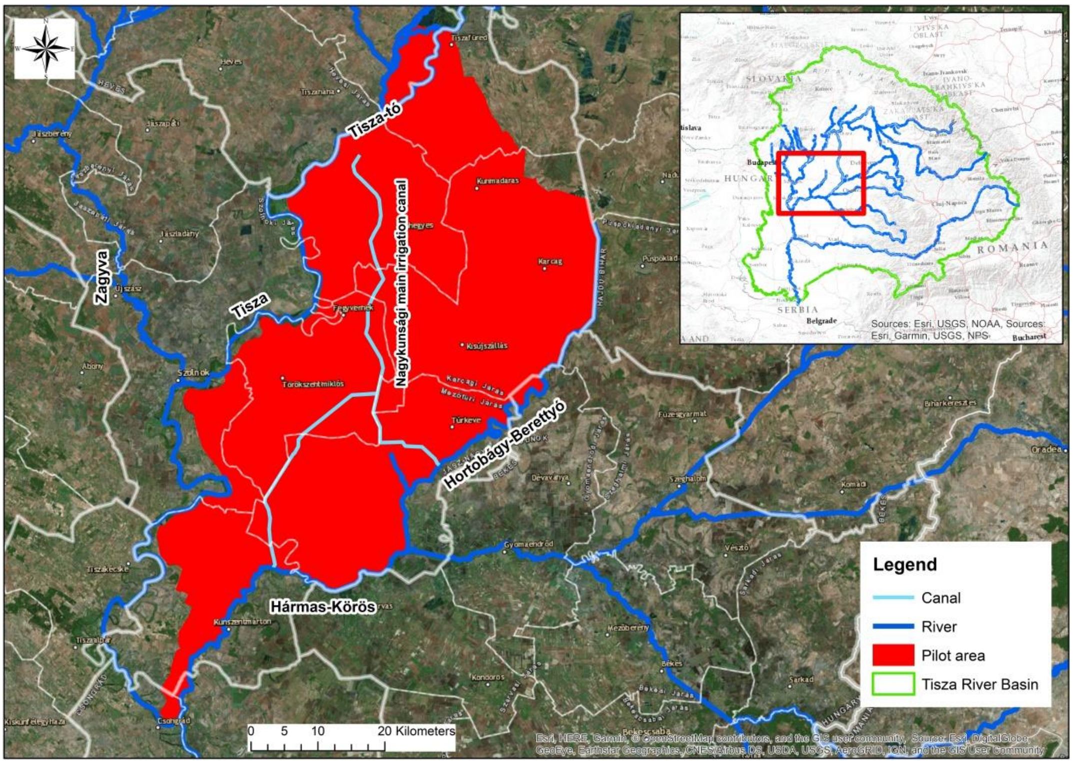


Figure VI.1: Location of the selected pilot area

The size of the pilot area is 2950.9 km^2. It is bordered by the Tisza River from the west, and by Lake Tisza from the north. The eastern border is the Hortobágy-Berettyó River and the Tiszafüredi main irrigation canal, and the southern border of the area is the Hármas-Körös River. The area is characterized by a very low elevation (79-100 mBf).

Hungary's water network is basically determined by the fact that the country is located in the middle of the Carpathian Basin. In the country, about three-quarters of the water resources are transported by the Danube and the Drava Rivers, while almost only a quarter of the available water resources are transported by the Tisza River.

The Tisza is the second most significant river in Hungary. The Tisza's full gradient in Hungary is 30 m (5 cm/km). The measured minimum flow at Kisköre was at 56 m^3/s and the maximum was at 2950 m^3/s. The average flow value in this Tisza river section is 507 m^3/s.

Table VI.1 shows high flows (HQ) of different probabilities at the river section near Kisköre:

Table VI.1: HQ values of the Tisza river at Kisköre

HQ (p=0.001) [m^3/s]	HQ (p=0. 01) [m^3/s]	HQ (p=0. 03) [m^3/s]	HQ (p=0. 1) [m^3/s]
3570	3012	2721	2363

The pilot area gets water from Lake Tisza, which is the largest artificial surface water in Hungary. The lake was artificially created when the Kisköre Barrage was constructed. The lake is operated as a reservoir, so it has two different operating water levels for summer and winter seasons. The summer water level usually lasts from the middle of March to the end of October and it is at 88.57±0.05 m. The surface of Lake Tisza is 127 km^2, with its volume being 253 million cubic meters; out of which more than 130 million m^3 can be utilized. Lake Tisza can be considered as a multi-purpose water management reservoir. The main utilizations are: recreation, water supply, hydropower generation (at the Kisköre Barrage), fishing and nature conservation.

The area has a dry continental climate and it has the driest climate in Hungary. The average annual temperature is between 10-11°C and the average monthly temperature in July is around 21°C. The mean annual temperature fluctuation is between 23.0-24.5°C. The annual amount of sunshine hours in the Hungarian Great Plain is over 2,000 hours.

Based on the measured data of the Middle Tisza District Water Directorate, the annual precipitation in this area is about 520 mm, which is the lowest average annual precipitation in the country. The territorial and temporal distribution of the precipitation is also extreme. The annual rainfall also varies within wide limits. Some years (e.g. the year of 2010, when the annual precipitation was 820 mm) had a lot of precipitation, causing floods and inland excess waters. In the last few decades it has become rather usual that an extremely wet period was followed by an extremely dry and hot period with heavy drought in just within two months.

The two most serious drought years of the last decades were the years of 2003 and 2012. In 2003, the average annual precipitation was 20 % below the long-term annual average over the Middle Tisza. The whole year was characterized by dry weather conditions. In the summer months, the spatial and temporal distribution of precipitation was imbalanced. In addition to the low amount of precipitation, the severity of the drought was further increased by the fact that this summer was one of the warmest of all time, which also contributed to high evaporation. The average monthly temperature was above 23 °C in all three summer months. From a hydro-meteorological point of view, the year 2012 was very similar to 2003.

In these years, the dry, warm weather caused hydrological and agricultural droughts. The flow of natural watercourses has been reduced. It was very important to store sufficient water in Lake Tisza and in the irrigation systems of the area and to distribute it as efficiently as possible. Shallow groundwater levels were also very low in these periods.

Climate change can play a major role in the emergence of extreme conditions. Future predictions suggest that even more extreme drought periods may also occur increasingly often (*Mauser et al. 2018*). Because of these extreme situations, a well performed and appropriate water resource management planning and regulations are important. The pilot study intended to contribute to a better planning process that takes into account the climate change-induced impacts on surface water quantity.

The pilot area has some particular characteristics that were taken into account when it was selected. The amount of water required by the stakeholders can be ensured only by a highly coordinated water management schedule of the District Water Directorate. Water demands can be served by a dense canal network supplied from the Tisza River. Even in a dry period, Lake Tisza as a reservoir can provide sufficient water for the region and the water distribution in the pilot area is exclusively managed by the District Water Directorate.

The above-described hydrological and management conditions determined the model type that could be of the best assistance in analysing water quantity management situations.

6.2 Application of the Shared Vision Planning methodology

The Shared Vision Planning methodology has been used in the pilot action. The method is presented in Chapter 2.6. Three Shared Vision Planning events were organized during the project to involve stakeholders in the planning and modelling process. The dates of the workshops were: 26-27 October 2017, 24 May 2018 and 28-29 November 2018.

The method and the pilot action were presented during the first workshop. Stakeholders also had the opportunity to comment and make suggestions according to the pilot action modelling. At a later stage of the event, the participants were divided into three groups with different topics: water supply, irrigation and flood risk management. The group participants identified the problems, opportunities, aims and possible performance indicators related to their topics in the pilot area *(Table VI.2)*.

Table VI.2: Identified problems, conflicts, possibilities, aims and indicators in the topics

	Water supply	Irrigation	Flood risk management
Problems, conflicts	• Subsurface water close to the surface is vulnerable • Wastewaters from settlements of less than 2000 PE pollute the soil and subsurface waters • Overuse of subsurface waters • Drinking water used for irrigation • Thermal water overuse • Water effluents without treatment • No proper or missing water meters • Illegal wells • Water supply systems are out of date • Rainwater harvesting is not solved • Reuse of waters for cleaning the filters is not solved	• Uncertainty of the climate change impacts on water resources • Spatial and temporal heterogeneity of the available irrigation water amount • Hard to determine the irrigation demand • High salinity of purified sewage and used thermal water • Limited utilization of alternative water resources • Salt content increase in surface waters • Uninsulated channels • Drinking water for irrigation purposes in case of gardens • Underground water resources can be used for irrigation • Inappropriate land use	• Significant floods in the past years • Cross-border watersheds • Downstream countries are vulnerable • Flood Protection System's technical conditions • Optimal form of the protection • Rivers change in a hydrological aspect • Hydromorphological issues, sedimentation • Uncertainty of the climate change impacts on flood events • Capacities of the reservoirs • Dense vegetation in the floodplain area • Social conflicts in relations to the flood protection interventions • Economic interests in relation to the flood protection interventions
Possibilities, aims	• Well "Amnesty" till 2019 • Measure the quantity for proper water balance calculation • Stop illegal water intakes • Policies/law	• Optimization of water supply • Optimization of drainage rate • Cultivation of native varieties • Water restriction measures • Increasing water retention (in channels, in soil)	• Flood Risk Management planning • Harmonization of the FRMP at a national and basin wide level • Increasing conveyance capacity of the riverbed/floodplain • Increasing capacity of the reservoirs

		• Multipurpose use of water and land • Define available water resources and to adapt land use	• Harmonization of the flood protection conservation reservoirs' operation system • To inform the downstream countries about the operation of the reservoirs • Improving the data communication between the concerned countries • Joint management of the cross-border areas • Find win-win solutions between the countries
Performance indicators	-	• Irrigation water needs for the catchment • Surface water resources for irrigation • Groundwater resources extracted for irrigation • Amount of the stored water • Increasing water retention • Quality of the irrigation water • Application of a greening program • Cultivating local, drought-tolerant varieties • Local multipurpose water and land use	• HQ_{100} • Designed Flood Level • Conveyance capacity of the riverbed/floodplain • Storage capacity of the reservoirs

The relevant factors that can be studied with a one-dimensional model were selected *(Table VI.3)*. The prioritization of the relevant problems, opportunities and goals provided the basis for defining modelling scenarios.

Table VI.3: The selected relevant issues for the modelling scenarios

	Low-water scenarios (Scenario 1-4)	**Flood scenarios (Scenario 5-7)**
Relevant problems	• Uncertainty of the climate change impacts on water resources • Spatial and temporal heterogeneity of the amount of available irrigation water • Hard to determine the irrigation water demand	• Significant floods in the past years • Rivers change in a hydrological aspect • Hydromorphological issues, sedimentation • Uncertainty of the climate change impacts on flood events • Capacities of the reservoirs

		• Dense vegetation in the floodplain area
Relevant aims	• Optimization of water supply • Water restriction measures • Increasing water retention (in channels)	• Increasing conveyance capacity of the riverbed/floodplain • Increasing capacity of the reservoirs

The study of the Joint Research Centre has been used to take into account the impacts of climate change on water resources and flood events (*Bisselink et al. 2018*). Scenarios 1-4 examine the optimization of water supply, water retention and the use of water restriction measures. Scenarios 5-7 analyse the flood-related problems: changes in hydrological trends, sedimentation, capacities of the reservoirs, dense vegetation in the floodplain area. These scenarios also include the possibilities of increasing the conveyance capacity and the capacity of the reservoirs. The defined scenarios were presented at the second stakeholder event with the first set of results. Stakeholders had the opportunity to comment and make suggestions according to the modelling scenarios. The final results of the pilot action were presented at the third SVP workshop.

6.3 Possible climate change impacts in the future

The Joint Research Centre (JRC) studied the effects of a changing climate, land use and water demand on water resources in the Danube River Basin using a climate-induced runoff modelling technique (*Bisselink et al. 2018*). The water resource calculations were done with the LISFLOOD 2.0 model, which is a GIS-based spatially-distributed hydrological rainfall-runoff-routing model (*De Roo et al. 2000, Van der Knijff et al. 2010, Burek et al. 2013*). As a result of the runoff modelling, water flow data were made available for our work for the rivers of the Tisza River Basin.

In the JRC analysis, 11 different European EURO-CORDEX climate scenarios have been used. The Coordinated Downscaling Experiment over Europe (*Jacob et al. 2014*) is an international climate downscaling initiative that aims to provide high-resolution climate projections for up to the year 2100 (*Bisselink et al. 2018*).

Flow time-series were made available for our work for every boundary condition calculated from the JRC runoff model. Time-series were from 2011 to 2099 for each 11 climate projections. In addition to the boundary conditions, discharge data were also available for a specific river section of the Tisza, providing the inflow into Lake Tisza. From a water management point of view, discharges at this point have important regulatory significance in the Middle Tisza. They are needed for the operation of the Kisköre Dam, for the assessment of the amount water that can be diverted into and utilized in the major irrigation systems of the Middle Tisza Valley. Moreover, if the flow at this river section decreases below 105 m^3/s, a water shortage alert might be issued, and when discharge falls below 60 m^3/s, restrictions on water uses are needed. Statistical analysis has been made for the 11 flow time-series of this river section, which can be used for quantification of future trends.

Based on the results of the statistical analysis, the months of September and October will have the highest probability of discharges of less than 60 m^3/s at the Tiszafüred gauge station. The return time for extreme low-water periods is 3-4 years in all 11 climate projections. Based on the data released by the JRC, the occurrence of increasingly long-lasting low-water periods is also predicted for the second half of the century. For example, runoff data based on the "SMHI-RCA4_BC_ICHEC-EC-EARTH_rcp85" climate projection have a 128-day period of discharges of less than 60 m^3/s.

In addition to the extreme low-flow conditions, some climate scenarios have also generated extraordinary flood waves. In case of the two projections (CLMcom-CCLM4-8-17_BC_CNRM-CERFACS-CNRM-CM5_rcp85, IPSL-INERIS-WRF331F_BC_rcp85), the maximum discharge was above 4000 m^3/s, which would pose a serious flood risk for the Middle Tisza, especially at the Kisköre barrage. This flow rate is higher than the actual 1000-year return period flood flow.

It is based on the statistical analysis to define which climate scenario should be used as the boundary condition of the hydrodynamic model. According to the analysis, the "SMHI-RCA4_BC_ICHEC-EC-EARTH_rcp85" is selected to study low-water periods and the "IPSL-INERIS-WRF331F_BC_rcp85" climate projection to study major flood events.

The detailed description of the statistical processing can be found in the background Deliverable 6.4.2 document.

6.4 1D hydraulic modelling of the pilot area's water system

In its current structure, the database of the model includes the 600 km long river section of the Tisza between Tiszabecs and Szeged and the channel system of the pilot area. The total length of watercourses involved in the calculations exceeds 2000 km. There are 102 bridges and 19 inline structures installed into the model. The model includes the Nagykunsági irrigation canal, which is the most important irrigation facility of the pilot area. The river network system covered by the hydrodynamic model is denoted by blue lines in *Figure VI.2*.

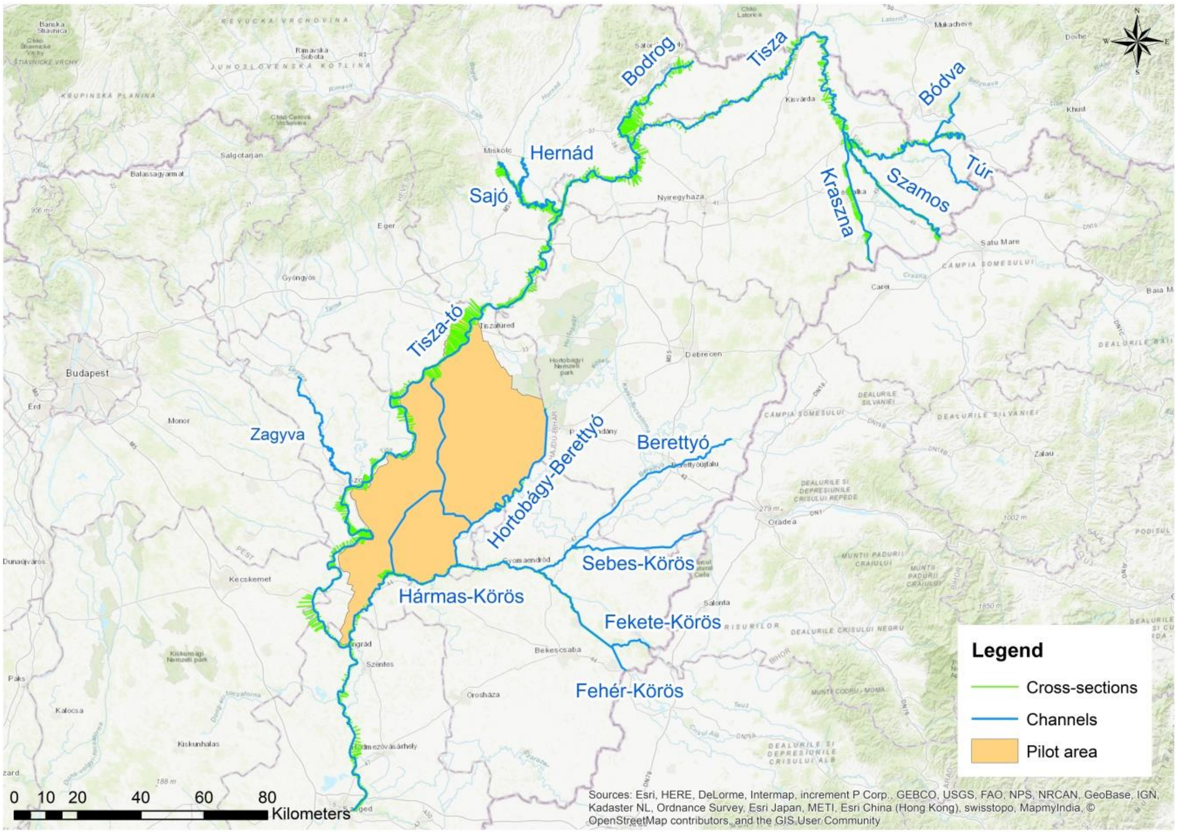


Figure VI.2: The layout and the boundary conditions of the model

We have advanced the stream system of the model by more than 2 000 cross sections. The cross sections are the basis of one-dimensional models. The calibration and the roughness coefficient only partly compensate for the possible inaccuracies of the cross-sections. The model's stability greatly improves if the cross sections are as dense as possible. Based on the previous modelling experience, the optimal distance between cross sections - from a model point of view - is 400 - 800 m for the Tisza and 200 - 400 m for the tributaries of the Tisza. For the irrigation canals, the optimal distance is 200 - 400 m.

The hydrodynamic model has 14 upstream and 1 downstream boundary conditions. The boundary conditions of the rivers are located on the Hungarian border sections. We have chosen these points to minimize the impact of the boundary conditions on modelling results in the pilot area. At each point there are flow data available for input data.

The water usage has been quantified in the model based on the water needs shown in *Figure VI.3*. These values are based on the nationwide survey of the Hungarian Chamber of Agriculture (HCA). The model includes a total of44 million m^3 annual water demand of the Nagykunsági irrigation system (HCA, 2018). Water consumptions of the irrigation sections in the Nagykunsági irrigation system appear as point-like extractions in the model.

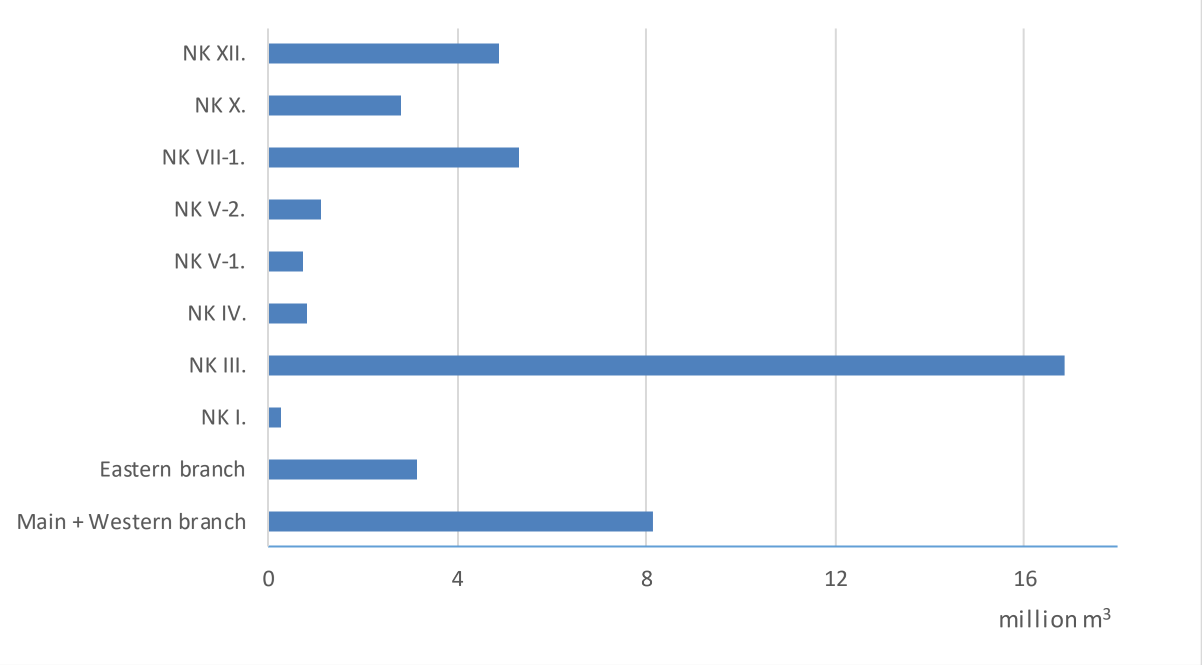


Figure VI.3: Water demand in the Nagykunsági main irrigation system

The applied HEC-RAS model gives a detailed description of the entire river system and provides an opportunity to take into consideration the hydraulic engineering structures, as well as bridges, barrages, culverts, overflow weirs, floodgates, bottom stages, bottom sills, side overflows and gates, static reservoirs, pump head stations and water intakes (*US Army Corps of Engineers, 2016*). The model includes 102 bridges and 16 inland structures and it also contains a number of water intakes. We took into the model every irrigation section of the Nagykunsági irrigation system as a point-like water intake. The model also contains every direct water use along the Nagykunsági main irrigation canal, so water consumption can be tested as a simple drainage. We used the possible water demand values for input data that are based on the survey of the Hungarian Chamber of Agriculture.

For the calculation of the water discharge capacity of the Tisza main river bed, as well as for taking the flood plain vegetation into consideration, we used the roughness (smoothness) factors given in Table 1 in the course of calibration of the model. We determined the vegetation in the flood plain by aerial photographs, i.e. by ortho-photographs, as well as by the results of on-site inspections. The roughness factor was changed crosswise according to the flood plain vegetation. The roughness (smoothness) factor assigned was determined on the basis of the Hungarian standard prescriptions, as well as on the basis of the values applied also by the HEC-RAS and proposed by *Chow (1959)*.

The calibration of the model was accomplished gradually, starting with the shorter sections. We assembled together the individual section and then performed the river sections.

The calibration of the Tisza and its tributaries was made for the low-water period of the year 2012. For the river section between Tiszabecs and Szeged, the difference between the calculated water level and the observed one was between 0 and 10 cm in absolute values, which can be considered a very good result. The pilot area's canal network was calibrated separately. We used data from the year of 2013 to calibrate the irrigation canals. The difference between the calculated water level and the observed one was between 0 and 10 cm, just like the river network. After the calibration was made, separate water streams were connected.

6.5 Results of the hydraulic modelling

6.5.1 Low-water scenarios (Scenario 1-4)

The Scenarios 1 - 4 (see *Table VI.3*) are long-lasting low-water periods, whereby the water flow to the area is lower than the sum of water flowing to the tail-water at the Kisköre Barrage and into the irrigation canals from Lake Tisza.

The boundary conditions are selected based on the statistical analysis of the water flow datasets produced by the JRC. As described in Chapter 6.3, the "SMHI-RCA4_BC_ICHEC-EC-EARTH_rcp85" climate scenario is selected to study low-water periods. In this climate scenario, there are several periods with water scarcity. The time series of the year of 2085 includes an extremely low-water period and the data sets of the year have been used as the boundary conditions of the model. At the river section of the Tisza near Tiszafüred, the flow of the river has been below 105 m^3/s for more than 3 months, which is a period of water scarcity.

In Scenario 1 - when the river's flow falls below 100 m^3/s - the water level of Lake Tisza gradually begins to decrease. The trend continues for two months when the discharge at the upper section of the river increases to above 100 m^3/s. During the critical period, the amount of water drained from Lake Tisza to the Nagykunsági main irrigation canal is continuously ensured and corresponds to the water demands. We studied how quickly the stored water of Lake Tisza would be consumed.

During the critical period, the amount of water drained from Lake Tisza to the Nagykunsági main irrigation canal is limited corresponding to the water restraint plan (*KÖTIVIZIG, 2018*). The amount of water flowing into and out of the Nagykunsági main irrigation canal is controlled. Water demands in Scenarios 2 and 3 are still satisfied. We studied the impact of the I. and II. level water restraint in Scenarios 2 and 3. The III. level of water restraint is taken into effect in Scenario 4, when the transferred amount of water from Lake Tisza to the Nagykunsági main irrigation canal is reduced to 0 m^3/s.

Figure VI.4 shows the discharge time series at the influence section of the Nagykunsági main irrigation canal. Water discharge values show that the transferred amount of water during the critical period is limited.

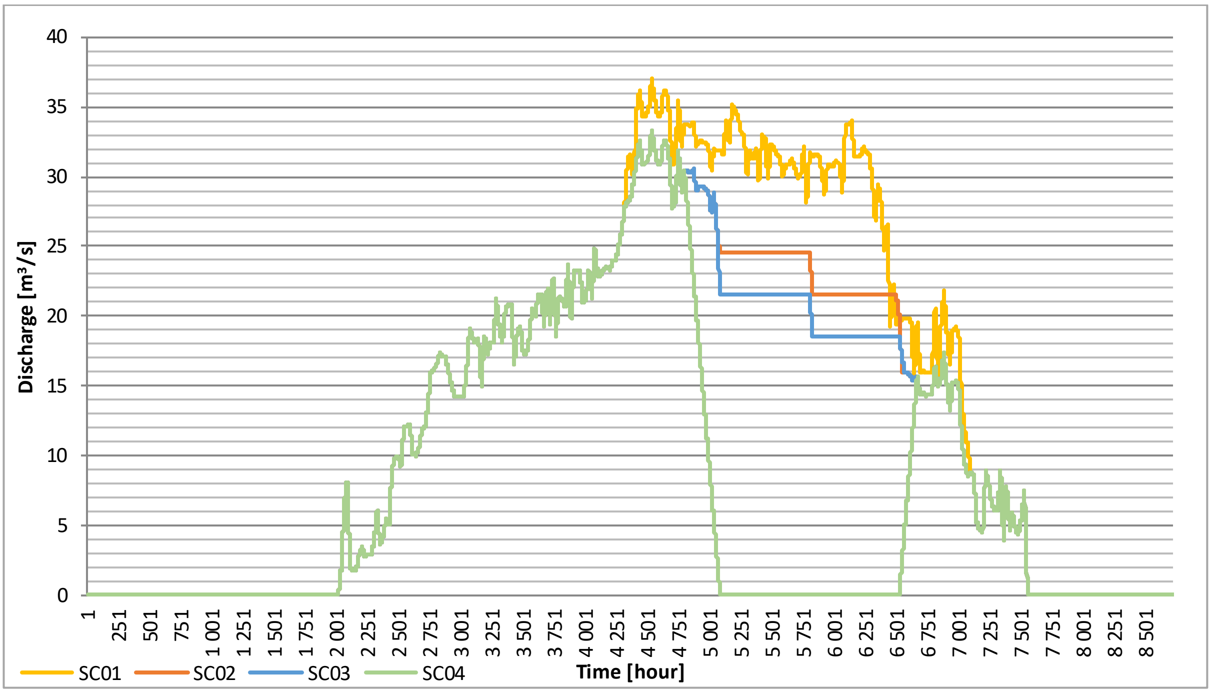


Figure VI.4: Discharge at the inlet point of the Nagykunsági main irrigation canal

Figure VI.5 shows the development of water level at the Kisköre barrage in the modelled year. In the first half of the year there is enough water flow to the river to maintain the operating water level (88.67 ± 0.05 m) of the reservoir. Then in the summer months, the river flow gradually decreases until it reaches the critical 60 m^3/s value at the river section near Tiszafüred. Water restrictions come into effect during this time in Scenarios 2, 3 and 4. This low-water condition lasts for one and a half months. Once the river's flow increases again to above 60 m^3 at the inflow section of Lake Tisza, the water restrictions are ended.

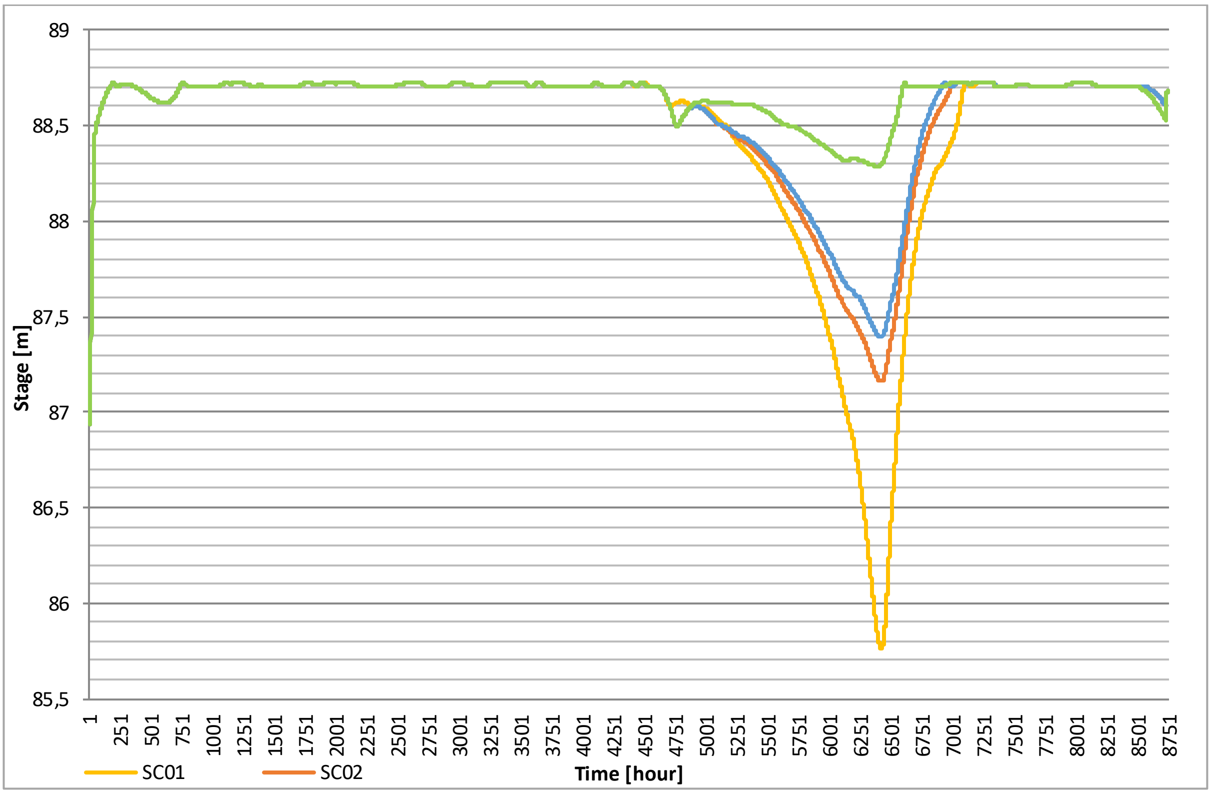


Figure VI.5: Water level at headwater of the Kisköre barrage

The minimum water levels at Lake Tisza in the different scenarios are as follows:

- Scenario 1: 85.76 m,
- Scenario 2: 87.15 m,
- Scenario 3: 87.40 m,
- Scenario 4: 88.29 m.

According to the regulations, a specific flowrate must be secured from the eastern branch of the Nagykunsági main irrigation canal to the Hortobágy-Berettyó, as well as from the western branch of the Nagykunsági main irrigation channel to the Hármas-Körös (*KÖTIVIZIG, 2018*) in each scenario. In the model scenarios, the minimum flowrate was guaranteed at the outflow sections of the Nagykunsági main irrigation canal.

Figure VI.6 and VI.7 show the development of water flow at the outflow section of the western and eastern branches of the Nagykunsági main irrigation canal in the modelled year. The time series shows that water discharge corresponds to the water restraint measures.

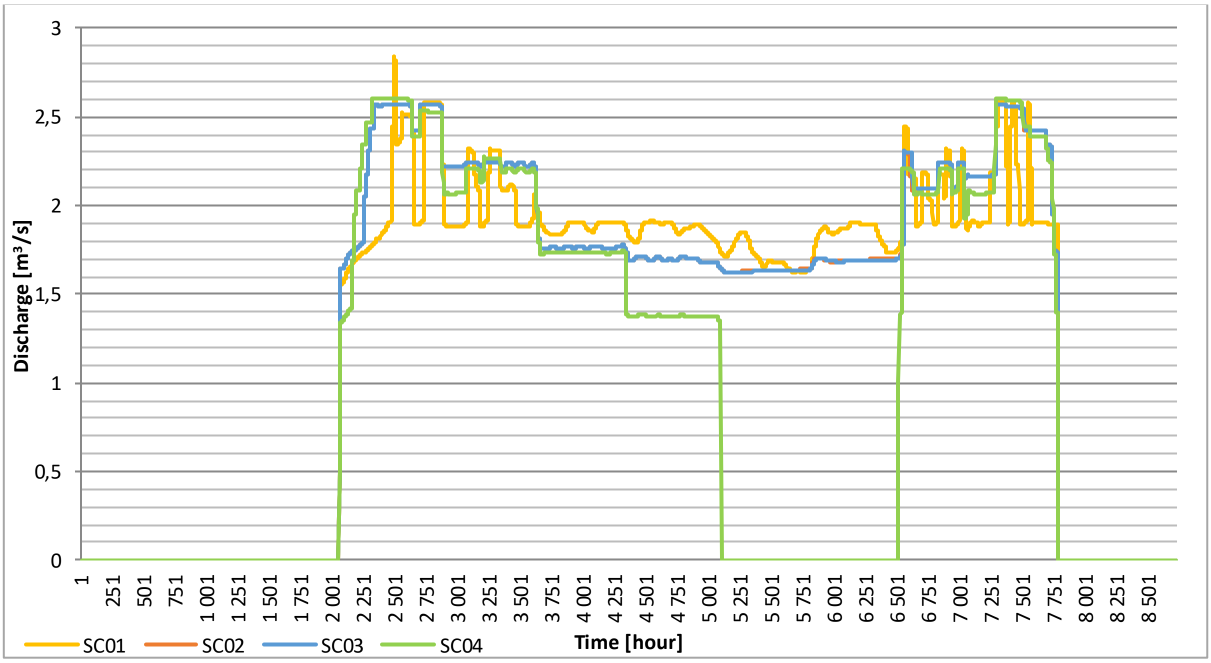


Figure VI.6: Discharge at the outflow section of the western branch of the Nagykunság main irrigation canal

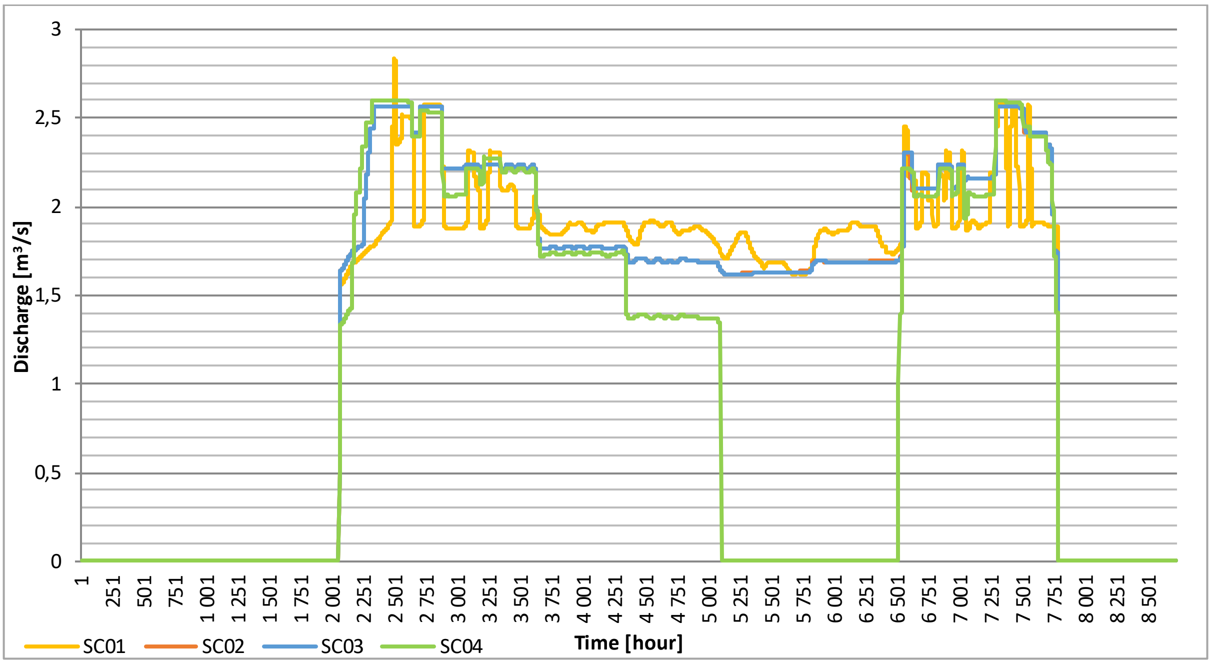


Figure VI.7: Discharge at the outflow section of the eastern branch of the Nagykunság main irrigation canal

Figure VI.8 shows the importance of the water drained from the Nagykunsági main irrigation canal to the Hármas-Körös in different modelling scenarios. In the summer season, only 5.9 m^3/s of water comes from the upper section of the river. Due to water restraints, as much as 19.9 m^3/s of water is transferred from the Hortobágy-Berettyó to Körös at Mezőtúr in Scenario 1, 14,6 m^3/s in Scenario 2, 11,6 m^3/s in Scenario 3 and 0.4 m^3/s in Scenario 4. A large part of this amount of water comes indirectly from the eastern branch of the Nagykunsági main irrigation canal. The next point of influence is located at Öcsöd, where 1.62 m^3/s of water is transferred from the western branch of the Nagykunság main irrigation canal in Scenarios 1, 2 and 3 and 0 m^3/s in Scenario 4. This longitudinal profile shows the conditions as of August 11, 2085.

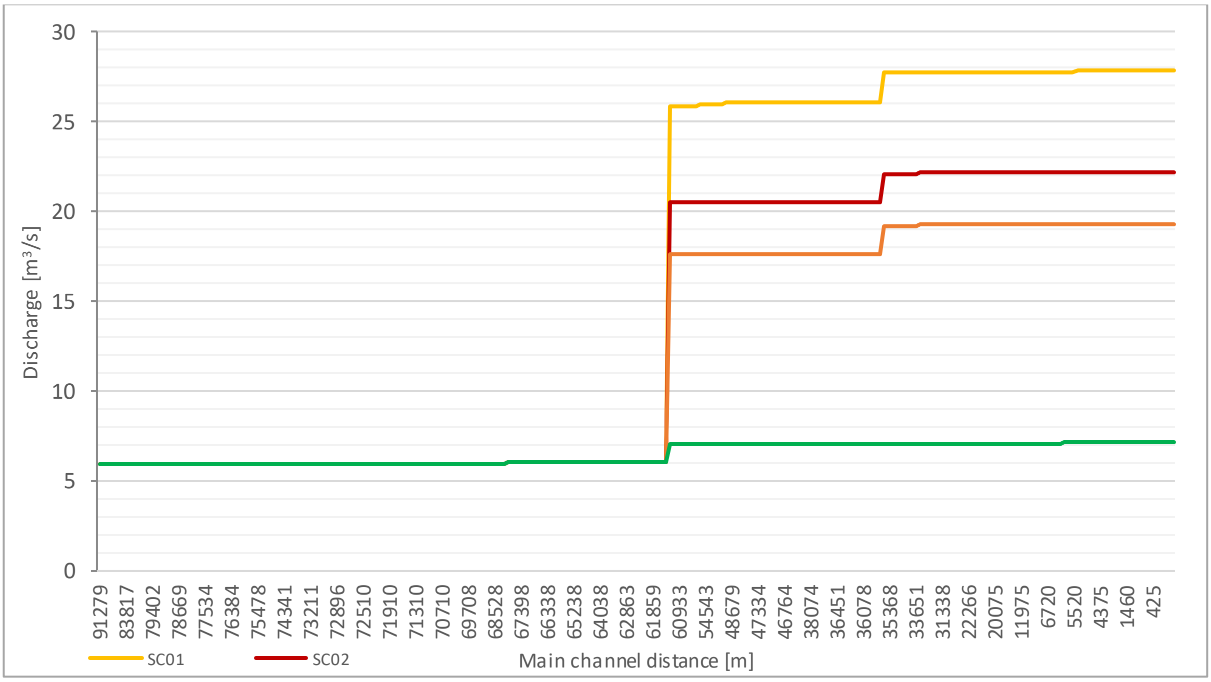


Figure VI.8: Longitudinal profile of the Körös River between Gyoma and Kunszentmárton

The results of Scenarios 1-4 show what happens to the water resources of Lake Tisza in an extreme low-water situation with a different level of water restrictions. The model runs also show that Lake Tisza is able to supply the area with water for a long time, but in extreme cases the water level may become critically low. The outputs show that the minimum water level at Kisköre is higher with the water restrictions. In turn, the water supply to the Hármas-Körös decreases (*Table VI.4*).

Table VI.4: Difference between the different Scenario results

Scenario	Water restriction	Difference in min. water levels [m]	Difference in water supply [%]
Scenario 1	-	0	0
Scenario 2	I. level	+1.39	32.5
Scenario 3	II. level	+1.64	51.0
Scenario 4	III. level	+2.53	100.0

6.5.2 Flood event scenarios (Scenarios 5-8)

Scenarios 5 - 8 (see *Table VI.3*) are long-lasting flooded periods, where the water flow approaches the HQ value with a 1000-year return period. In these model versions, we have implemented measurements increasing the conveyance capacity and showing the importance of the reservoirs in the Middle Tisza.

Scenario 5 does not contain any measurement and the reservoirs are not used. Scenario 6 shows the effects of the three flood reservoirs along the Tisza River. The roughness coefficient (n) is reduced in Scenario 7 by 20 % from Tiszafüred to Szolnok on both overbanks. In Scenario 8, the roughness coefficient (n) is reduced by 50 %, which means that maximum forests without undergrowth are allowed on the floodplain.

The boundary conditions selections are also based on the statistical analysis of the water flow datasets produced by the JRC. As described in Chapter VI.4, the “IPSL-INERIS-WRF331F_BC_rcp85” climate scenario is selected to study floods. In this climate scenario, there are several periods with remarkable floods. The time series of the year of 2091 includes an extremely flooded period, and the data sets of the year have been used as the boundary conditions of the model. At the river section of the Tisza near Tiszafüred the flow of the river exceeds 2800 m^3/s for more than 3 months.

Figure VI.9 shows the development of water level at the Kisköre barrage in the modelled year. From August to September there is a remarkable period with several flood waves. With the help of the reservoirs and the increased conveyance capacity, the maximum water level values can be reduced. The highest water level at Kisköre was 91.62 m in 2000 and the Design Flood Level (DFL) is 92.00 m.

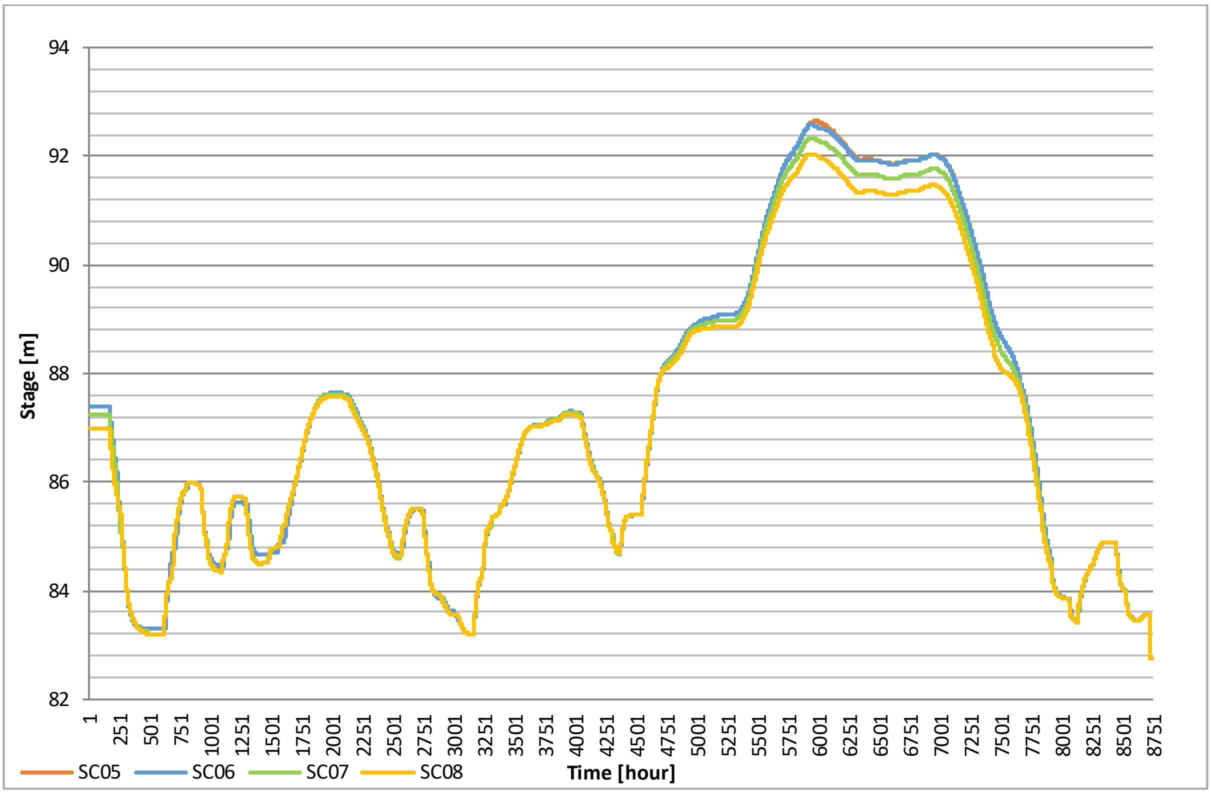


Figure VI.9: Water level at the Kisköre barrage

The maximum water levels at Kisköre in the different scenarios are as follows:

- Scenario 5: 92.02 m,
- Scenario 6: 91.91 m,
- Scenario 7: 91.71 m,
- Scenario 8: 91.52 m.

Figure VI.10 shows the development of discharge at the Kisköre barrage. The discharge was between 3300 and 3500 m^3/s in each scenario, which is close to the HQ value with a 1000-year return period.

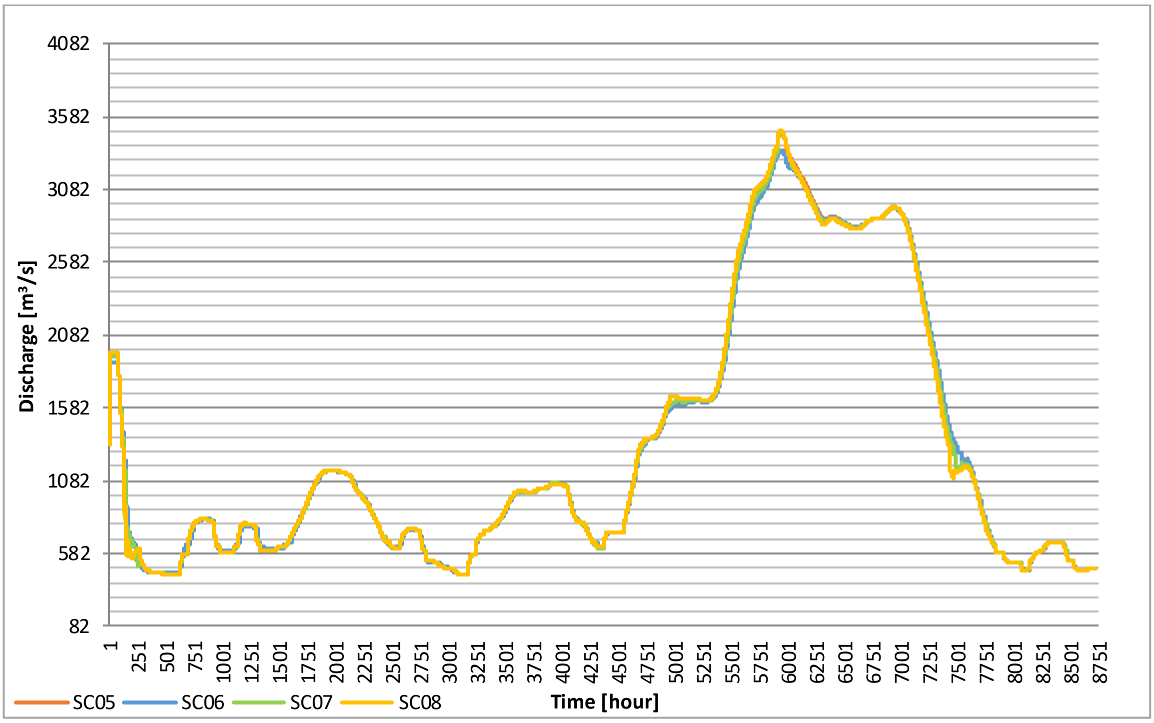


Figure VI.10: Discharge at the Kisköre barrage

The maximum discharge values at Csongrád in the different scenarios are as follows:

- Scenario 5: 3342 m^3/s,
- Scenario 6: 3296 m^3/s,
- Scenario 7: 3316 m^3/s,
- Scenario 8: 3353 m^3/s.

The difference between the maximum values of Scenarios 5 and 6 shows positive effects of the reservoirs. In contrast, increasing the conveyance capacity may have a negative effect at the downstream of the river, which can be seen from the maximum discharge values of Scenarios 7 and 8. *Figure VI.11* shows the discharge values at a lower section of the Tisza near Csongrád between August and November.

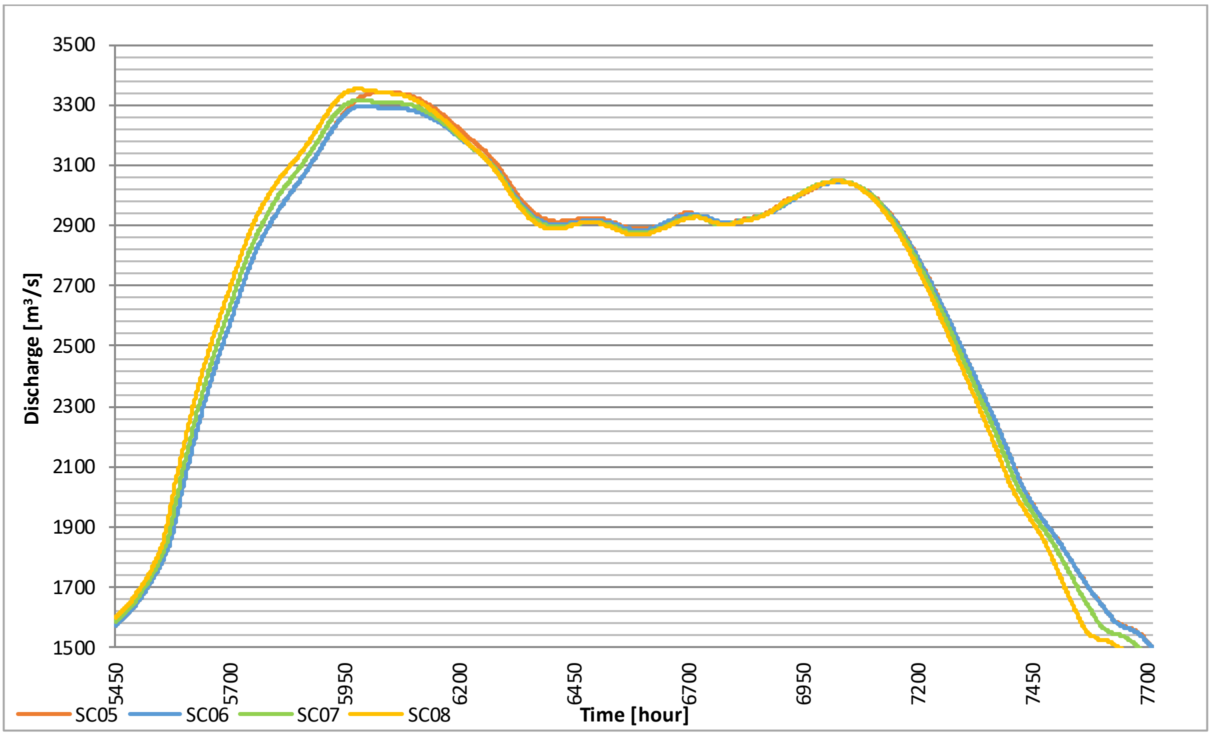


Figure VI.11: Discharge at Csongrád

This extreme flood begins during the irrigation period. Regardless of this, adequate water should be provided for different purposes in the pilot area under the flood event. A special measure has been implemented in the model. When an extraordinary flood goes down the Körös, the barrage at the outflow section of the Hortobágy-Berettyó at Mezőtúr has to be closed. In such cases, water is transferred from the Hortobágy-Berettyó to the Körös with pumps. If the capacity of the pumps is not enough to drain the water at Mezőtúr, the water can be passed to the Körös through the Nagykunsági main irrigation canal (*Figure VI.12*).

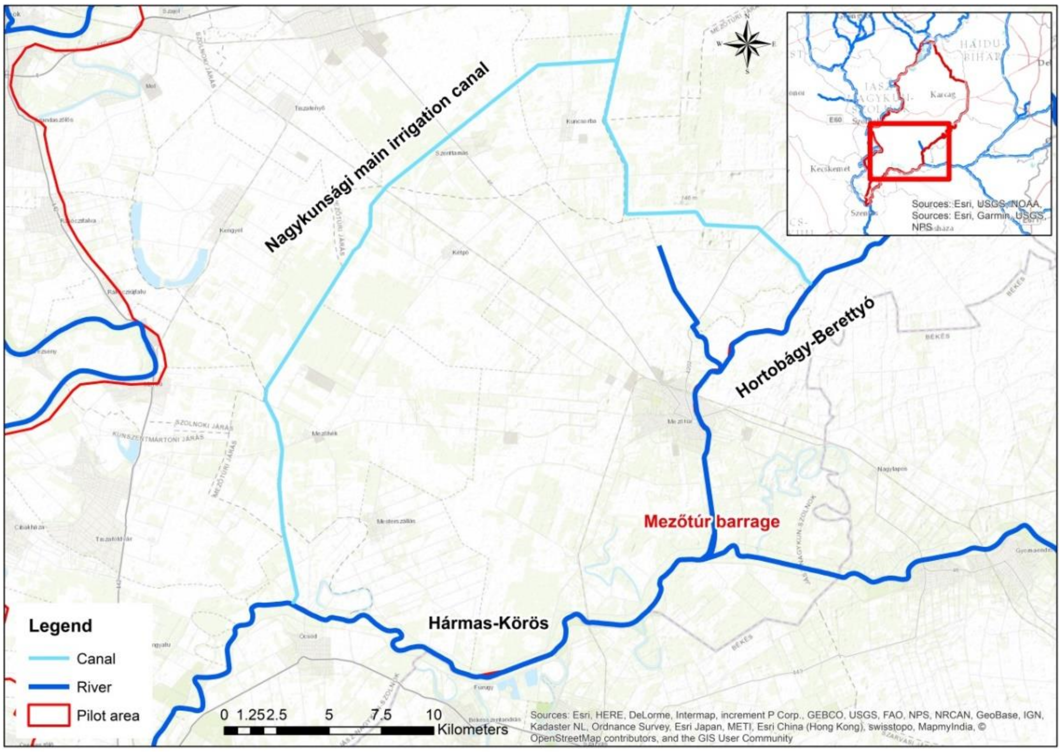


Figure VI.12: Alternative flow direction when the Mezőtúr barrage is closed

Figure VI.13 shows the water level and discharge during this period. In the critical period, up to 40-60 m³/s of water can be transferred from Hortobágy-Berettyó to the Nagykunsági main irrigation canal.

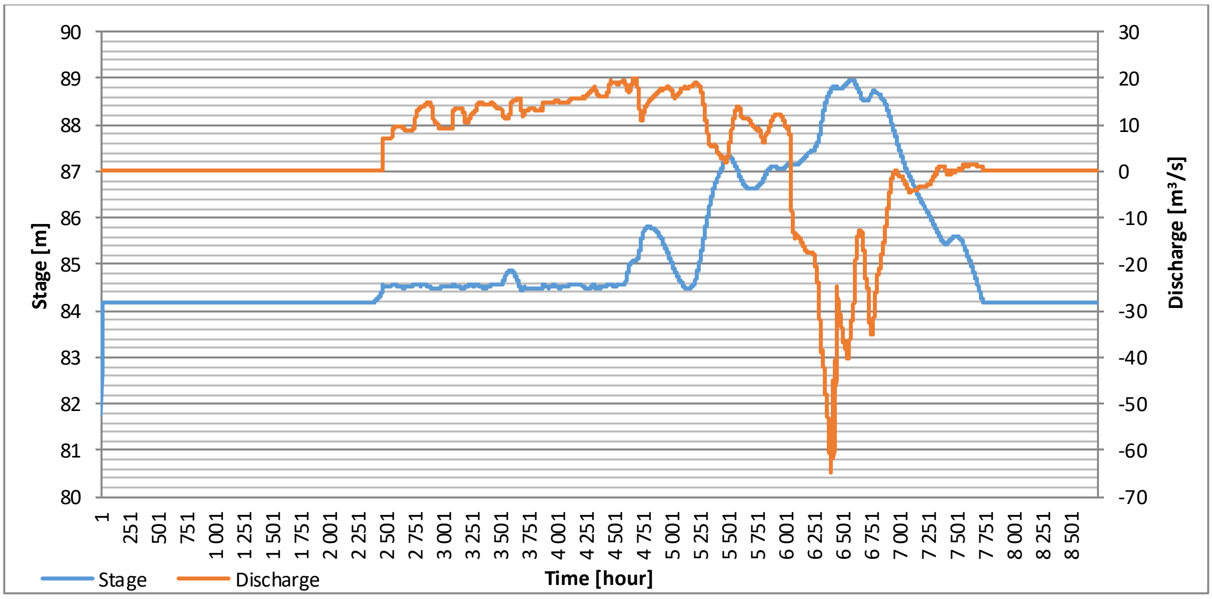


Figure VI.13: Water level and discharge at the outflow section of the eastern branch of the Nagykunsági main irrigation canal

Figure VI.14 shows the water level and discharge at the outflow section of the western branch of the Nagykunsági main irrigation canal. The water flow is lower at this canal section, due to the water uses of the pilot area.

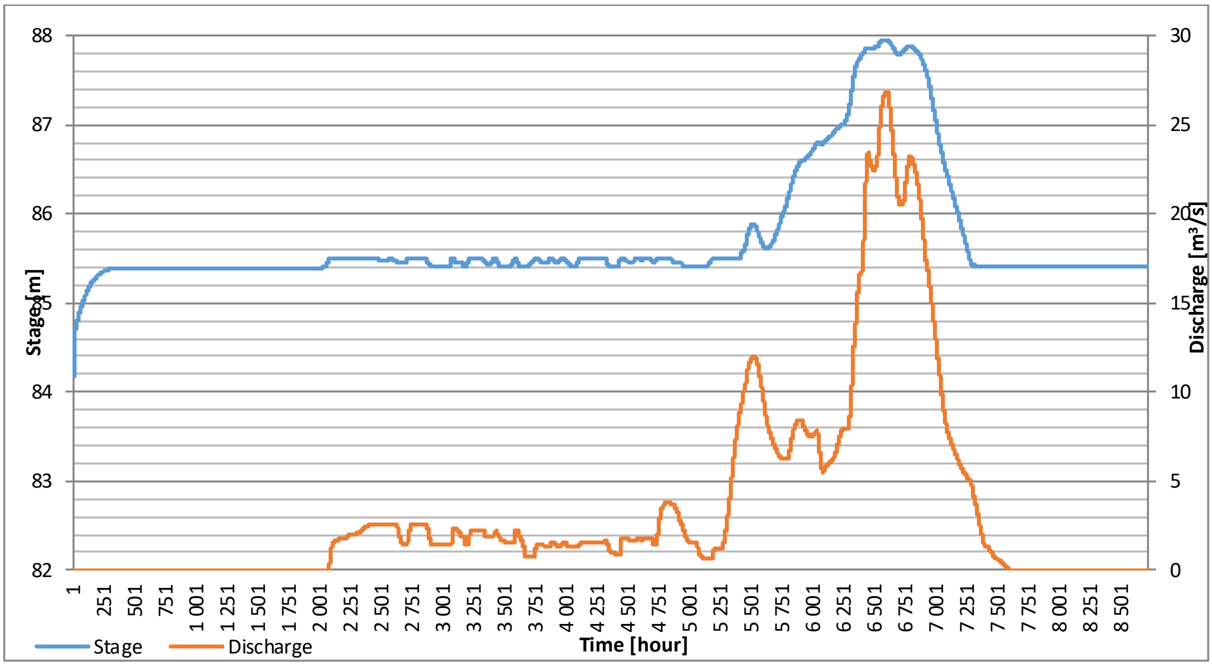


Figure VI.14: Water level and discharge at the outflow section of the western branch of the Nagykunsági main irrigation canal

We studied the impacts of the reservoirs and the increased conveyance capacity with Scenarios 5-8. The water flow approaches the HQ value with a 1000-year return period. *Table VI.5* shows the differences between the flood scenario results. The water level-reducing effect of the three reservoirs is 11 cm at Kisköre with this extraordinary flood. A further 32 and 28 cm water level reduction could be achieved by reducing the roughness of the floodplain. Water level could be reduced to the DFL in Scenario 8. At the same time, the discharge is increased because of the increased conveyance capacity. There was no significant difference at Csongrád at this high-water level.

Table VI.5: Differences between results of Scenarios 5 to 8

Scenario	Applied measurement	Difference in flood peak at Kisköre [cm]	Difference in flood peak at Kisköre [m³/s]	Difference in flood peak at Csongrád [cm]	Difference in flood peak at Csongrád [m3/s]
Scenario 5	-	-	-	-	-
Scenario 6	Reservoirs	-11	+81	-1	-46
Scenario 7	Reservoirs + reduced roughness by 20 %	-32	+95	-2	-26
Scenario 8	Reservoirs + reduced roughness by 50 %	-60	+116	-4	+11

The backwater effect of the Kisköre barrage was also studied. The difference between the headwater and downstream water level of the barrage is 24 cm, which is acceptable for such a high-water level.

An alternate flow direction has also been applied to the model. During an extraordinary flood on the Hármas-Körös, water could be drained from the Hortobágy-Berettyó to the Hármas-Körös through the Nagykunság main irrigation canal. A 40-60 m³/s discharge could be transferred to the canal to help manage the flood.

6.6 International aspects of the pilot area study

The main aim of this pilot activity is to investigate the impacts of climate change-induced drought and flood related issues on a smaller region. The Middle Tisza pilot area was selected because of the special hydrological characteristics. The natural runoff of the area is not too relevant and the water needs are satisfied with the help of artificial irrigation systems. Floods, inland excess waters and droughts also occur often in the pilot area. The JRC studies stated that these extreme hydro-meteorological events can happen even more frequently in the future. The implementation of water management planning at the TRB level has a very high priority to reduce the damage caused by these events.

In order to make the planning process more effective, the Shared Vision Planning methodology was used. The main goal with the SVP method is to give the stakeholders the opportunity to share their opinions and suggestions during the pilot action work. As a result, the modelling has studied issues, which are relevant to the local stakeholders. This method also provides an opportunity to bring local stakeholders closer to the planning and implementing organizations.

The low-water modelling scenarios investigated the effects of the water restriction measures. These scenarios have shown that Lake Tisza has been able to supply the area with enough water for a long time. However, a large decrease in the water level of Lake Tisza can cause major ecological, economic and social problems along the reservoir. The low-water scenarios have also highlighted a previously known problem of how lowland areas are vulnerable to extreme hydro-meteorological events. For this reason, water management of the countries with this characteristic (e.g. Hungary, Serbia) is highly dependent on the coming discharges from the neighbouring countries.

SVP events have also shown that it is difficult to determine the optimal water restriction process. The water limitation procedure set out in the Water Management Act can also cause conflicts between water users.

The flood event scenarios have given an opportunity to study the importance of the flood reservoirs and the increased conveyance capacity in the Middle Tisza. The stakeholders have identified dense vegetation on the floodplain and decreasing conveyance capacity as serious problems. Many flood protection measures (e.g. VTT, NMT) in Hungary try to moderate the risk of these problems. Using the flood reservoirs can also help reduce these negative impacts. However, it is important that these measures can be accepted at the international level.

Abbreviations

AHTG	ad hoc task group
ARSO	Agencija Republike Slovenije za okolje - Slovenian Environment Agency
CARPATCLIM	A project for the Climate of the Carpathian Region
CC	climate change
CCIV	climate change impacts, vulnerability and/or risk
CEE	Central and Eastern Europe
CH	Chapter
CLC	CORINE Land Cover – Copernicus Land Monitoring Service
COM	commission
COMARO-D project	Cooperating towards Advanced MAnagement ROutines for land use impacts on the water regime in the Danube river basin
COP	Conference of the Parties
DanubeSediment project	Danube Sediment Management - Restoration of the Sediment Balance in the Danube River
CORDEX	Coordinated Regional Downscaling Experiment
CORINE	Coordination of Information on the Environment (EU data base)
DFL	design flood level
DMCSEE	Drought Management Centre for Southeastern Europe
DQ	Design Qualification
DriDanube project	Drought Risk in the Danube region
DTP	Danube Transnational Programme
DVS	Drought User Service
EC	European Commission
EEA	European Environment Agency
EODC	Earth Observation Data Service
ERDF	European Regional and Development Fund
EU	European Union
EU CCAS	European Union – Communal Centre For Social Action
EU CIS	European Union – Commonwealth of Independent States
EUSDR	European Union – Strategy for the Danube Region
FRD	Flood Risk Directive
GIS	geographic information system
GWP CEE	Global Water Partnership, Central and Eastern Europe
HCA	Hungarian Chamber of Agriculture

HQ	high flow
HEC-RAS	HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels.
ICPDR	International Commission for the Protection of the Danube
IPA	Instrument for Pre-Accession Assistance
IPCC	Intergovernmental Panel on Climate Change
ITRBM	Integrated Tisza River Basin Management Plan
JCI	Jaroslav Cerni Institute
JOINTISZA project	Strengthening Cooperation between River Basin Management Planning and Flood Risk Prevention to Enhance the Status of Waters of the Tisza River Basin
JRC	Joint Research Centre
LIFE Programme	The LIFE programme is the EU’s funding instrument for the environment and climate action
MTDWD	Middle Tisza District Water Directorate
NAP	National Adaptation Programme
NAS	National Adaptation Strategies
ORIENTGATE	A structured network for integration of climate knowledge into policy and territorial planning
OVF	Országos Vízügyi Főigazgatóság, General Directorate of Water Management, Hungary
PA	priority area
PAI	Pálfai Drought Index
PoMs	programme of measures
RBM	river basin management
RBMP	River Basin Management Plan
RCP	Representative Concentration Pathways
SCI	site of community importance
SEECOF	South-East European Climate Outlook Forum
SPA	special protection area
SRES	Special Report on Emission Scenarios
SVP	Shared Vision Planning
SW	surface water
SWD	staff working documents
SWMI	Significant Water Management Issues
TIKEVIR	Tisza-Körös völgyi Együttműködő Vízgazdálkodási Rendszer - Tisza-Körös Valley Collaborative Water Management System
TKVWMS	Tisza-Körös Valley Water Management System
TRB	Tisza River Basin
UNECE	United Nations Economic Commission for Europe

WFD	Water Framework Directive
WMO	World Meteorological Organization
WP	work package
WS&D	water scarcity and drought

List of Terms

- "Adaptive capacity (or adaptability)": The ability of a natural or human system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences. (ESPON Climate, 2011)
- "Climate change impacts": Consequences of climate change on natural and human systems. (consequences of climate changes - field of impacts - according to the degree and nature of exposure and sensitivity)
- "Climate-proof": Activities to increase the resistance and resilience of the policies, plans and programs that will be directly or indirectly affected by the climate change impacts, acknowledging the new conditions where the baseline is inherently unstable and changing and including climate protection aims (UNECE 2009).
- "Exposure": The nature and degree to which a system is exposed to significant climatic variations.
- "Low-regret options": Adaptation measures where the associated costs are relatively low and where the benefits, although mainly met under a projected future climate change, may be relatively large (UNECE 2009).
- "No-regret options": Cost-effective adaptation measures that are worthwhile (i.e. they bring net socio-economic benefits) regardless of the extent of future climate change; they include measures that are justified (cost-effective) under the current climate conditions (including those addressing its variability and extremes) and are also consistent with addressing the risks associated with the projected climate changes (UNECE 2009).
- "Sensitivity": The (nature and) degree to which a system could be affected, either adversely or beneficially, by a climate-related stimuli. The effect may be direct or indirect.
- "Vulnerability": The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation which a system is exposed to, its sensitivity and adaptive capacity.
- "Win-win options": Cost-effective adaptation measures that minimize climate risks or exploit potential opportunities but also have other social, environmental or economic benefits; win-win options are often associated with those measures or activities that address climate impacts but which also contribute to climate change mitigation or meet other social and environmental objectives (UNECE 2009).

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JOINTISZA project deliverable 4.2.1 TRB report on water quantity

JOINTISZA project deliverable 4.3.3 Catalogue of existing measures' evaluation

JOINTISZA project deliverable 5.2.2 - Flood risk management-proposed measures in the TRB

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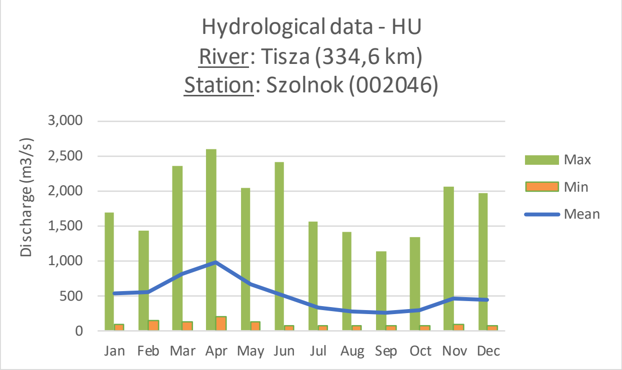
Annex 1

Table 1: TRB Mean Annual discharges (m^3/s)

Year	UA		RO	SK	HU		RS
	Chop	Vilok	Satu Mare	Streda nad Bodrogom	Tiszabecs	Szolnok	Senta
1986	33.0	190	117.47	100.493	203	468	768
1987	30.0	156	97.09	87.447	168	376	584
1988	39.7	193	128.78	111.266	193	491	732
1989	37.3	202	120.66	121.509	203	517	732
1990	23.2	144	82.84	79.116	139	336	465
1991	21.8	138	89.47	76.423	145	368	572
1992	32.8	206	96.73	103.756	181	424	690
1993	25.4	180	114.03	82.440	183	364	537
1994	33.4	194	105.06	96.801	176	461	662
1995	42.6	284	155.02	112.799	263	557	800
1996	26.8	155	121.89	82.140	158	450	770
1997	30.4	193	155.49	96.122	191	517	884
1998	65.3	329	197.61	155.622	298	808	1130
1999	46.0	241	162.95	135.499	255	704	1170
2000	41.7	196	143.85	136.784	187	563	929
2001	43.8	246	141.80	124.865	263	649	949
2002	36.4	216	131.59	96.637	237	517	777
2003	23.4	118	79.39	71.128	127	348	575
2004	36.7	208	132.30	121.142	219	511	866
2005	39.1	183	166.39	140.189	182	615	1100
2006	38.4	231	191.47	135.089	232	739	1230
2007	31.4	220	138.53	101.852	215	491	752
2008	36.6	248	140.35	116.417	258	542	827
2009	32.3	164	111.48	100.830	172	428	646
2010	60.9	262	212.89	204.159	272	950	1430
2011	27.3	142	94.42	90.151	142	455	732
2012	22.7	136	67.30	78.132	135	296	442
2013	32.4	172	104.39	113.024	176	513	736
2014	18.4	108	69.96	68.249	112	298	496
2015	16.9	139	91.09	63.122	141	315	530

Table 2: TRB Minimum Annual discharges (m^3/s)

Year	UA		RO	SK	HU		RS
	Chop	Vilok	Satu Mare	Streda nad Bodrogom	Tiszabecs	Szolnok	Senta
1986	3.92	36.2	170	15.020	30	61.4	164
1987	4.90	37.9	190	18.480	43	75.8	130
1988	5.45	32.2	170	30.680	30	105.0	183
1989	7.04	58.2	210	34.270	41	110.0	253
1990	5.23	32.4	96	33.280	33	75.7	95.0
1991	5.15	40.3	200	31.890	43	122.0	237
1992	3.16	31.6	180	28.040	27	59.5	132
1993	5.49	56.8	190	30.130	53.2	89.0	90.0
1994	5.31	32.5	168	27.480	10.1	69.6	90.0
1995	6.24	35.0	180	31.790	42.3	113.0	251
1996	7.70	42.3	210	32.640	50	115.0	188
1997	8.56	74.2	170	37.860	81.9	161.0	306
1998	11.8	62.3	80	44.630	77.8	226.0	360
1999	7.98	60.0	200	31.500	60.4	145.0	326
2000	6.50	26.3	180	31.280	26.7	94.7	242
2001	7.90	69.2	110	39.720	41.8	198.0	272
2002	4.96	44.8	100	26.030	44.5	105.0	220
2003	3.78	22.2	140	21.770	22.3	66.2	128
2004	7.00	40.5	130	34.585	41.3	101.0	213
2005	5.67	42.8	185	38.795	44	163.0	373
2006	6.22	40.2	200	30.031	47.3	148.0	312
2007	3.72	46.5	193	26.234	44	79.7	193
2008	7.58	48.0	208	32.049	44	151.0	265
2009	5.48	29.0	197	22.859	31.6	67.5	180
2010	10.4	75.0	385	45.070	81	308.0	541
2011	4.14	25.0	248	21.688	29.4	81.9	151
2012	4.40	26.0	233	20.453	22.3	72.9	120
2013	3.85	33.5	263	21.969	33.3	64.9	135
2014	5.70	42.7	196	28.392	45.7	94.7	222
2015	2.96	23.4	340	13.331	27.5	63.7	137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River: Tisza (334,6 km)
Station: Szolnok (002046)
Discharge (m3/s)
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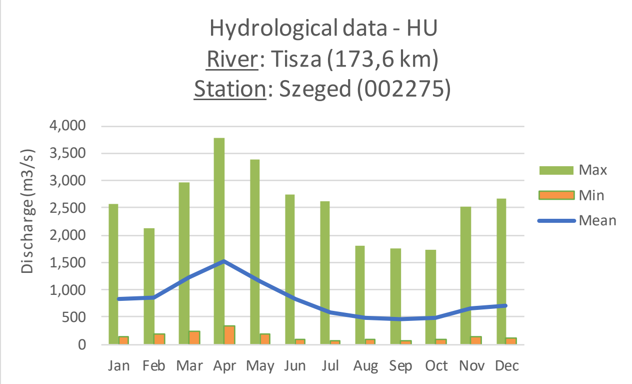
2,500
2,000
1,500
1,000
500
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean


Hydrological data - HU
River: Tisza (173,6 km)
Station: Szeged (002275)
Discharge (m3/s)
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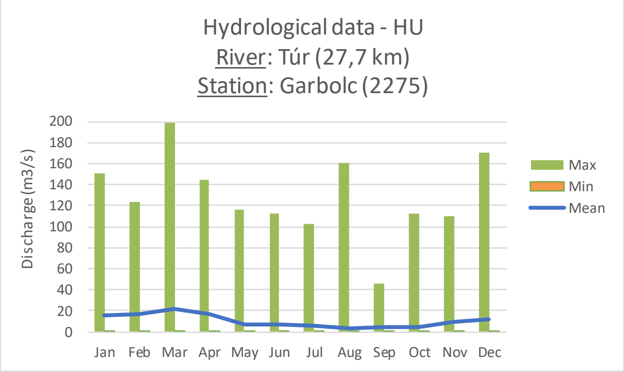
3,000
2,500
2,000
1,500
1,000
500
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean


Hydrological data - HU
River: Túr (27,7 km)
Station: Garbolc (2275)
Discharge (m3/s)
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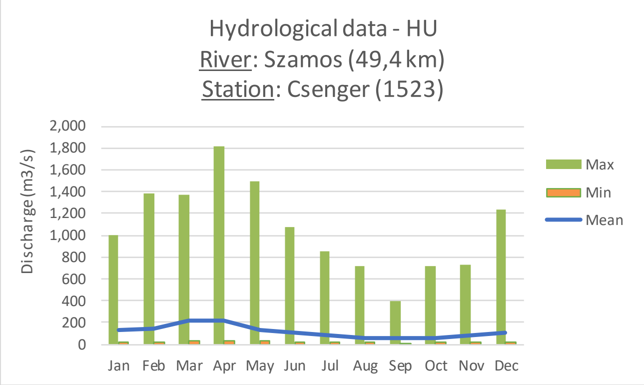
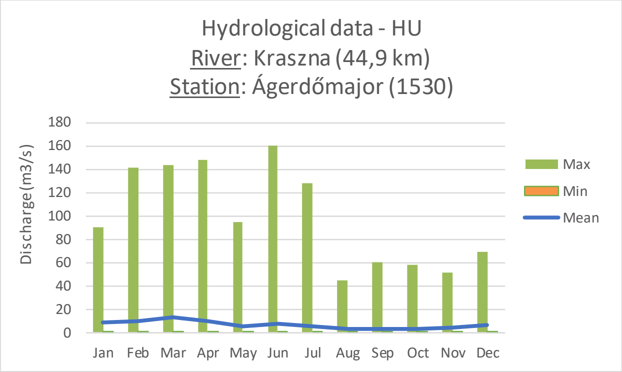
180
160
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean


Hydrological data - HU
River: Szamos (49,4 km)
Station: Csenger (1523)
Discharge (m3/s)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean


Hydrological data - HU
River: Kraszna (44,9 km)
Station: Ágerdőmajor (1530)
Discharge (m3/s)
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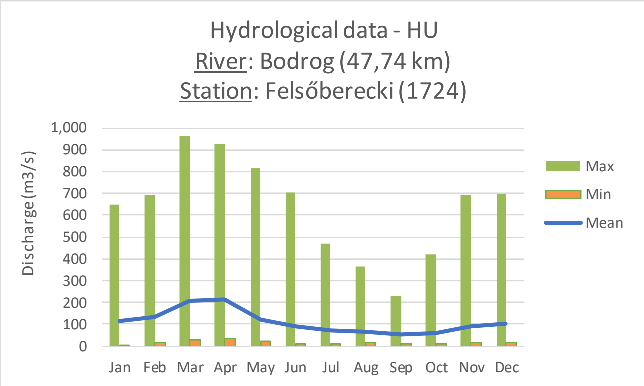
160
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean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River: Bodrog (47,74 km)
Station: Felsőberecki (1724)
Discharge (m3/s)
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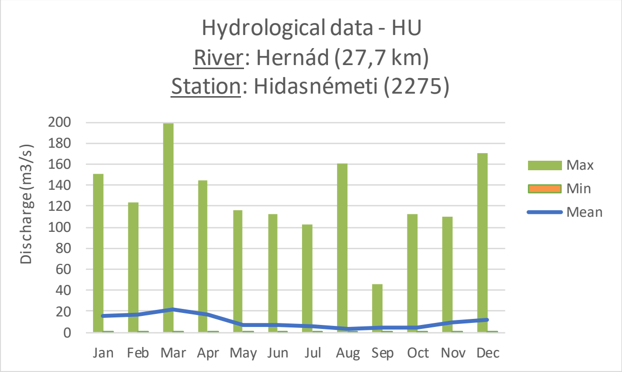
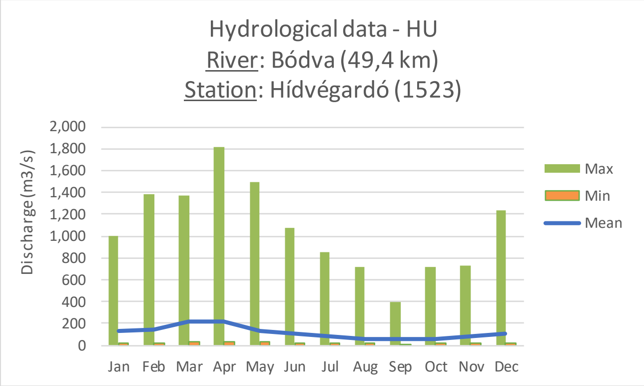
800
700
600
500
400
300
200
100
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean


Hydrological data - HU
River: Hernád (27,7 km)
Station: Hidasnémeti (2275)
Discharge (m3/s)
200
180
160
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean


Hydrological data - HU
River: Bódva (49,4 km)
Station: Hídvégardó (1523)
Discharge (m3/s)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Max
Min
Mean