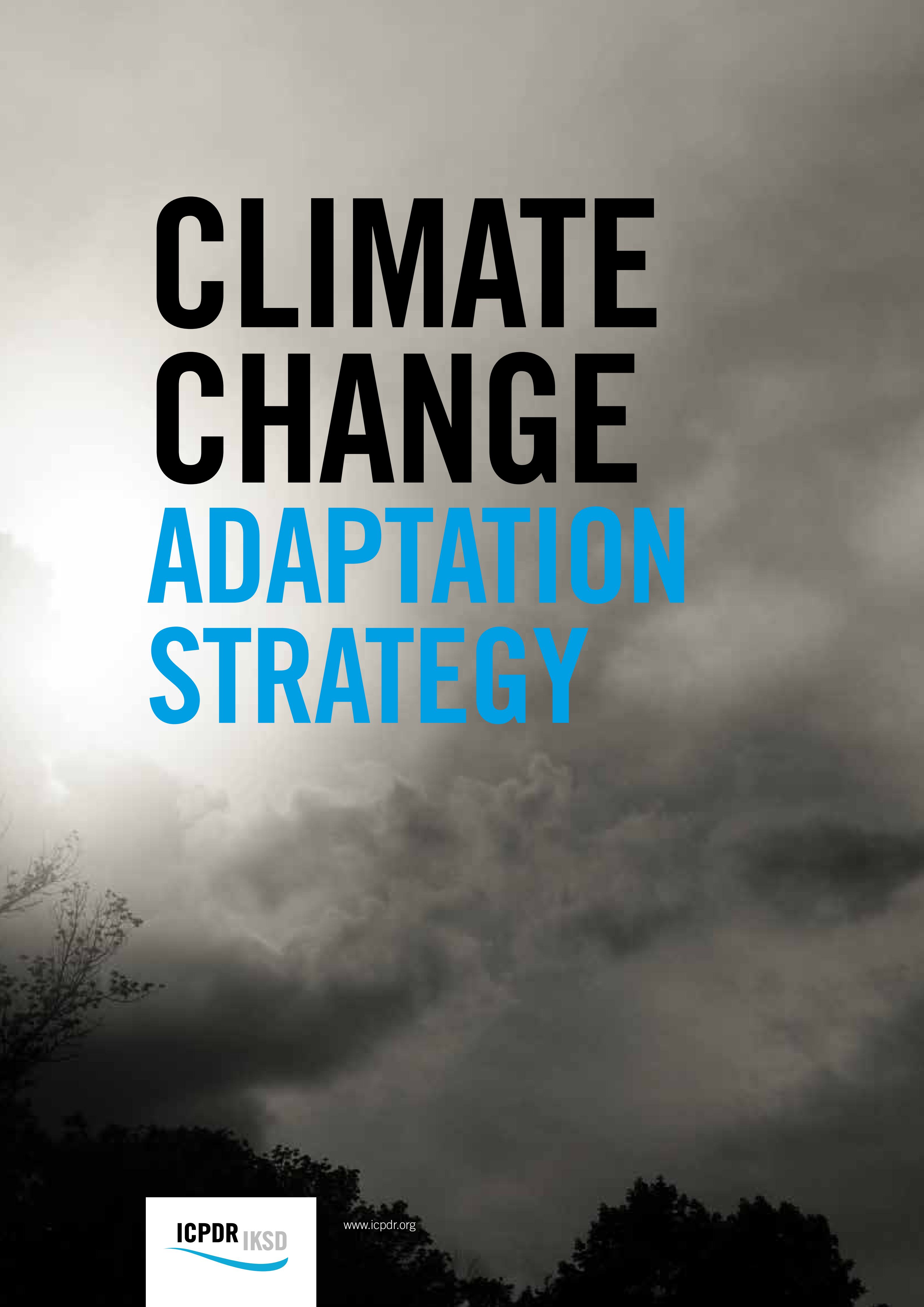
CLIMATE CHANGE ADAPTATION STRATEGY



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The ICPDR Strategy on Adaptation to Climate Change aims at offering guidance on the integration of climate change adaptation into ICPDR planning processes. It promotes action in a multilateral and transboundary context and serves as reference document influencing national strategies and activities. The ICPDR Strategy on Adaptation to Climate Change 2012 was updated and revised in the year 2018 taking into account new scientific results and implementation steps taken in the Danube countries.

EXECUTIVE SUMMARY

SECTION I
Introduction and Framework Conditions

The ICPDR Strategy on Adaptation to Climate Change provides an overview of the background and framework conditions of climate change adaptation for water-related sectors in the Danube River Basin (DRB). Relevant water related EU Directives and Policies include the EU Strategy on Adaptation to Climate Change, the EU Water Framework Directive, the EU Floods Directive as well as the EU Biodiversity Strategy 2020. National Climate Change Adaptation Strategies of Danube countries focus on the assessment of the present situation and highlight areas likely to be affected as well as requirements for adaptation to climate change and suggested adaptation measures with regard to water-related issues at the national level. An overview of the status of National Climate Change Adaptation Strategies in the Danube River Basin as of July 2017 is outlined. The ICPDR Strategy on Adaptation to Climate Change describes the approach of the ICPDR to integrate the issue of climate change adaptation into its activities, in particular in the Danube River Basin Management Plan and the Flood Risk Management Plan. Being a frontrunner and pioneer among transboundary river basin commissions in climate change adaptation activities, the ICPDR adopted the first ICPDR Strategy on Adaptation to Climate Change in the year 2012. Based on its strategy, the ICPDR was able to fully integrate climate adaptation issues in the updated DRBM Plan and the first DFRM Plan in 2015.

SECTION II
Knowledge Base

Climate Change Scenarios for the Danube River Basin
The scientific knowledge base of the updated ICPDR Strategy on Adaptation to Climate Change is the updated and revised Danube Study, which was completed in 2018. In this study, all available information on future climate change in the Danube River Basin and its effects on the water sector were compiled and analysed. Moreover, existing adaptation strategies and documents dealing with climate change adaptation such as national communications were analysed as well.

In the future, temperature and precipitation are expected to change significantly in the DRB and developments of both are highly certain. Future climate change is simulated under the representative concentration pathways RCP4.5 and RCP8.5. These pathways stand for a radiative forcing due to atmospheric greenhouse gas concentration of 4.5 W/m² and 8.5 W/m². This equals to an increase of global mean temperature of 1.1-2.6 °C (mean: 1.8 °C) under RCP4.5 and 2.6-4.8 °C (mean: 3.7 °C) under RCP8.5. For the Danube River Basin, the following temperature changes are calculated from data of the EURO-CORDEX initiative relative to the period 1981-2010 (status: September 2018).

- Increase of annual mean temperature between 1.1°C and 1.5°C until 2050 under RCP4.5
- Increase of annual mean temperature between 2.0°C and 2.6°C until 2100 under RCP4.5
- Increase of annual mean temperature between 1.3°C and 1.7°C until 2050 under RCP8.5
- Increase of annual mean temperature between 4.0°C and 5.0°C until 2100 under RCP8.5

In contrast to the increase in annual mean temperature, which can be quantified relatively precisely, annual mean precipitation shows little variation until 2050 under RCP4.5 and RCP8.5.

Nevertheless, particular trends were identifid:

- Wet regions tend to become wetter and dry regions drier
- Strong precipitation gradient: northwest (high) – southeast (low)
- Highly certain significant changes in seasonality → wetter winters, drier summers

Besides the general trends in future temperature and precipitation development, a future increase in extreme weather events is expected for the whole Danube River Basin. The simulations show both, a future increase in the intensity and frequency of dry spells, hot days and heat waves, as well as local and regional increases in heavy rainfall, although the latter is uncertain in spatial and temporal localisation.

Water-related impacts of climate change in the Danube River Basin

Due to the expected changes in climatic conditions, water availability is likely to decrease in the southern and eastern parts of the DRB, whereas it will remain unchanged or even increase in the northern and western part. Changes in water availability can highly differ locally and regionally. Nevertheless a north-westward shift of regions affected by water stress is expected until the end of the 21st century. Runoff is projected to significantly decrease until the end of the 21st century, whereas only little change is projected in the next decades. According to precipitation, changes in runoff seasonality are expected.

The assessment of future extreme hydrological events like floods and droughts includes high uncertainty. However, there is consensus that extreme hydrological events will occur more often and be more intense.

Following the future increase in air temperature, water temperature will most likely increase in the DRB. Due to changes to all temperature-dependent chemical and biological processes, as well as increasing flood and drought events, the pressure on water quality in rivers and lakes will increase.

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An intensification of extreme events, such as floods and droughts, leads to high impacts for agriculture, forestry and industry, as well as built-up areas and infrastructure. As a consequence of decreasing water availability, a shortage in water supply is expected in some areas. There will not be enough water to meet the requirements for irrigation in agriculture and the vegetation period will shorten in large areas in the south of the DRB. In contrast, in the northern parts there will be enough water for productive farming. A shift in species distribution and an increasing risk of invasive species is expected due to changing climatic conditions.

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

In order to take the appropriate adaptation measures, it is important to assess the certainty of the statements above. Recent developments in climate modelling and project results of high confidence led to an increased certainty for nearly every field of climate change effects. The certainty of changes in temperature and precipitation seasonality is found to be very high. The certainty of changes in runoff, forestry, agriculture, floods, droughts and ecosystems is high. In contrast the certainty level of the impact of climate change on biodiversity, water-related energy production and navigation remains medium. The improved level of certainty may allow the preparation of adaptation measures at an early stage and/or with more detail, whereas a low level of certainty may lead to more general types of measures.

Vulnerability

In order to improve the effectiveness of adaptation measures, an assessment of vulnerability to climate change is an important point, which should precede a detailed planning for action. According to the IPCC Assessment Report 5, the concept of vulnerability was widened by the concept of risks. Risk is defined as the interaction of vulnerability, exposure and (climate-related) hazards. To facilitate the basin-wide coordination of adaptation measures and their prioritisation, a spatially detailed, consistent and homogeneous vulnerability assessment for the Danube River Basin would be a helpful instrument for a future basin wide adaptation process.

The added value of an encompassing vulnerability assessment – depending on its spatial and temporal scope – can fulfil the purposes of:

- Identifying regional or sectoral hotspots (current or potential)
- Prioritising adaptation needs or crucial intervention
- Monitoring and evaluating adaptation measures
- Strategically allocating resources
- Identifying and avoiding conflicting objectives in adaptation measures

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SECTION III
From Knowledge to Action

The ICPDR follows the approach of Integrated Water Resources Management (IWRM) as basis of its activities and in particular by coordinating the implementation of the Water Framework Directive and Floods Directive in the Danube River Basin. Adaptation to climate change as a key cross-cutting issue requires the involvement of a range of relevant ICPDR Expert and Task Groups, and the Strategy provides orientation on how to utilise existing expertise for adaptation.

Guiding Principles for Adaptation to Climate Change

Guiding principles, which provide support for the integration of adaptation to climate change into river basin management, including flood and drought risk management, are structured according to the following five main fields of actions, allowing orientation for relevant experts dealing with specific issues in the frame of river basin management:

- **I.** Climate modelling, projections, scenarios, potential impacts and uncertainty
- **II.** How to build adaptive capacity for management under climate change?
- **III.** Water Framework Directive and adaptation
- **IV.** Flood risk management and adaptation
- **V.** Drought management, water scarcity and adaptation

Overview of Possible Climate Change Adaptation Measures

Adaptation should start now with a priority on win-win, no-regret and low-regret measures, which are flexible enough for various conditions. The adaptive approaches within the management framework also require flexibility so they can be modified if new information or understandings become available. This way of working has the benefit of increasing resilience and decreasing vulnerability for the whole Danube ecosystem. It has to be pointed out that the ICPDR Strategy on Adaptation to Climate Change focuses on basin-wide adaptation measures facing the challenges of climate change of the next decades. However, additional or adapted measures may well be necessary due to local characteristics. The adaptation measures can be classified into five different categories, targeting different objectives. Preparation and technological measures target monitoring and infrastructural issues; eco-system based measures should enhance the capacity of eco-systems to adapt, and behavioural and managerial measures aim at raising awareness and encouraging knowledge exchange. Policy approaches are most important for basin-wide transboundary solutions.

An overview of possible adaptation measures for the most relevant impact fields is included with a link to an online tool, which supports users in obtaining detailed information on the measures of interest.

ICPDR Approach for Integrating Climate Change Adaptation

Climate change is a cross-cutting issue, causing impacts to different sectors on a transboundary scale. The quality of water and its availability are very much at the heart of the expected changes and therefore require coordinated action in an integrative way. Due to the transboundary character of water and its relevance for various issues and water-related sectors such as its role for biodiversity and the ecosystem, energy, transport, agriculture, floods and droughts, integrated river basin management is key for the ICPDR's approach to climate change adaptation. Building on this basic rationale, work on climate change adaptation is anchored in existing ICPDR structures and planning instruments as well as the corresponding national institutions and structures.

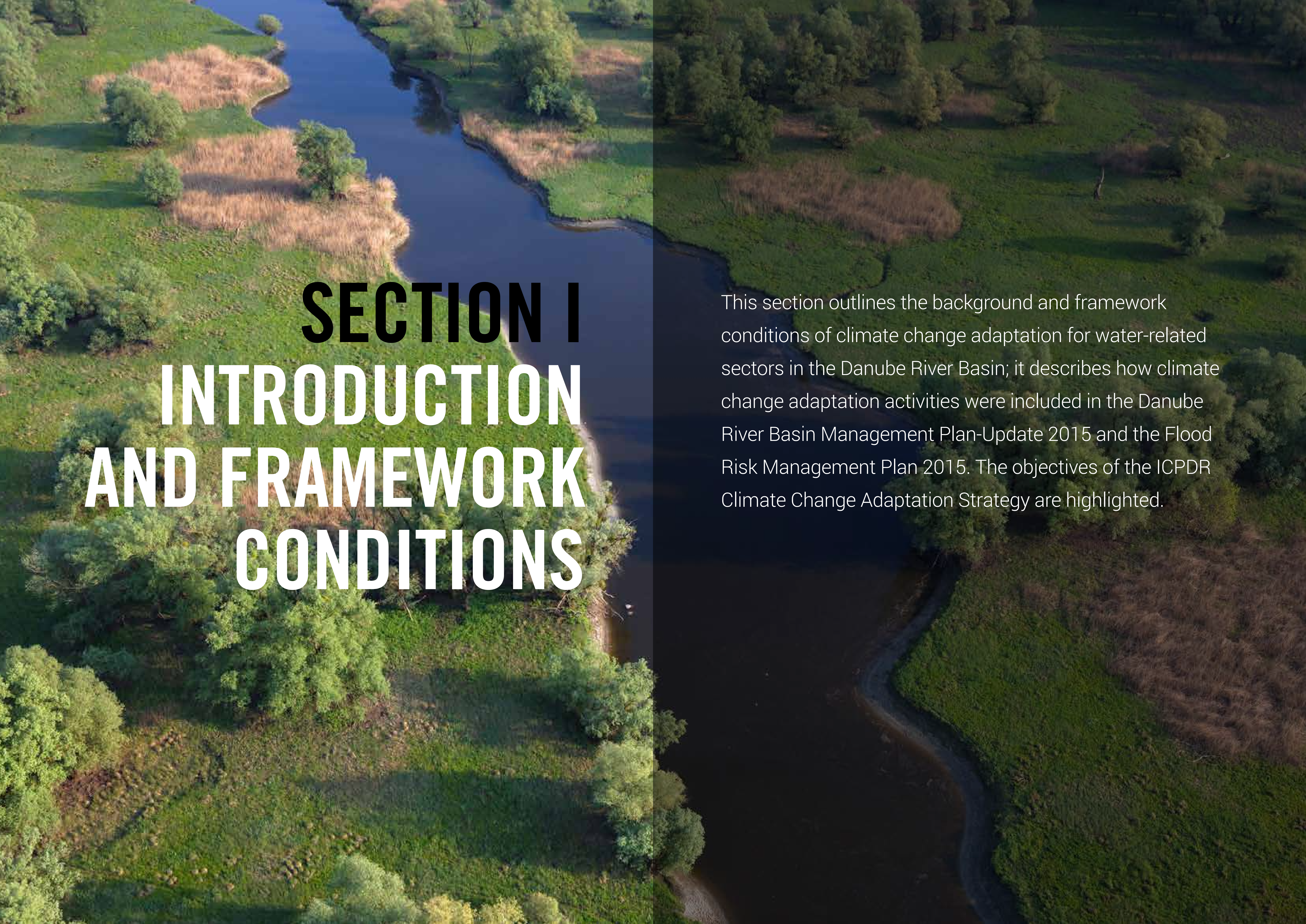
The ICPDR approach for integrating climate change adaptation in ICPDR activities includes a joint understanding of scenarios, impacts and adaptation measures and does not include a separate programme of measures, but relevant action is incorporated in the Danube River Basin Management Plans and Flood Risk Management Plans. The ICPDR Climate Change Adaptation Strategy focuses on issues relevant at the Danube basin-wide level (level A) and needs to be complemented with further detailed planning for adaptation at sub-basin, national and/or sub-unit levels. Consultation on competing uses and priorities to prevent potential conflicts is needed to take into account potential target conflicts and competition between different water-related users and sectors such as agriculture, navigation, water supply, energy, industry, tourism, environment and nature protection. The communication, coordination and stakeholder involvement on climate change adaptation issues between different levels of management in the Danube River Basin is ensured at the national level through the ICPDR and also through different projects. Building resilience against climate change impacts on water resources through capacity building, transboundary cooperation and benefit-sharing is a key priority to address climate change in the Danube River Basin.

Relevance, ICPDR Activities and Next Steps

The relevance of the Danube basin wide Climate Change Adaptation Strategy for Danube countries – in addition to national and regional strategies – is in particular seen in the context of promoting action in a multilateral and transboundary context as outlined as one of the key priorities of the EU Strategy on Adaptation to Climate Change. The ICPDR Climate Change Adaptation Strategy serves as a reference document influencing national strategies and activities in general and more specifically providing input for national RBMPs and FRMPs on possible adaptation measures of relevance for the Danube River Basin.

To underline the added value of a basin-wide strategy, ICPDR activities including the ICPDR Transnational Monitoring Network (TNMN) and the planned Danube Hydrological Information System (HIS), expanded knowledge and exchange of information on water scarcity and droughts as well as other ICPDR activities such as the planned Guidance document on sustainable agriculture in the Danube River Basin covering climate change aspects are outlined. A close cooperation with the JRC in regional modelling of climate change scenarios for the Danube River Basin is ongoing.

Awareness of ongoing adaptation processes is created and an exchange takes place between experts working on adaptation at different levels, such as national, sub-basin or international levels. This will be guaranteed through the involvement of national experts in the international working groups of the ICPDR, respectively via existing coordination approaches between the basin-wide and the sub-basin level within the Danube River Basin (Sava, Tisza, Danube Delta, Prut). The ICPDR Strategy on Adaptation to Climate Change will be fully taken into account during the next steps of the implementation of the Water Framework Directive and Floods Directive in the Danube River Basin. Closing of knowledge gaps and identification of further research requirements will be constantly aimed for.



SECTION I
INTRODUCTION AND FRAMEWORK CONDITIONS

This section outlines the background and framework conditions of climate change adaptation for water-related sectors in the Danube River Basin; it describes how climate change adaptation activities were included in the Danube River Basin Management Plan-Update 2015 and the Flood Risk Management Plan 2015. The objectives of the ICPDR Climate Change Adaptation Strategy are highlighted.

1 INTRODUCTION

1.1 Background

With the publication of the 5th IPCC Assessment Report[1] human influence on the climate system and impacts on human and natural systems due to recent climate changes -has been scientifically confirmed.

Globally, atmospheric and ocean temperatures have increased, the snow cover extent has decreased and ice has diminished, and the global mean sea level has risen. Changes in many extreme weather and climate events have been linked to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme river runoff and an increase in the number of heavy precipitation events in a number of regions. Anthropogenic greenhouse gas emissions and atmospheric concentration of CO_2 and other greenhouse gases as drivers of climate change have increased since the pre-industrial era driven largely by economic and population growth.

Adaptation and mitigation measures are complementary for reducing and managing the risks of climate change. While adaptation is the process of adjustment to actual or expected climate and its effects in order to either lessen or avoid harm or exploit beneficial opportunities, mitigation is the process of reducing emissions, so as to limit future climate change. Both adaptation and mitigation can reduce and manage the risks of climate change impacts. Effective implementation depends on policies and cooperation on all scales – international, regional, national and sub-national – and can be enhanced through integrated responses that link mitigation and adaptation with other societal objectives.[2]

The main climate change impacts related to water resources are increases in temperature, shifts in precipitation patterns and snow cover, an increase in the frequency of flooding and droughts, and an increase in evapotranspiration rate over continents and water bodies. Depending on the region, climate change will have widely differing effects. Changes in water resources will have consequences for several economic sectors. Low water and droughts have severe consequences on most sectors, particularly agriculture, forestry, energy, and drinking water provision. Activities that depend on high water abstraction and use, such as irrigation, hydropower generation and use of cooling water, will be affected by changed flow regimes and reduced annual water availability. Moreover, wetlands and aquatic ecosystems will be threatened; sectors that depend on the goods and services they provide will be affected.[3]

[1] 5th IPCC Assessment Report to be downloaded from http://www.ipcc.ch/report/ar5/syr/.
[2] IPCC, Climate Change 2014 Synthesis Report: http://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf.
[3] https://www.eea.europa.eu/themes/water/water-resources/climate-impacts-on-water-resources.

1.2 ICPDR Mandate and Approach Towards Strategy Development

As a frontrunner and pioneer among transboundary river basin commissions in climate change adaptation activities, the ICPDR adopted the first ICPDR Strategy on Adaptation to Climate Change in 2012.[4] Based on its strategy the ICPDR was able to fully integrate climate adaptation issues in the updated DRBM Plan and the first DFRM Plan in 2015.

At the Danube Ministerial Meeting in February 2016 Ministers asked "the ICPDR to foresee an update of its strategy, in particular with regard to its knowledge base, in 2018 in order to prepare the updated strategy in time for the next planning cycle of the EU Water Framework Directive and EU Floods Directive". The ICPDR nominated Germany, Austria and Serbia to lead the activity within the framework of the ICPDR, with the River Basin Management Expert Group as the responsible ICPDR Expert Group steering the different activities. In support of the development of the update of the Strategy, additional experts were nominated by the Danube countries, to be involved in and provide expertise during the elaboration process.

Based on its mandate to update the ICPDR Strategy on Adaptation to Climate Change of the year 2012, the ICPDR decided to follow a step-by-step approach with the following three steps:

[4] https://www.icpdr.org/main/activities-projects/climate-change-adaptation.
[5] http://publications.jrc.ec.europa.eu/repository/handle/JRC111817.

1) Update of the existing knowledge base and scientific Danube Study as adopted in 2012

As a first step, Ludwig-Maximilians-Universität Munich (LMU) revised and updated its 2012 Danube Study on "Integrating and editing new scientific results in climate change research and the resulting impacts on water availability to revise the existing adaptation strategies in the Danube River basin" until January 2018. The study provides the basis for a common, Danube-wide understanding of the future impacts of climate change on water resources and suitable adaptation measures for the development of the updated Danube Climate Adaptation Strategy. In addition in May 2018 the JRC Technical Report "Impact of a changing climate, land use, and water usage on water resources in the Danube river basin"[5] was published. This report provided additional valuable information for developing the updated ICPDR Strategy.

2) Discussion of the key findings and conclusions of the updated knowledge base and scientific Danube Study

The key findings and conclusions of the scientific Danube Study were discussed in various ICPDR Expert Groups and Task Groups. The results were presented in a broad stakeholder involvement process at the ICPDR Climate Change Adaptation Workshop, which took place in March 2018 in Belgrade.

3) Update of the existing strategy based on current scientific results as well as legislative and policy instruments in place at the EU and Danube country levels

The discussions and output of the workshop allowed taking first steps in the update of the Strategy, which was subsequently further developed with the broad participation of relevant ICPDR Expert Groups and Task Groups, including nominated experts and ICPDR observer organizations in 2018.

1.3 Objectives

The Danube basin wide Climate Change Adaptation Strategy for Danube countries aims at promoting action in a multilateral and transboundary context as outlined as one of the key priorities of the EU Strategy on Adaptation to Climate Change. In this context, the ICPDR Climate Change Adaptation Strategy serves as a reference document influencing national strategies and activities in general and more specifically providing input for national RBMPs and FRMPs on possible adaptation measures of relevance for the entire Danube River Basin as well as for the Danube River Basin Management Plan and the Danube Flood Risk Management Plan. The ICPDR Climate Change Adaptation Strategy provides an overview of the background and framework conditions of climate change adaptation for water-related sectors in the Danube River Basin. Building resilience against climate change impacts on water resources through capacity building, transboundary cooperation and encouraging basin-wide approaches as well as benefit-sharing is a key priority and objective to address climate change in the Danube River Basin.

1.4 Climate Change Adaptation in the DRBM Plan-Update 2015 and DFRM Plan 2015

The EU Water Framework Directive, adopted in 2000, constitutes the most relevant legislation for river basin management in the European Union; it establishes a legal framework for integrated water resources management based on a river basin management approach. Additionally, the EU Floods Directive, adopted in 2007, focusing on the assessment and management of flood risks is of high priority for the ICPDR. All ICPDR contracting parties, including non-EU countries, agreed to use the ICPDR as platform for a coordinated implementation of the EU WFD and EU FD in the Danube River Basin.

The first Danube River Basin Management Plan was adopted in 2009; taking into account the six years planning cycle enshrined in the EU WFD, an update of the Danube River Basin Management Plan was performed in 2015 including updated assessments on the main pressures impacting Danube basin's waters, updated information on water status and progress achieved, as well as the joint further actions agreed by the Danube countries to be undertaken until 2021.[6] In parallel, the first Danube Flood Risk Management Plan was adopted in 2015 focusing on measures to reduce the probability of flooding and its potential consequences by addressing all phases of the flood risk management cycle.[7]

As adaptation to climate change is a key integration and cross-cutting issue in the ICPDR, ICPDR Expert Groups and Task Groups were mandated to fully integrate adaptation to climate change in the implementation of the EU WFD and EU FD in the Danube River Basin. Proposed measures of the Joint Programme of Measures went through a "climate check" of the relevant ICPDR Expert Groups and Task Groups. The DRBM Plan 2015 makes a cross-reference to the ICPDR Climate Change Strategy in chapter 6 on integration issues as well as in the Joint Programme of Measures (JPM). The Danube Flood Risk Management Plan outlines impacts of climate change in its chapter 9. Future impacts of climate change are also included in several vision and management objectives outlined in the DRBM Plan 2015.

Due to the varying severity and nature of climate impacts between regions in Europe, most adaptation initiatives will however be taken at national, regional or sub-basin levels. Apart from activities at the Danube basin-wide level, key actions on climate change adaptation are thus undertaken at national and/or sub-basin levels based on national and/or sub-basin climate adaptation strategies or adaptation plans elaborated by Danube countries.

[6] *http://www.icpdr.org/main/activities-projects/river-basin-management-plan-update-2015.*
[7] *https://www.icpdr.org/main/activities-projects/flood-risk-management.*

2
FRAMEWORK CONDITIONS

2.1
Relevant Water-Related EU Directives and Policies

The European Union strives to take climate change considerations in several legislative and policy relevant documents into account. Mainstreaming climate concerns (both mitigation and adaptation) into different policies is considered as the most effective way to address climate change and spend climate finance budgets. In 2010, a directorate-general for climate action (DG CLIMA) was established by the European Commission in order to ensure a cross-sectoral integration in all EU policies. In April 2013, the European Commission adopted an EU strategy on adaptation to climate change, which aims at making Europe more climate-resilient. By taking a coherent approach and providing for improved co-ordination, it will enhance the preparedness and capacity of all governance levels to respond to the impacts of climate change. With regard to water issues, the EU Water Framework Directive and the EU Floods Directive provide the key legislative framework for adaptation to climate change. The EU Biodiversity Strategy aims at halting the loss of biodiversity and ecosystem services.

2.1.1
EU Strategy on Adaptation to Climate Change

The EU Strategy on Adaptation to Climate Change[9] focuses on three key objectives:

- **Promoting action by Member States:** The Commission encourages all Member States to adopt comprehensive adaptation strategies and provides funding to help them build up their adaptation capacities and take action. It also supports adaptation in cities through the Covenant of Mayors for Climate and Energy initiative.
- **"Climate-proofing" action at the EU level** by further promoting adaptation in key vulnerable sectors such as agriculture, fisheries and cohesion policy, ensuring that Europe's infrastructure is made more resilient, and promoting the use of insurance against natural and man-made disasters.
- **Better informed decision-making** by addressing gaps in knowledge about adaptation and further developing the European climate adaptation platform (Climate-ADAPT) as the 'one-stop shop' for adaptation information in Europe.

In 2016, the European Commission launched an evaluation of the EU Adaptation Strategy to examine the actual implementation and performance of the strategy including an assessment of relevance, effectiveness, efficiency, coherence, and EU added value. An evaluation of the EU Strategy on Adaptation to Climate Change is planned to be completed by the end of the year 2018.

Additionally, the European Commission has recognised major challenges from water scarcity and droughts in the Communication "Addressing the challenge of water scarcity and droughts" adopted in 2007. The implementation of the Communication was periodically assessed through annual Follow-up Reports[10].

2.1.2
EU Water Framework Directive

The Water Framework Directive 2000/60/EC[11] establishes a legal framework to protect and restore the water environment and to ensure the long-term sustainable use of water. The Directive itself does not include specific provisions to address climate change impacts. However, the step-wise and cyclical approach of the EU WFD river basin management planning process makes it well-suited to handle climate change.[12] Climate change should be comprehensively considered in the different steps of the WFD implementation and river basin management planning and implementation process, such as characterisation, analysis of pressures and impacts, economic analysis, monitoring, design of the programmes of measures and water body objective setting processes.

[8] *https://ec.europa.eu/clima/policies/adaptation/what_en.*
[9] *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0216.*
[10] *http://ec.europa.eu/environment/water/quantity/scarcity_en.htm.*
[11] *https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1536557420860&uri=CELEX:32000L0060.*
[12] *European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.*

2.1.3
EU Floods Directive

The EU Floods Directive 2007/60/EC[13] establishes a legal framework for the assessment and management of flood risks, and aims at reducing the adverse consequences of floods to human health, the environment, cultural heritage and economic activity. Contrary to the EU WFD, climate change is explicitly included in the Directive; it is one of the key issues to consider when Member States undertake an initial assessment of the flood risks and draw up the risk management plans. In addition, for the implementation of the EU Floods Directive, coordination with the implementation of the EU WFD is required in order to ensure that differing and conflicting interests can be properly balanced and maximum synergies are gained.

2.1.4
EU Biodiversity Strategy 2020

The EU Biodiversity Strategy[14] aims at halting the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020. One particular target focuses on the maintenances and restoration of ecosystems. Many ecosystems and their services across the EU territory are now degraded and fragmented because of intensive agriculture, urban sprawl, grey infrastructure such as railways, roads and bridges, as well as the impacts of pollution, invasive alien species and climate change. The loss and degradation of valuable ecosystems also undermines the benefits that flow from nature to people and the economy. The Biodiversity Strategy aims at maintaining and restoring ecosystems and their services by including green infrastructure in spatial planning and restoring at least 15 % of degraded ecosystems by 2020.

2.2
National and International Climate Change Adaptation Activities

National Climate Change Adaptation Strategies of Danube countries focus on the assessment of the present situation and highlight areas likely to be affected as well as requirements for adaptation to climate change and suggested adaptation measures with regard to water-related issues at the national level.

Most of the Danube countries have a national climate change strategy in place or are in the status of preparation and have adopted national action plans. Water related issues play an important role in the National Climate Change Adaptation Strategies and reflect the growing recognition of climate change impacts and the rising awareness of the necessity to adapt to climate change. An evaluation of the adaptation tasks and applied measures of water related issues within the National Climate Change Adaptation Strategies is considered important for future updates. River Basin Management as well as Flood Risk Management Plans shall integrate key objectives of the National Climate Change Adaptation Strategies.

At the international level the UNECE Guidance on Water and Adaptation to Climate Change (2009)[15] can be mentioned which aims at supporting decision makers from the local to the transboundary and international level by offering advice on the challenges caused by climate change to water management and water-related activities and for developing adaptation strategies.

[13] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32007L0060.
[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52011DC0244.
[15] https://www.unece.org/fileadmin/DAM/env/water/publications/documents/Guidance_water_climate.pdf.

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SECTION II
KNOWLEDGE BASE

Knowledge about the magnitude of climate change and of its uncertainties as well as of the effects of a changing climate is crucial for the development and implementation of a climate change adaptation strategy. Hence, for the revision of the ICPDR Strategy on Adaptation to Climate Change, the "Danube Study – Study to provide a common and basin-wide understanding towards the development of a Climate Change adaptation strategy in the Danube River Basin", published in 2012, was revised and updated. New scientific results in climate change research and the resulting impacts on water availability were integrated and edited. Moreover, the set of adaptation measures was updated. The "Revision and Update of the Danube Study" was broadly discussed at the ICPDR Climate Change Adaptation Workshop held in Belgrade on 27/28 March 2018 and provides the main knowledge base for the update and revision of the adaptation strategy. Like the first Danube Study, it is based solely on existing and available information. The following sections summarise the main results of the Danube Study. The Danube Study also provides a comprehensive list of literature on which the statements and facts in this section are based on.

Additionally, the JRC (Joint Research Centre) Technical Report "Impact of a changing climate, land use, and water usage on water resources in the Danube river basin" – generally confirming the results of the revised and updated Danube Study – was analysed. This applies both for the trends in temperature and precipitation and for the resulting impacts on the hydrology in the DRB. The added value of the JRC Report is that the climate change effects on the entire Danube River Basin are modelled by using the state of the art climate model data. Along with this, the higher model resolution allows assessing climate change impacts on a much finer scale. This applies in particular for smaller tributary rivers, where no data was available so far. The JRC Report is the first report to provide a consistent overview of climate change impacts on the entire Danube River Basin based on the new representative concentration pathways defined in the 5th IPCC assessment report. This includes the lower Danube River Basin, which has been characterized by data scarcity and too little available information, respectively. Furthermore it is the first report which attempts to assess the impacts of land use change on the hydrological system.

3
CLIMATE CHANGE SCENARIOS FOR THE DANUBE RIVER BASIN

Future development of climate parameters is assessed by analysing results of various global (GCM) and regional climate models (RCM). Most of the analysed projects and documents on future climate projections are based on model results that used the IPCC SRES (Special Report on Emissions Scenarios) emission scenarios. The SRES scenarios reflect a range of possible future societal, economical, and technological developments, resulting in a range of possible future atmospheric greenhouse gas concentrations. The scenarios used the most are the A1B and A2 scenarios. With the 5th Assessment Report of the IPCC in 2014[16], the SRES scenarios were superseded by the representative concentration pathways (RCPs) in which particular radiative forcing on top of the atmosphere were defined. Various societal, economical, and technological developments may result in the same radiative forcing, which causes a particular temperature increase. RCP8.5 is the one mostly used in the analysed projects and documents. The second most commonly used pathway is RCP4.5, where the increase in global mean temperature may remain below 2 °C by the end of the century (compared to a reference period of 1986 to 2005)[17]. This would mean that the goals of the Paris Agreement (2015)[18], which set a limit of 2 °C compared to preindustrial times, would be achieved. Despite RCPs having replaced SRES scenarios, they have been underrepresented in projects and documents since 2012. The main reason is that projects, which are based on the newly defined RCPs, are still ongoing or have just started and only a few have been completed so far. There are a huge number of different RCMs with various underlying scenarios applied in the Danube region. However, downscaling products from the EURO-CORDEX[19] (Coordinated Regional Climate Downscaling Experiment) initiative can be regarded as the most advanced and up-to-date ones.

The development of the future climate was assessed by analysing the climate parameters temperature, precipitation, and their extremes. The most certain and reliable trends are found for temperature values. In contrast, results for precipitation development are more ambiguous within the analysed projects. Nevertheless, findings regarding changes in precipitation seasonality are very certain. The results of the evaluated new projects mainly confirm findings of the first Danube Study and thus allow more precise statements with higher certainty. The findings often agree in the sign of changes but differ in magnitude. In some areas results do not agree or are contradictory.

[16] *IPCC, Climate Change 2014 Synthesis Report.*
[17] *5th IPCC Assessment Report to be downloaded from http://www.ipcc.ch/report/ar5/syr/*
[18] *Paris Agreement 2015: https://treaties.un.org/doc/Treaties/2016/02/20160215%2006-03%20PM/Ch_XXVII-7-d.pdf.*
[19] *EURO-CORDEX is the European branch of the international CORDEX initiative, which aims to improve regional climate downscaling. EURO-CORDEX provides data on regional climate change. For further information see Jacob et al. 2014 (doi:10.1007/s10113-013-0499-2).*

Table 1

Explanation of IPCC SRES A1B and A2 scenarios and RCP 4.5 and RCP 8.5

A1B
A balanced energy production across all energy sources is reflected in the A1B-scenario embedded in the A1-storyline that describes a future world of very rapid economic growth, a global population that peaks in the middle of the century, and the rapid introduction of new and more efficient technologies
A2
The A2-storyline describes a very heterogeneous world with a preservation of local identities and a primarily regionally oriented economic and technological development. Hence the global population continuously increases. The A2-scenario reflects a future with high emission rates.
RCP4.5
Stabilised radiative forcing without overshooting to 4.5 W/m² shortly after 2100. This equals to an increase of global mean temperature of 1.1-2.6°C (mean: 1.8°C) at the end of the century.
RCP8.5
Greenhous gas emissions increase over time which leads to a radiative forcing of 8.5W/m². The increase of global mean temperature by the end of the century will be in a likely range of 2.6-4.8°C (mean: 3.7°C).

When analysing climate development, usually the mean of a 30-year future period is compared to the mean of a 30-year reference period in the past. The mostly used reference periods in the documents are 1971-2000 and 1961-1990. The future is mainly divided into a near future until 2050 and a far future until 2100. It has to be noted that there may be many years within these periods where temperature or precipitation values are much higher or lower than the mean value. In addition, temperature and precipitation changes are described for meteorological seasons, i.e., spring includes the months March, April, and May; summer is June, July, and August; autumn includes September, October, and November; and winter is defined as the months December, January, and February.

There is general agreement that extreme weather events are increasing in most parts of the Danube basin. However, extreme events, especially heavy rainfall, are very difficult to model and therefore the results are associated with higher uncertainties. Unlike the first adaptation strategy, examples of expected changes are not illustrated on a country-by-country basis but on a higher resolution to show the regional differences, even within a country. Reference data for the following maps *(Figure 2 to Figure 5)* are EURO-CORDEX ensemble runs (status: September 2018) of the period 1981 – 2010 and thus represent the most advanced and up-to-date results.

3.1
Air temperature

Identified trends from the first Danube Study are largely confirmed by the update and show a general increase in future annual and seasonal air temperature with a gradient from northwest to southeast for the Danube River Basin. This trend is very certain (for detailed explanation on the criteria used to evaluate certainty see section 4.2 and Danube Study page 16pp). The documents available for the Danube Study show a regionally varying increase in mean annual air temperature between 0.5°C and 2.6°C until the middle of the 21st century.

The increase reported in these documents is projected to intensify until the end of the century with values between 1.8°C and 5.4°C. The following figures show modelling results from the EURO-CORDEX project. The range of increase of annual mean temperature for the near future period (until 2050) under RCP4.5 is between 1.1°C and 1.5°C and for the far future period (until 2100) 2.0°C and 2.6°C relative to the reference period 1981-2010 *(Figure 2)*. The ranges for temperature increases under RCP8.5, are 1.3°C - 1.7 °C and 4.0°C – 5.0 °C. *(Figure 3)*. Modelling results from EURO-CORDEX offer a more differentiated view with regard to spatial heterogeneity of the range of temperature increase and show pronounced warming hotspots in the alpine area and southeast Europe *(Figure 2 and 3)*.

Key messages and changes compared to the 2012 strategy

- Transition from SRES scenarios to RCPs
- Highly certain temperature increase all over the DRB
- More differentiated picture of temperature changes due to advances in climate modelling → warming hotspots
- Confirmation of general trends shown in the 2012 strategy

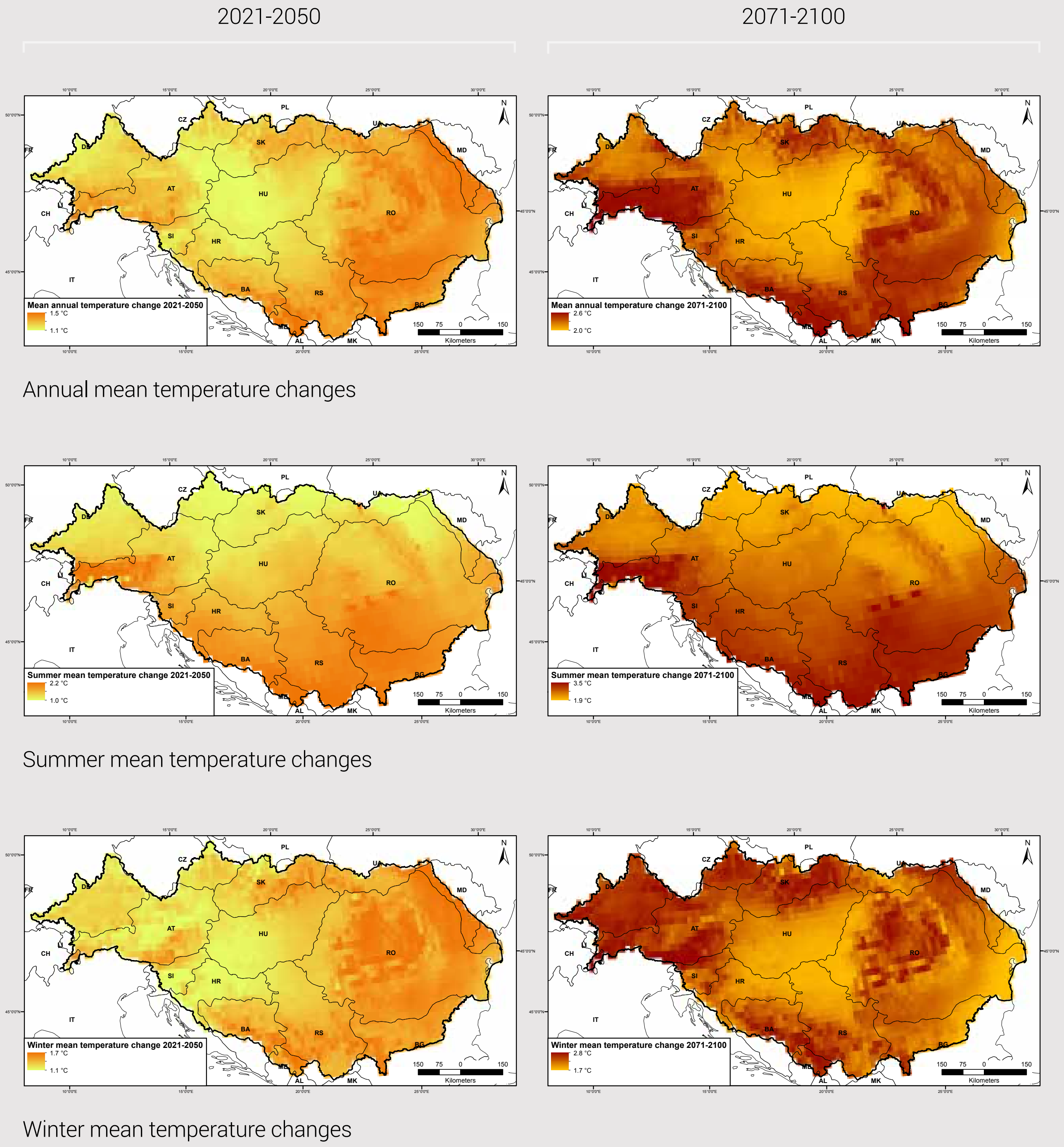
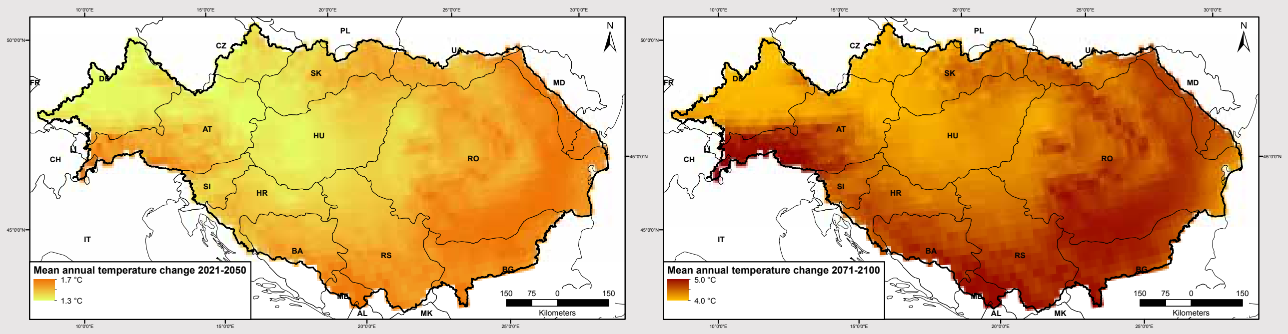
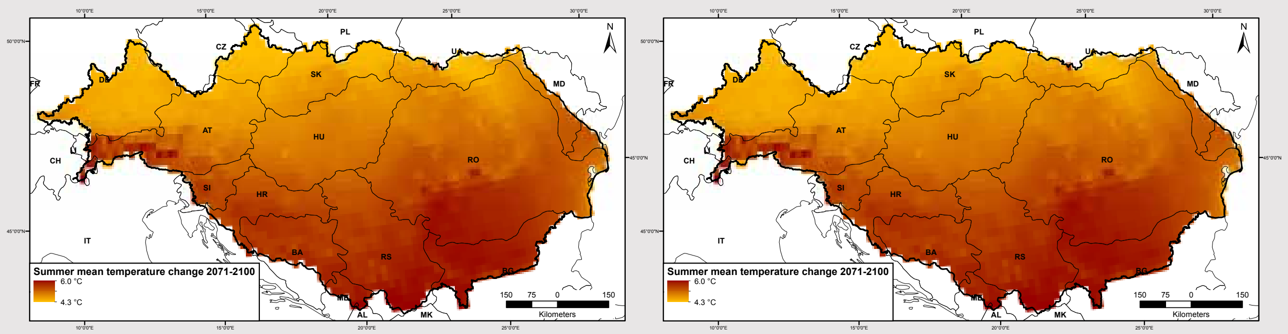


Figure 2: Change of mean annual, summer (JJA) and winter (DJF) temperature in the Danube River Basin for 2021-2050 and 2071-2100 according to RCP4.5 of the EURO-CORDEX ensemble results (Status: September 2018)

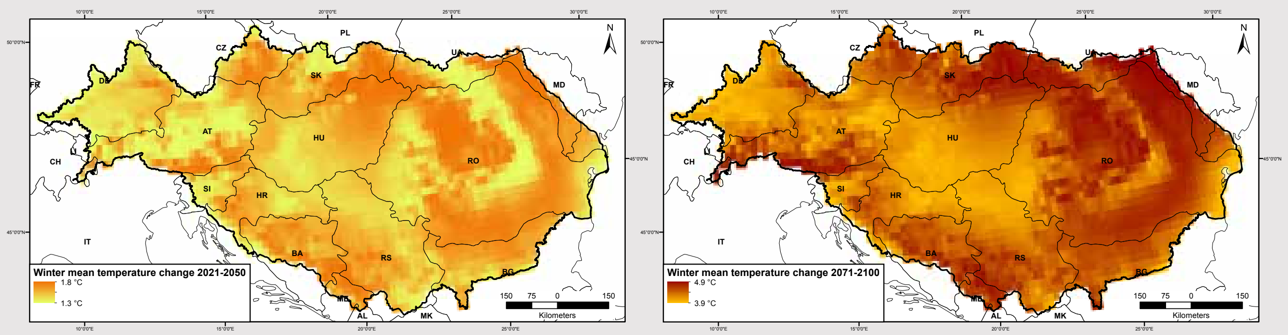
2021-2050 | 2071-2100



Annual mean temperature changes



Summer mean temperature changes



Winter mean temperature changes

Figure 3: Change of mean annual, summer (JJA) and winter (DJF) temperature in the Danube River Basin for 2021-2050 and 2071-2100 according to RCP8.5 of the EURO-CORDEX ensemble results (Status: September 2018)

3.2
Precipitation

The Danube River Basin is located in the transition zone between expected increasing (in Northern Europe) and decreasing (in Southern Europe) future precipitation. Documents analysed in the update of the Danube Study confirm this general trend of wet regions becoming wetter and dry regions becoming drier. The trend is more obvious in the second half of the century. Although the mean annual precipitation in many regions will probably remain almost constant, a tendency for the next decades towards more precipitation (than in the last decades) in the northern parts of the basin and less precipitation in the southern parts is apparent. The general trend of wet regions becoming wetter and dry regions becoming drier is also reflected in the alpine region, where the already drier south-eastern part of Austria is likely to become drier.

According to the documents analysed in the first and second Danube Study, trends in mean annual precipitation are rather insignificant until the middle of the century and become significant until the end of the century. However, the most significant change is projected in seasonal precipitation distribution. The summer months are likely to become drier (up to -58%) whereas the winter months show a tendency for increasing precipitation (up to +34%). The numbers indicate the maximum expected decrease and increase for greater regions in the Danube River Basin but numbers in particular regions may vary largely *(see Figure 4 and 5)*. The figures display the precipitation change from the EURO-CORDEX initiative in mm relative to the reference period 1981-2010. The comparatively clearest trends are increasing winter precipitation in mountain regions and decreasing summer precipitation in regions already suffering from too little precipitation. On the other hand, there are regions where summer precipitation is projected to increase *(figure 5)* due to increased frequency of thunderstorms and short heavy precipitation events.

Because the general trend is consistent in most simulations, the certainty level for precipitation in Figure 4 is high; however, compared to air temperature it is less robust and reliable (see section 4.2 and Danube Study). Moreover, it has to be distinguished between mean annual precipitation (Figure 4), where trends are less certain and the future seasonal distribution of precipitation *(see Figure 5 and 6)*, where trends are highly certain.

As for temperature trends, studies that are based on the newly implemented RCPs (e.g. the JRC report 2018)[20] mostly confirm previous results. Furthermore, data from the EURO-CORDEX initiative provides a more detailed picture of spatially distributed trends *(see Figure 4 to 6)*.

Higher temperatures in winter affect the cryosphere. Instead of snow, it might rain more often and, together with an earlier beginning of snow melt, the snow cover is expected to decrease and the snow season thus becomes shorter at all altitudes. However, some findings for mountainous areas state no trend or even a slight increase of snowfall due to a possible increase in winter precipitation. Glaciers show a significant retreat in the DRB. Climate change leads to the total disappearance of glaciers in all mountainous areas of the Middle Danube River Basin (MDRB). In the alpine part of the Upper Danube River Basin (UDRB), only a few small glaciers will remain in the far future.

[20] *Bisselink, B., Bernhard, J., Gelati, E., Adamovic, M., Jacobs, C., Mentaschi, L., Lavalle, C. and De Roo, A., Impact of a changing climate, land use, and water usage on water resources in the Danube river basin, EUR 29228 EN, Publications Office of the European Union, Luxembourg, 2018.*

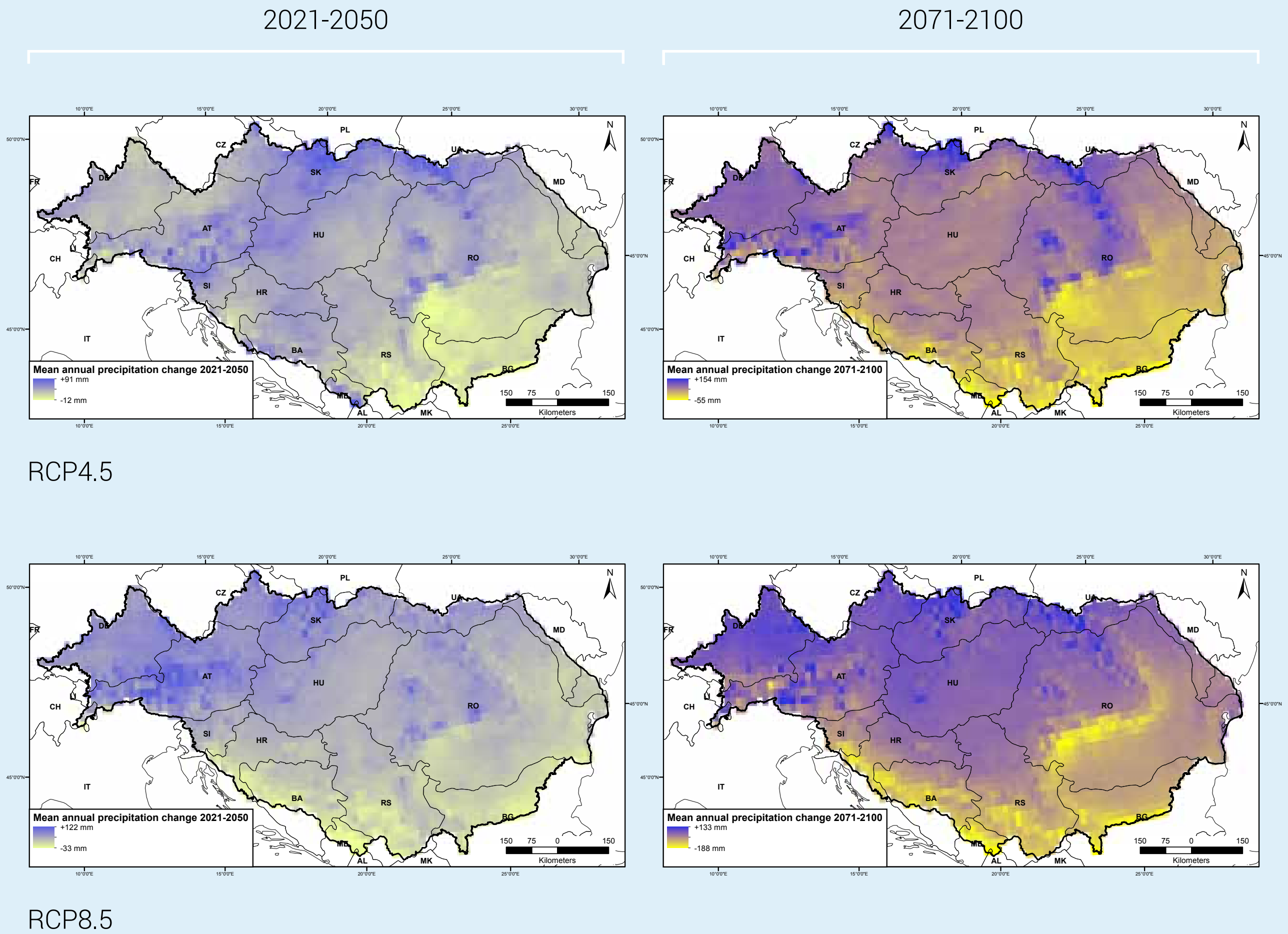
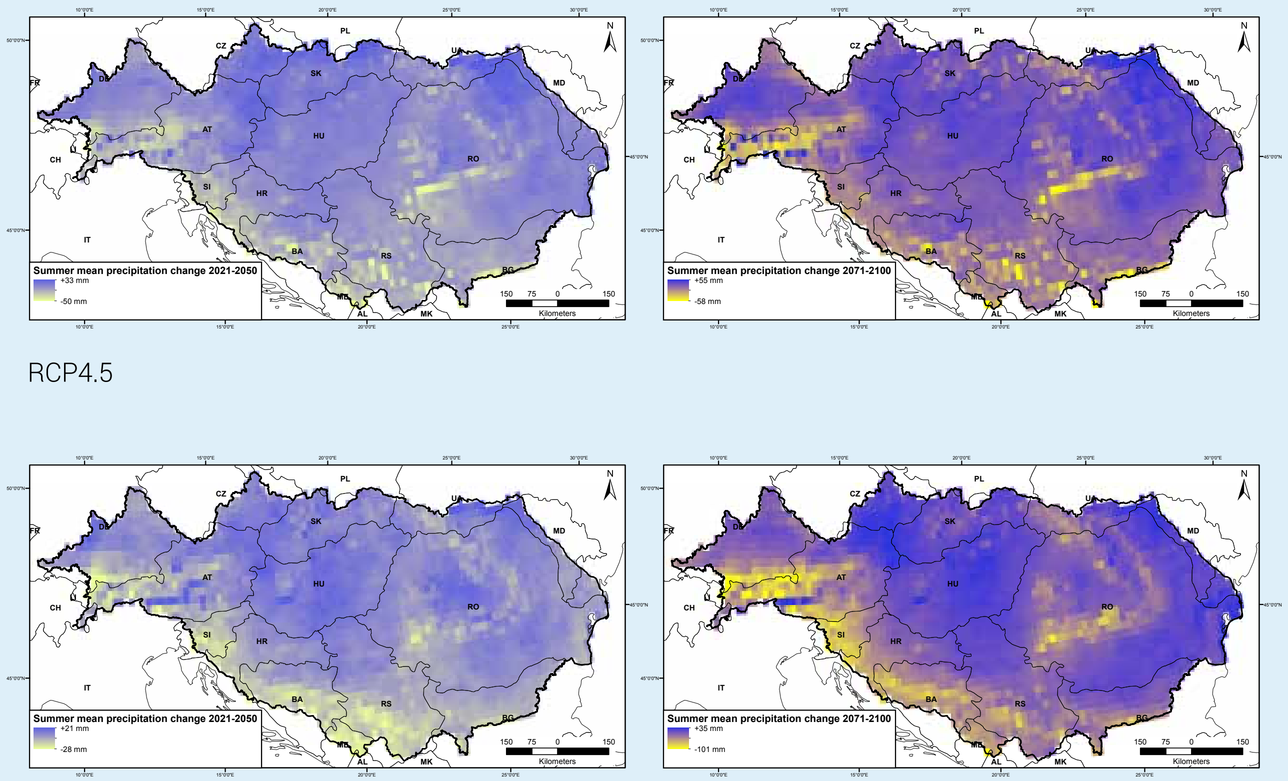


Figure 4: Change of mean annual precipitation in the Danube River Basin for the periods 2021-2050 and 2071-2100 according to RCP4.5 and RCP8.5 of the EURO-CORDEX ensemble runs (status: September 2018)

Key messages and changes compared to the 2012 strategy
- Wet regions become wetter, dry regions become drier
- Strong precipitation gradient: northwest (high) – southeast (low)
- Insignificant trends in mean annual precipitation
- Highly certain significant changes in seasonality → wetter winters, drier summers
- More differentiated picture of precipitation changes due to advances in climate modelling

2021-2050 | 2071-2100



RCP4.5

RCP8.5

Figure 5: Change of mean summer (JJA) precipitation in the Danube River Basin for the periods 2021-2050 and 2071-2100 according to RCP4.5 and RCP8.5 of EURO-CORDEX ensemble runs (status: September 2018)

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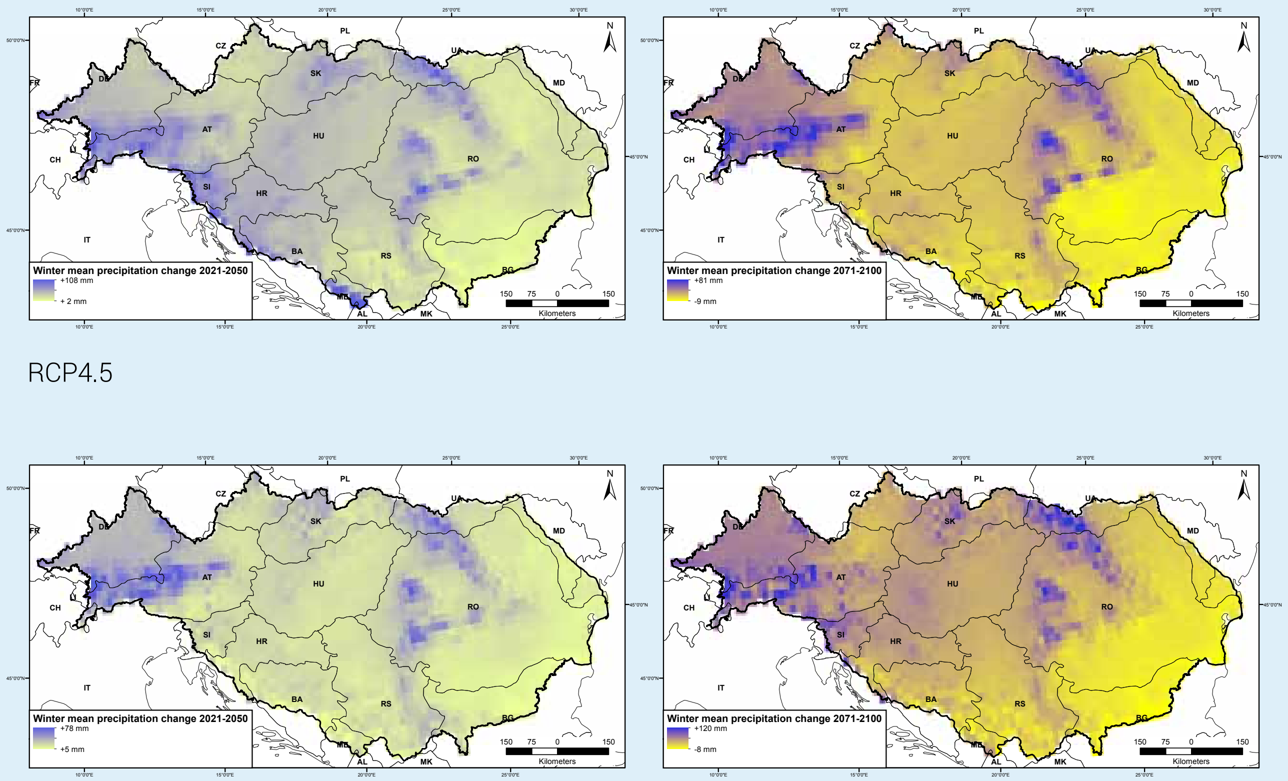
2021-2050 | 2071-2100



RCP4.5

RCP8.5

Figure 6: Change of mean winter (DJF) precipitation in the Danube River Basin for the periods 2021-2050 and 2071-2100 according to RCP4.5 and RCP8.5 of EURO-CORDEX ensemble runs (status: September 2018)

3.3
Extreme Weather Events

A future increase in extreme weather events is expected for the whole Danube River Basin. The simulations show both, a future increase in the intensity and frequency of dry spells, hot days and heat waves, as well as local and regional increases in heavy rainfall, although the latter is uncertain in spatial and temporal localisation. For the Upper Danube River Basin, an increased risk of storm-related heavy precipitation with high wind speeds is assumed. For the Middle Danube River Basin, it is expected that the occurrence of extreme precipitation days will be intensified in winter and reduced in summer. Due to the warming trends for the whole basin, fewer frost days are expected in winter. Generally, statements from the first Danube Study are confirmed by the update. Nevertheless, most recently analysed documents show a more pronounced trend towards seasonality in the occurrence of extreme events. Therefore, the agreement concerning an increasing number of extreme winter precipitation events over Europe for the far future period must be emphasised. Statements regarding extreme summer precipitation especially in Eastern Europe are inconsistent.

Key messages and changes compared to the 2012 strategy

- General increase in extreme weather events (intensity and frequency)
- Difficult spatial and temporal localisation of extreme events
- Confirmation of general statements presented in the 2012 strategy

4
WATER-RELATED IMPACTS OF CLIMATE CHANGE IN THE DANUBE RIVER BASIN

4.1
Overview of the Main Impacts

Alongside the already mentioned regional and seasonal temperature and precipitation changes expected in the course of this century, the direct and indirect effects of these changes are of essential interest. This includes impacts on different fields related to water availability, extreme hydrological events, water quality, water and land use, and ecology. Despite the high heterogeneity and the often low comparability of the project results, the expectations for future climate conditions and their related impacts show mostly similar trends. Hence, only qualitative information can be given for the different impact fields instead of quantitative or probabilistic statements. For the main fields, the expected impacts are listed in the following tables. The JRC report of 2018 [21] is the first report to investigate climate change impacts on runoff and water availability, floods, drought, low flows, water scarcity, and on the energy sector, especially for the DRB using EURO-CORDEX data. It largely confirms the results of the Update and Revision of the Danube Study. Contradictions for mean runoff and water availability are mentioned in the impact tables below.

[21] Bisselink, B., Bernhard, J., Gelati, E., Adamovic, M., Jacobs, C., Mentaschi, L., Lavalle, C. and De Roo, A., Impact of a changing climate, land use, and water usage on water resources in the Danube river basin, EUR 29228 EN, Publications Office of the European Union, Luxembourg, 2018.

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Table 2

Expected impacts on water availability

For the next few decades, a decrease in water availability for the southern and eastern parts of the DRB is indicated, whereas in the northern and western parts no trend or even a slight increase is projected. Changes in water availability can highly differ locally or regionally. This may result in medium to severe water stress in the MDRB, and in severe water stress in the Lower Danube River Basin (LDRB). Water stress is expected to remain low in the UDRB because of generally high water availability there. It is expected that regions affeced by water stress will shift northwestward, which leads to increasing water stress in the UDRB by the end of the 21st century.

Runoff
Insignificant changes until the middle of the 21st century and a significant decrease of mean annual runoff until the end of the 21st century are projected for the entire DRB. Even in the UDRB, the area with the highest water availability, water shortages are expected in unfavourabel areas in the far future. In contrast the JRC report of 2018 projects a slight increase of mean annual runoff in the DRB. Runoff seasonality will change largely resulting in a future increase of the mean discharge in winter and a decrease in summer for the entire DRB. However, the JRC report of 2018 shows no increased winter streamflow in the UDRB. Seasonal changes may differ locally. The main causes are changes in precipitation and in snow (and ice) storage. A decrease in snow precipitation, and accordingly in snow cover, together with an earlier snow melt, causes a shorter snow season in all altitudes and will in turn lead to a shift of the runoff regime. In the head watersheds of the Alps and the Carpathian Range, this will cause a shift in peak runoff from early summer to spring, with an increasing risk of floods also in the surrounding lowlands. An increase in glacier melt has relevance only for the summer runoff situation in the head watersheds and has almost no influence on the runoff regime of larger river systems.

Snow/Ice/Permafrost
Decrease of water storage in form of snow and ice. A further retreat of permafrost in mountainous regions will lead to a higher frequency of rock falls, other natural hazards and more sedimentation in rivers.

Groundwater
A general decline in groundwater storage and recharge for Central and Eastern Europe, especially in summer, is assumed. Besides shortages in water availability, a decline in groundwater recharge could also lead to negative effects for groundwater quality. Additionally, a possible increase in irrigation using groundwater resources could intensify the decline. Regarding regional differences, a pronounced decline is particularly indicated for the Pannonian Plain Area, which has already been monitored in the past. For some alpine regions, however, a local increase in groundwater storage is likely to occur.

Evaporation
Mean annual potential evaporation will increase due to warmer temperatures in all regions of the DRB, especially in summer, which can even lead to an acceleration of water stress. In regions with low water availability, such as the southeastern parts of the DRB, actual evaporation will decrease, especially during dry periods, because less water is available to evaporate or transpire through plants.

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Table 3

Expected impacts on extreme hydrological events

In general, it is less reliable to model the future development of extreme hydrological events such as floods than changes in the average water balance although intensification of hydrological extremes is frequently menitioned as one of the most relevant impacts of climate change. This is especially true at the local scale. The assessment of future floods therefore includes high uncertainty. However, there is consensus that extreme hydrological events will occur more often and be more intense. Extreme weather events sometimes have a significant impact on hydrology. Therefore, torrential rainfall may cause a flash flood and a dry and hot period may cause a drought situation. Since extreme weather events are expected to become more frequent and intense, extreme hydrological events are expected to follow. The main causes are the expected future changes of temperature and precipitation patterns. Anthropogenic developments (e.g. land use changes, silting up of flood plains, and overgrowth of flood channels by vegetation or river regulations) will influence future flood appearances. Moreover, the scale has to be strongly considered when looking at extremes since impacts can differ greatly or even be opposite depending on the scale.

Drought/Low flow/Water scarcity

Drought/Low flow/Water scarcityWithin the DRB, drought and low flow events, as well as water scarcity situations, are likely to become more intense, longer and more frequent. The most affected rivers will be smaller tributary rivers in the South and East. The frequency could increase especially for moderate and severe events. Due to less precipitation in summer, these extreme events will occur more frequently in summer than in winter. In some parts of the DRB, the drought risk is expected to increase dreastically in the future, leading to possible economic loss, potential for water conflicts and water use restrictions. The Carpathian Area, particularly the southern parts of Hungary and Romania, as well as the Republic of Serbia, Bulgaria and the region of the Danube Delta, are likely to face severe droughts, and water stress resulting in water shortages. In alpine areas (e.g. some glaciated alpine watersheds of Austria) as well as areas in the north west, no clear trend or even a slight improvement of the mean annual low flow and drought situations were identified. This is supported by the JRC report of 2018. Therefore, alpine head watersheds remain important for downstream areas during drought periods. Due to the huge amounts of water in the Danube downstream section, no critical intensification is projected for this section of the Danube river itself until the end of the century. However, smaller tributary rivers will face an intensification of drought and low flow events. The future low flow situation also depends on changes in water use, which could worsen or improve the general trend.

Flood

Generally an intensification of flood events all over the DRB is expected. Small and mountain catchments will be most affected. Within the basin, there are different local tendencies, especially for the development of extreme flood events. An increase in flood intensity and frequency is likely to occur with emphasis on small and medium flood events, especially in alpine regions in late winter/spring, triggered by changes in winter precipitation and snow storage.

Flash flood

Short-term flood events may occur more frequently. For small catchments, an increase in flash floods due to more extreme weather events (torrential rainfall) is expected (e.g. in the Carpathian Range or the Sava and Tisza headwaters).

Table 4

Expected impacts on water quality

Following the future increase in air temperature, water temperature will most likely increase in the DRB. Due to changes to all temperature-dependent chemical and biological processes, as well as increasing flood and drought events, the pressure on water quality in rivers and lakes will increase.

Water temperature

Exact numbers differ regionally and locally, but 1-2 °C are often mentioned, particularly of surface waters and groundwater in summer. Freezing periods in winter are most likely reduced and the ice cover on lakes and rivers may decrease.

Water quality

Water quality is expected to be reduced (e.g. by a decreasing oxygen concentration in rivers, aquifers and lakes). Increased algal blooms may appear with higher water temperatures. More frequent flooding and flash floods can cause a higher mobility of particle-associated pollution, and changes of the redox balance of inorganic compounds can cause the release of organic colloids. After long droughts, preferential flow paths are of particular relevance in groundwater protection zones given the fact that pollutants can pass rapidly along them and almost unimpeded into groundwater. Water quality issues are considered as one of the most relevent climate change impacts.

Table 5

Expected impacts on water use / land use

Climate change may affect all types of land use. An intensification of extreme events, such as floods and droughts, leads to high impacts for agriculture, forestry and industry, as well as built-up areas and infrastructure. As a consequence of decreasing water availability, a shortage in water supply is expected. An increased risk of conflicts over water use can occur in the event that no adequate adaptation measures are taken. Possible consequences are difficulties in water supply with an increased risk of water shortages and an over-exploitation of aquifers in the future. Besides climate change impacts, future water demand is also triggered by anthropogenic impacts, political regulations and restrictions, and new technologies.

Water supply

An assumed general increase in water demand for households, industry and agriculture, together with pronounced water scarcity during summer in the Lower and Middle Danube Basin and in some areas of the UDRB, is likely to lead to high water stress. Industrial production losses are possible during droughts and hot summers due to scarce water supply, as well as increased difficulties in accessing water resources and higher costs for water resource use.

Water demand

Due to a warmer climate, increased water demand by, and water withdrawal for, agriculture, industry, energy and human consumption is probable, especially in the southeast DRB and in the hot season. This includes increased water use, for example, for garden watering and field irrigation, household showers and cooling water for industrial plants.

Agriculture

Because of warmer and drier summers, water demand for livestock and irrigation can become higher. Additionally, the appearance and development of pests and diseases can increase. Moreover, a shift of species will take place all over the DRB. In the UDRB, water availability will be high enough for productive farming. In the MDRB, and especially in the LRDB, a shortening of the growing season with yield losses is expected. Due to more unstable weather conditions, the inter-annual variability of crop yields will increase, so that farmers will have higher economic risks.

Irrigation

Irrigation for agricultural purposes is likely to increase in the entire DRB, especially in the southeastern parts, due to an expected expansion of droughts during the growing season in the future. In some areas there will be too little water available for irrigation of the entire agricultural land. An increase may deteriorate the ecological and chemical balance of freshwater bodies and could lead to an increase of contaminated surface and groundwater bodies after enhanced agricultural use.

Navigation

More frequent limited or impassable navigation conditions are expected due to more frequent extreme water levels and unstable conditions, especially on routes comprising free-flowing river reaches. Higher future temperatures in winter have a positive effect because of less frost and icing. Low water levels lead to reduced cargo and limited navigability. This is particularly true for the MDRB countries Slovakia and Hungary, especially in summer for the hot lowlands with less precipitation in future. The development of navigability in the MDRB also depends on climate change impacts in the upper area. For the UDRB, a consistent conclusions regarding low flows and its effect on navigationcannot be made.

Hydropower

Future mean annual and mean summer hydroelectric power generation is likely to decrease in the DRB, although increases can occur in winter due to changes in water availability. However, the degree of change is expected to differ regionally and locally, and depends, inter alia, on the type and strategic plans of each hydropower station. The decline of the mean annual and mean summer production values can be especially pronounced in the southeastern parts of the DRB. Particularly in mountain areas, a possible seasonal shift due to changes in precipitation and snow cover with a more balanced production over the year is expected. Damages due to increasing flood events are possible.

Thermal electricity production

Possible temperature loads may increase and become problematic in the future. Thermal power stations using cooling water will be seriously affected if water becomes warmer and additionally the amount of available water decreases.

Forestry

A lower productivity and health status of forests due to an increase in droughts is possible, especially in the southeast. However, due to higher annual temperatures, the length of the growing season may be extended. Changes in the distribution, density and biodiversity of forests are also assumed. Forests may be impacted by an increasing risk of damage from forest-weakening pests (e.g. bark beetle), storms and forest fires. Cold- and snow-related damages are likely to become less common, while an increase in spring frost damage is possible.

Table 6

Expected impacts on ecology

An increase in air and water temperature, combined with changes in precipitation, water availability, water quality and increasing extreme events, such as floods, low flows and droughts, may lead to changes to ecosystems, life cycles, and biodiversity in the DRB in the long-term. This is frequently mentioned to be one of the most relevant climate change impacts. The habitats and ecosystems in the southeastern region of the DRB and in the Hungarian Great Plain area are especially likely to become drier and more fire accidents might occur.

Biodiversity

Migration patterns are expected to expand northeastward and to higher altitudes, whereby a rearrangement of biotic communities and food webs, and an earlier onset of life cycles, could take place. Certain species will likely face extinction.The species expected to disappear are mainly native, whereas invasive species may increase.

Ecosystems

Higher stress for aquatic ecosystems, predominantly for littoral communities and fish, may occur, especially in the MDRB and LDRB. Shifts of and changes to aquatic and terrestrial flora and fauna are expected. Some aquatic systems show a higher risk of algal blooms and eutrophication, indicating an endangerment of lakes and wetlands.

Soils/Erosion

Nearly all regions of the DRB show a possible decrease of soil water content. Longer dry soil periods are predicted, especially for the MDRB and LDRB regions during summer droughts.Therefore, soil degradation is also possible in these regions. Changes in precipitation patterns and an increase in torrential rain and flash flood events can lead to more intense soil erosion. An increase in soil temperature especially affects physical, chemical and biological processes occurring in top soil layers. Sedimentation in the river system is likely to increase due to more extreme events and permafrost thawing.

Limnology

The water temperature of the top lake layer will increase remarkably. This could lead to changes to lake stratification and energy balance. A decrease in lake levels is possible, especially in summer.

Marine coastal zones

Increasing sea surface temperatures could lead, for example, to a redistribution and loss of marine organisms, an increase of invasive species and an increase in toxic bloom events. Rising sea levels could trigger coastal erosion with damage to buildings and a retreat of the inland coast, as already monitored in the Danube Delta and the Romanian coastline of the Black Sea. Higher sea levels will likely increase the salinisation of estuaries and land aquifers with saltwater intrusions, and will reduce the coastal protection of dams and quay walls.

Table 7 summarises the trends of projected climate change and impacts for the Danube River Basin sub-regions and the entire Danube River Basin in different sectors. It provides an overview of the trend indicating whether the trend is beneficial or adverse or neither beneficial nor adverse for the whole Danube River Basin as well as specified for the upper, middle and lower part of the Danube River Basin.

Table 7

Trend of projected climate change and impacts for the DRB sub-regions

Sector	*UDRB* *Upper Danube River Basin*	*MDRB* *Middle Danube River Basin*	*LDRB* *Lower Danube River Basin*	*DRB* *Danube River Basin*
Changes in the climate system				
Mean annual air temperature	↗	↗	↗	↗
Mean summer air temperature	↗	↗	↗	↗
Mean winter air temperature	↗→	↗	→↘	↗
Mean annual precipitation	→	↗↘		↗↘
Mean summer precipitation	↗↘	↘	↘	↘
Mean winter precipitation	↗→	↗↘		↗→
Heat extremes	↗	↗↘		↗
Extreme precipitation	↗	↗→	↗	↗
Changes in discharge / water availability				
Mean annual discharge	↗→	→↘	→↘	→↘
Average summer discharge	↘	↘	↘	↘
Average winter discharge	↗	→↘	↘	→↘
Timing of the annual peak flow	↘	↘	↘	↘

Legend on page 47

Sector **Changes in droughts and low/flows**	UDRB Upper Danube River Basin	MDRB Middle Danube River Basin	LDRB Lower Danube River Basin	DRB Danube River Basin
Drought	↗→	↗→	↗	↗→
Low flow	↗→	↗→	↗→	↗→

Changes in floods				
Floods	↗	↗	↗	↗

Changes in agriculture				
Growing season	↗	↗	↘	↗↘
Damage from extreme events	↗	↗	↗	↗
Reliable production	→	→↘		→↘
Water demand	↗	↗	↗	↗
Invasive species/pests	↗	↗	↗	↗
New species/shift	↗	↗		↗

Changes in forestry				
Growing season	↗	↗↘		↗↘
Forest fires	↗→	↗→	↗	↗
Structure and stability	↘	↘		↘
New species/shift	↗	↗	↗	↗

Sector **Changes in biodiversity/ecosystems**	UDRB Upper Danube River Basin	MDRB Middle Danube River Basin	LDRB Lower Danube River Basin	DRB Danube River Basin
Number of native species	↘	↘	↘	↘
Number of invasive species	↗	↗	↗	↗
Water temperature	↗	↗	↗	↗
Shift of habitats	↗→	↗→	↗→	↗→
Vulnerability to changes in discharge	→	↗	↗	↗

Changes in water-related energy production				
Hydropower potential	→	→↘	↘	→↘
Thermal electricity potential	→	↘	↘	↘

Changes in navigation				
Ice cover	↘	↘	↘	↘
Low flow conditions	→	↗	↗	↗→

Legend

→ *Beneficial change*
→ *Adverse change*
→ *Change neither beneficial nor adverse/small change*

↗	↘	↗→	→↘	↗↘	→	
Increase throughout most of a region	*Decrease throughout most of a region*	*Increase in substantial parts of a region*	*Decrease in substantial parts of a region*	*Increase as well as decrease in a region*	*Only small changes*	*No information (empty cell)*

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4.2
Overview of Certainty for the Impacts due to Projected Climate Changes

Many different factors influence the certainty of the statements about climate projections and climate change related impacts on the water sector analysed in the "Danube Study – Climate Change Adaptation" and in the following "Update and Revision of the Danube Study". Figure 7 summarises the main factors, which lead to different levels of uncertainty for these statements. They are further described in detail.

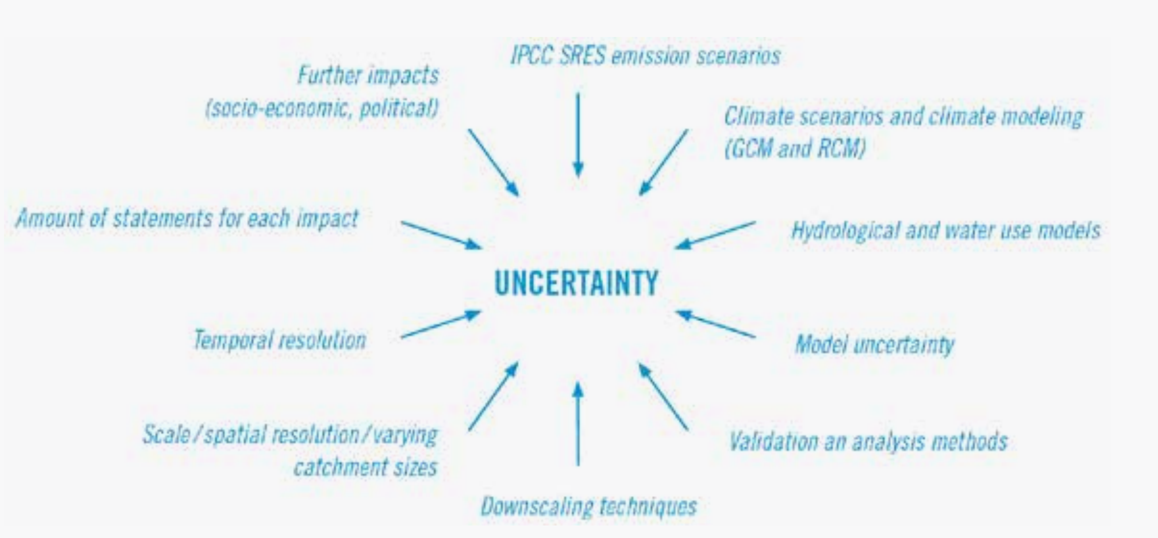


Figure 7: Main factors influencing uncertainty in climate change analysis

For climate change projections, different possible future assumptions (inter alia, for the emissions of greenhouse gases and socio-economic development), reflected by various IPCC SRES scenarios, serve as a basis (see section 3). In its 5th Assessment Report the IPCC introduced the RCPs, which follow a different approach than the SRES scenarios. Analysed projects of the update of the Danube Study are based on both, SRES scenarios and RCPs, which leads to difficulties in comparison. Furthermore, for the same SRES scenario or RCP, the outcomes of different climate models are diverse because the models represent the climate process in different ways. Generally, each climate and hydrological projection is subject to limitations in its ability to model the climate and water-related system. Even if some projects use the same Global Circulation Model (GCM), they can still differ in further aspects such as regional modelling and downscaling techniques. In the Danube countries, different Regional Climate Models (RCM) and, in several catchment areas, different hydrological models are used. Only a few projects use a water use model, which can compute both water use and availability on a river basin scale.

Different methods are applied for validation and analysis of the projections. Downscaling techniques are used to attain climate change information from global to regional and local scales. In addition to these different methods, the findings often differ widely in relation to space and time – in the end; therefore, they cannot be simply compared and summarised.

For each issue (see section 4.2), a different number of projects and studies are available. For some impacts, only very few statements are available, whereas for others, many studies are analysed. However, a high number of available studies do not automatically imply a high agreement of their findings. Finally, climate change is accompanied by other influences such as political or socio-economic impacts.

To give "uncertainty" respectively "certainty" a tangible form, three variables are used in the "Danube Study" as well as in the "Update and Revision of the Danube Study" to determine a certainty category for climate parameters and impacts: 1) certainty of statements; 2) level of agreement between different statements; and 3) number of analysed studies. The first and second variables are assigned to one of eight values within the range 0.5 and 4. The third variable is a real number, coded in eight categories. Further details are described in the 'Danube Study' and the "Update and Revision of the Danube Study".

Figure 8 summarises the certainty for the impacts in the Danube River Basin due to projected climate changes of the first Danube Study and its revision and update. The comparison reveals the changes in certainties that are explained in the following. Due to the above mentionedvariables, the certainty of the projections for temperature is very high as in the first Danube Study (for detailed explanation of the factors see Danube Study pp16). In contrast to the first Danube Study, the update now reveals very high certainty for projections of precipitation seasonality, while the certainty for the development of mean annual precipitation remains high. Precipitation- and temperature-related impacts on runoff, flood events, droughts and low flows, agriculture, forestry, irrigation, and the development of ecosystems have become more certain since the first Danube Study. In contrast, certainty of climate change impacts on biodiversity, water-related energy production, and navigation remains unchanged.

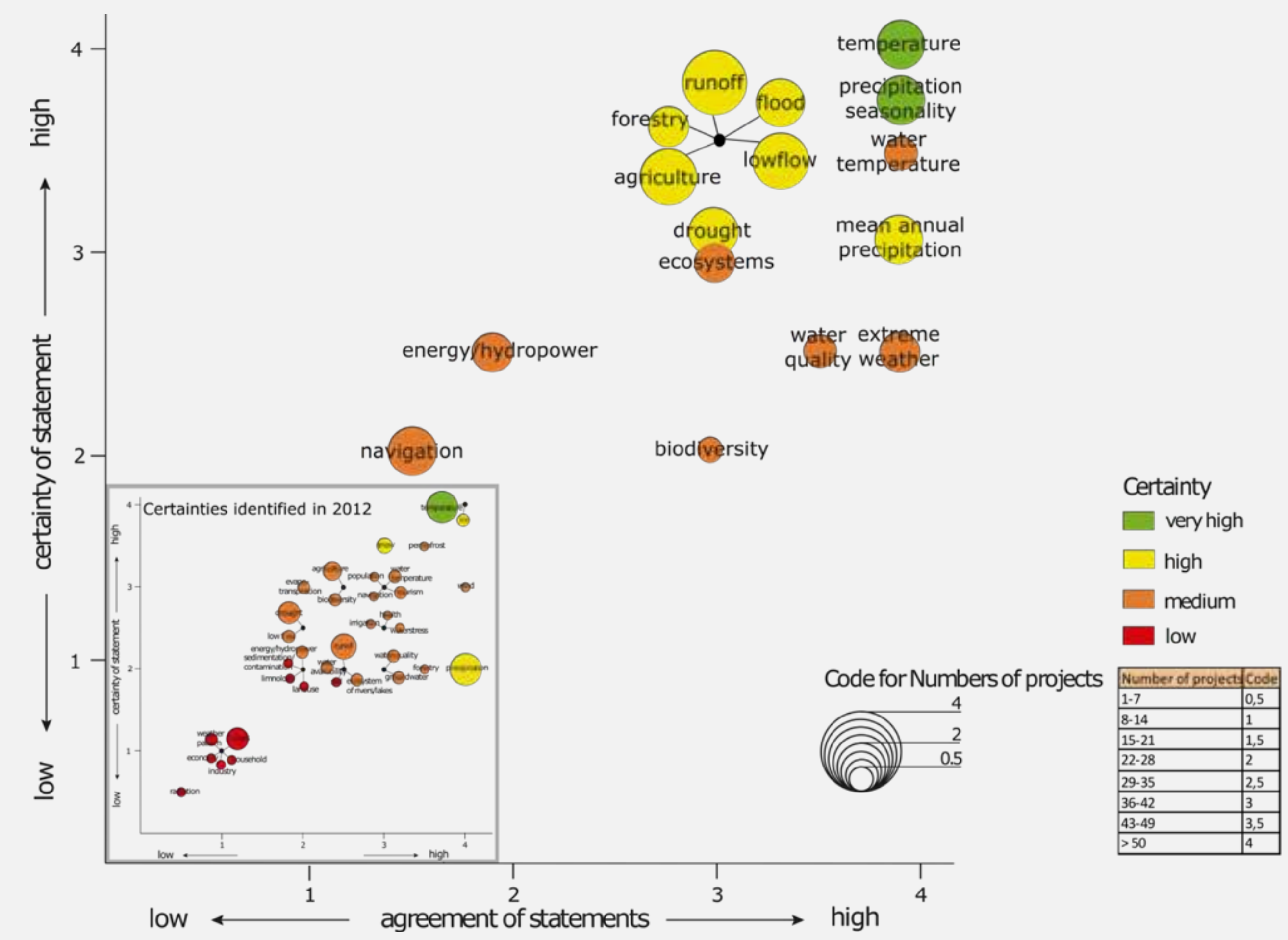
The overall level of certainty should be taken into account in the development of future adaptation measures. A high level of certainty may allow for the preparation of adaptation measures at an early stage and/or with more detail, whereas a low level of certainty may lead to more general types of measures (e.g. no-regret measures or win-win solutions, see section 7).

Future development of hydrological extreme events, i.e. floods, droughts, and low flows, meteorological extremes, i.e. heat waves and heavy precipitation, and seasonality in precipitation are frequently mentioned as the most relevant factors that have to be dealt with. Therefore, for these phenomena, the classification and hence the interpretation of the certainty category are explained in more detail. Flood events are triggered by many factors such as temperature, precipitation, atmospheric conditions, runoff, routing, snow melt and the anthropogenic influence on the land surface. The future development of these factors is not fully clear. Additionally, precipitation-driven flood events are mainly short-term events that occur locally. As a result, intensity and temporal and spatial occurrence of floods are difficult to simulate with models. This applies in particular for small catchment areas that have poor spatial and temporal resolution for precipitation data. However, there is high certainty and agreement of statements that flood events will occur with greater frequency and intensity. Analysed projects showed high certainty and agreement of statements that drought and low flow events will intensify in summer all over the Danube River Basin and especially in the southeast. The future development of floods, droughts and low flows goes hand in hand with the development of meteorological extremes and precipitation seasonality. Statements regarding a temperature increase are highly certain. The same applies for the seasonality of precipitation, which will result in decreasing summer precipitation and increasing winter precipitation until the end of the century. This will promote summer droughts and low flows as well as rain-on-snow events in winter, causing floods. Regarding future development of extreme weather events, there is very high agreement that extreme events will happen more frequently and with higher intensity. However, the determination of their spatial and temporal occurrence is associated with great uncertainties.

Perspectives of future uncertainty reduction through science

Not all of the factors influencing uncertainty are determined by a current lack of scientific knowledge. Natural short-term weather fluctuations, as well as the uncertainty about assumed future greenhouse gas emission scenarios, create ambiguities which cannot be reduced through an increase of scientific knowledge. Therefore, the discussion on the formulation and choice of suitable scenarios should be segregated from the uncertainty discussion and treated independently.

Science can, however, further reduce the uncertainty of the results of a scenario simulation by improving the skills of global and regional climate modelling as well as of the diverse climate impact models over the next decades. This will most likely be achieved by replacing current model parameterisations, which are based on past statistical relations, by first order science principles found in current climate and impact models. In the meantime, considerable uncertainties can be expected to prevail. This calls for evaluating and quantifying these uncertainties thoroughly and finding scalable adaptation measures that can be adjusted as new evidence arises. Nevertheless, progress in model development since the first Danube Study have already led to a significant decrease in uncertainty, in particular in water-related fields.



Number of projects	Code
1-7	0,5
8-14	1
15-21	1,5
22-28	2
29-35	2,5
36-42	3
43-49	3,5
> 50	4

Figure 8: Revised and updated overview of certainty for the impacts in the Danube River Basin due to projected climate changes and certainties identified in 2012

5 VULNERABILITY

5.1 IPCC Concept of Vulnerability

In the IPCC Assessment Report 5 (AR5) the concept of vulnerability, developed in the AR4, was expanded to the concept of risk, because the vulnerability concept of AR4 was limited by several factors (i.e. focus on risk only as a function of global mean temperature). The new concept aims to identify and evaluate the risk of impacts from climate change. Risk is defined as the interaction of vulnerability, exposure and (climate-related) hazards. The use of the term exposure in IPCC AR5 differs from the way it is used in the IPCC AR4 concept *(see table 8)*. Figure 9 shows the interaction between the physical climate system, exposure and vulnerability producing risk.[22]

Changes in both the climate system (left side) and socioeconomic processes (right side) are central drivers of the different core components (vulnerability, exposure, hazards) that constitute risk. The socioeconomic processes trigger anthropogenic climate change by increased emissions and land use change. However, there is also a back coupling effect, because the changing climate also triggers land use change, which again influences socioeconomic processes.
The widening of the vulnerability concept with the concept of risk in the AR5 displays the complex and coupled systems of interactions in relation to water-related issues far better than before. Applying these concepts to the Danube River Basin shows aspects, which have not or only to a minor extent been covered by adaptation strategies in the Danube region up to now.[23]

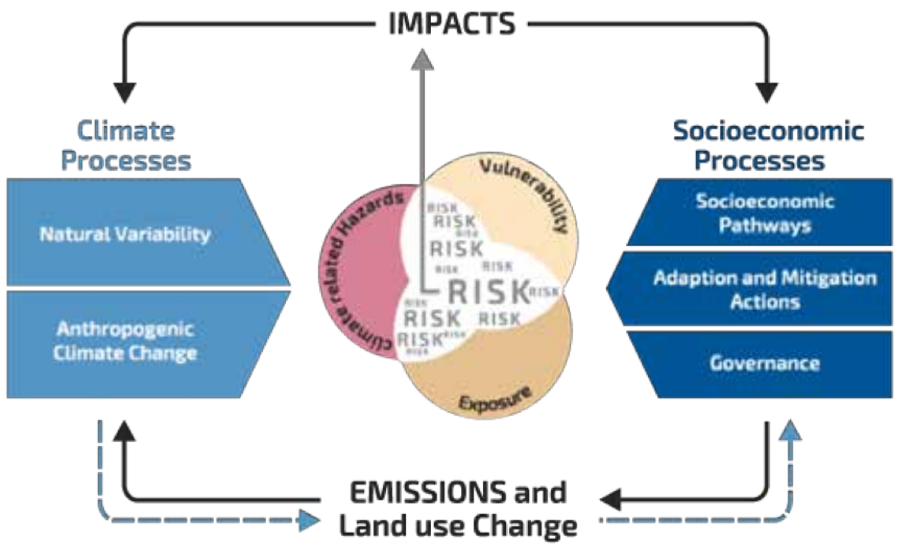


Figure 9: Interaction between the physical climate system, exposure and vulnerability producing risk

Vulnerability

Vulnerability is influenced by a wide range of factors: social, economic, political, cultural and environmental. The different water-related issues are connected through complex and coupled systems of interaction between these factors as well as by historical experience. In order to quantify vulnerability, these interactions have to be addressed to a local and regional level.

Not taken into account up to now is the historical experience of the population. Without such an experience, e.g. with floods or droughts, the implementation of adaptation measures is often limited. Such populations are more vulnerable than those who have had experience with these issues.

The interaction of extremes (heat/droughts/floods) with demographic shift, food security and economy is an underestimated aspect for wide parts of the DRB. An older population is more susceptible to resulting food insecurity as well as agriculturally dependent economies. The very actual technical paper 2018/1 of the European Topic Centre on Climate Change, Impacts, Vulnerability and Adaptation (ETC/CCA)[24] addresses the problem in cities generally, but for rural areas and large parts of the DRB this aspect is missing in adaptation strategies.

Risk

Scenarios of high confidence show that emergent risks also arise from indirect, trans-boundary and long-distance impacts of climate change. Adaptive responses and mitigation measures in one place sometimes increase such risks in another place. Such possible adverse impacts have not been considered in adaptation strategies and are only addressed to a minor extent in few working group reports up to now. The German LAWA report on climate change and water management as one example is listed in the Annex as good practice example.[25] This underlines the importance of basin wide and transboundary alignment of adaptation measures.

The risk of climate change to water-related and thus to human systems (e.g. agriculture and water supply) is increased by the loss of ecosystem services that are supported by biodiversity (e.g. water purification, pollination of crops). This potential risk is only partly addressed in the update of the Danube Study due to a lack of projects in this field.

The methodological challenge for an assessment that aims at estimating future vulnerability to climate-related impacts is to "foresee" the future system. The description of potential future climate change conditions (hazard) is usually not the bottleneck since highly confident data is available from scenarios and improved models.

[22] *The figure was adapted to the purpose of the ICPDR Strategy on Adaptation to Climate Change according to IPCC (2014): Fifth Assessment Report WGII: Impacts, Adaptation, Vulnerability, p.1046.*
[23] *IPCC (2014): Fifth Assessment Report WGII: Impacts, Adaptation, Vulnerability, pp 1042-1056.*
[24] *Breil, M., Downing, C., Kzmierczak, A., Mäkinen, K., Romanovska, L. (2018): Social vulnerability to climate change in European cities – state of play in policy and practice. European Topic Centre on Climate Change impacts, Vulnerability and Adaptation (ETC/CCA) Technical paper 2018/1.*
[25] *LAWA (2017): Impacts of Climate Change on Water Management – Stocktaking, option for action, and strategic fields of action. German Working Group on Water Issues of the Federal States and the Federal Government.*

Table 8

Comparison of key terms (following the IPCC's definition) between AR4 and AR5

<table>
<tr><th>Definition of keywords</th><th>IPCC AR4</th><th>IPCC AR5</th></tr>
<tr><td>Vulnerability</td><td colspan="2">The extent to which a system or actor is susceptible to, or incapable of coping with, the detrimental consequences of climate change, including climate variability and extremes. Vulnerability depends on the character, magnitude, pace and variability of the climate change to which the system is exposed, as well as the sensitivity and adaptive capacity of the system or actor.</td></tr>
<tr><td>Exposure</td><td>The degree of climate stress upon a particular unit or system; it may be represented as either long-term climate change or by changes in climate variability, including extreme events.</td><td>Related to specific exposed elements or elements at risk. The presence of a system or actor, services and resources, or economic or social assets in places and settings that could be adversely affected.</td></tr>
<tr><td>Sensitivity</td><td>The degree to which a system or actor is either adversely or positively influenced by climate variability or climate change.</td><td>The term sensitivity is not explicitly used in AR5. It is summarised under the term vulnerability.</td></tr>
<tr><td>Adaptive capacity</td><td colspan="2">The capability of systems, organizations or (individual) actors that enables them to adapt to actual or expected climate conditions and its effects, to adjust to potential damage, to take advantage of opportunities, or to cope with consequences.</td></tr>
<tr><td>Risk</td><td></td><td>Risk is the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In the context of this strategy, the term risk is used primarily to refer to the risks of climate-change impacts.</td></tr>
</table>

To create awareness for further adaptation needs on top of the common evidence base, it is important to gradually expand the adaptation process taking the IPCC concept of risk into consideration.

A trans-boundary and (sub)basin-wide dialog is of great importance to avoid adverse impacts. The major goal of adaption is to reduce risk.

5.2
Approach for the Danube River Basin

The addressed points in section 5.1 are of importance for a vulnerability assessment approach in the Danube River Basin. They have not yet been or have been only partly addressed in adaptation measures so far, and in particular not in national adaptation strategies.

To estimate potential vulnerability of water issues to climate change, a consistent and homogenous quantitative or semi-quantitative risk/vulnerability assessment is of importance. This was already pointed out in the ICPDR Strategy on Adaption to Climate Change in 2012 and should be emphasised again. However, neither qualitative (descriptive) nor quantitative (based on indicators) assessments are available for the Danube River Basin as a whole yet. Quantitative vulnerability assessments were conducted in Germany in 2015[26] and in Austria in 2010. Quantitative assessments for smaller regions were carried out within INTERREG-projects and other European research projects. Other national projects are covering only local areas or catchments or certain water-related issues like groundwater. The necessity of a basin wide vulnerability assessment is also addressed in the recently published outline of the Climate Adaptation Strategy of the Sava River Basin.[27]

The comprehensive studies covering larger parts of the Danube River Basin are the ESPON (European Spatial Planning Observation Network) Climate and the ClimWatAdapt (Climate Adaptation – modelling water scenarios and sectoral impacts) projects, conducted in 2009-2011 and already analysed in the Danube Study of 2012. The result are still of great value.

As part of the project CLIMSAVE (Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe), a web-based tool was designed to assist the whole process from impact to vulnerability assessment.[28] The project was conducted between 2010 and 2013 under the European Commission's Seventh Framework Programme. The outcome of this pan-European project is an Integrated Assessment Platform, an interactive web-based tool that should enable European stakeholder to explore the complex multi-sectoral issues surrounding impacts, adaptation and vulnerability to climate change across Europe.

Table 9

The CLIMSAVE project

The project CLIMSAVE was designed to cover whole Europe. The overall aim was to deliver an integrated methodology to assess cross-sectoral climate change impacts, adaptation and vulnerability. It did put science in the service of stakeholders and policy-makers by providing a common platform for an improved integrated assessment of climate change impacts, vulnerability and related cost-effective adaptation measures covering key sectors in Europe. The major final output from CLIMSAVE is the "Integrated Assessment Platform". This ready to use interactive web-based tool enables users to analyse the effects of climate change impacts and vulnerability in a selected area within Europe.

[26] *German Umweltbundesamt (ed.) 2015: Vulnerabilität Deutschlands gegenüber dem Klimawandel.*
[27] *Dworak, T. (2018): Outline of the Climate Adaptation Strategy and basin-wide priority measures for the Sava River Basin.*
[28] *Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe: www.climsave.eu.*

The UN (United Nations) Economic Commission for Europe stated that "a vulnerability assessment should be relevant to decision-making and be seen as an ongoing process". The vulnerability assessment is seen as especially important at the transboundary level.[29] The vulnerability to, and the potential impacts of climate change need to be evaluated in a holistic and integrated assessment of the effects of our changing future. To facilitate the basin-wide coordination of adaptation measures and their prioritisation, a spatially detailed, consistent and homogeneous vulnerability assessment for the Danube River Basin would be a helpful instrument for a future basin wide adaptation process.

The added value of an encompassing vulnerability assessment – depending on its spatial and temporal scope – can fulfil several purposes:

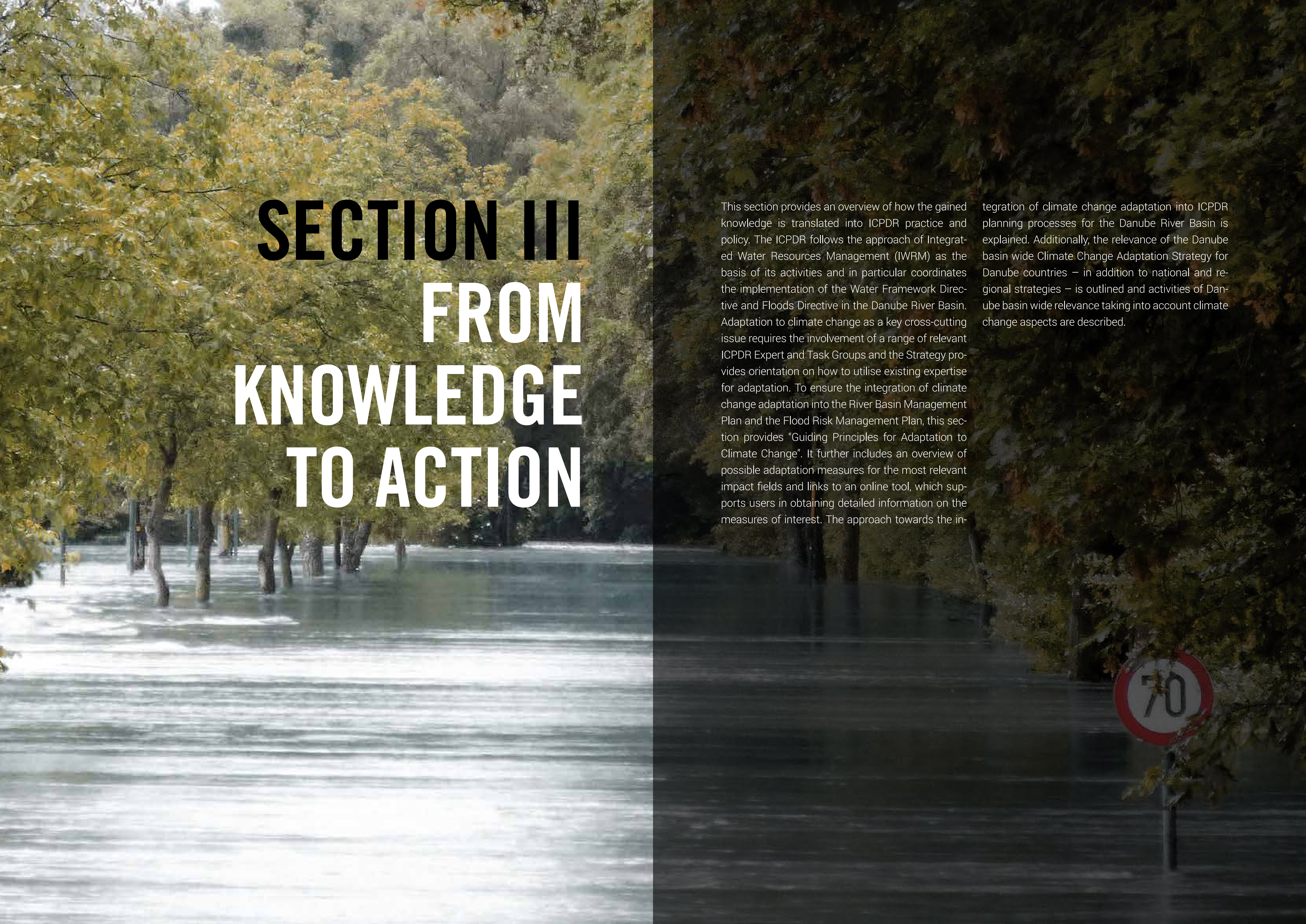
- Identifying regional or sectoral hotspots (current or potential)
- Prioritising adaptation needs or crucial intervention
- Identifying and avoiding conflicting objectives in adaptation measures
- Monitoring and evaluating adaptation measures
- Strategically allocating resources

As a first step towards a vulnerability assessment, the present impact analysis (see Section II.4) is well set to create a common understanding and knowledge base. In addition, information on the water-related effects of climate variability sourced from National Climate Adaptation Strategies, already available national or sub-basin wide vulnerability assessments and European Guidance and Management Plans should be taken into consideration. Furthermore the "Guidelines for Climate Impact and Vulnerability Assessment", published by the German Environmental Agency (Deutsches Umweltbundesamt) in 2017 [30], the German LAWA report on climate change and water management (2017)[31] and the CLIMSAVE web-tool could be of value too.

[29] *UN Economic Commission for Europe (2015): Water and Climate Change Adaptation in Transboundary Basins: Lessons Learned and Good Practices.*

[30] *German Umweltbundesamt 2017: Guidelines for Climate Impact and Vulnerability assessment.*

[31] *LAWA (2017): Impacts of Climate Change on Water Management – Stocktaking, option for action, and strategic fields of action. German Working Group on Water Issues of the Federal States and the Federal Government.*



SECTION III FROM KNOWLEDGE TO ACTION

This section provides an overview of how the gained knowledge is translated into ICPDR practice and policy. The ICPDR follows the approach of Integrated Water Resources Management (IWRM) as the basis of its activities and in particular coordinates the implementation of the Water Framework Directive and Floods Directive in the Danube River Basin. Adaptation to climate change as a key cross-cutting issue requires the involvement of a range of relevant ICPDR Expert and Task Groups and the Strategy provides orientation on how to utilise existing expertise for adaptation. To ensure the integration of climate change adaptation into the River Basin Management Plan and the Flood Risk Management Plan, this section provides "Guiding Principles for Adaptation to Climate Change". It further includes an overview of possible adaptation measures for the most relevant impact fields and links to an online tool, which supports users in obtaining detailed information on the measures of interest. The approach towards the integration of climate change adaptation into ICPDR planning processes for the Danube River Basin is explained. Additionally, the relevance of the Danube basin wide Climate Change Adaptation Strategy for Danube countries – in addition to national and regional strategies – is outlined and activities of Danube basin wide relevance taking into account climate change aspects are described.

6 GUIDING PRINCIPLES FOR ADAPTATION TO CLIMATE CHANGE

An overview of guiding principles, which provide support for the integration of adaptation to climate change into river basin management, including flood and drought risk management, is given in the following table.[32] The principles are generally applicable, and assist relevant experts, who are active in the framework of the ICPDR, during the implementation process of the Water Framework Directive and Floods Directive on national level and in the Danube River Basin.

The guiding principles are structured according to the following five main fields of actions, and provide orientation for relevant experts dealing with specific issues in the frame of river basin management:

I. Climate modelling, projections, scenarios, potential impacts and uncertainty
II. How to build adaptive capacity for management under climate change?
III. Water Framework Directive and adaptation
IV. Flood risk management and adaptation
V. Drought management, water scarcity and adaptation

[32] Further detailed descriptions, suggested actions and practical examples for each of the guiding principles, as summarised in Table 10 (referring to table 1 from the CIS Guidance Document No.24), can be obtained from the CIS Guidance Document No. 24.

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Table 10

Guiding principles for adaptation to climate change from CIS Guidance Document No. 24

I. Climate modelling, projections, scenarios, potential impacts and uncertainty

Issue	*Guiding principles*
Models, projections and scenarios	1. Climate projections and scenarios should be used for improving river basin management planning. 2. It is crucial to have a clear understanding of the assumptions made and the uncertainties related to these assumptions. 3. The best climate change model or scenario for a certain region or river basin should be decided on a case-by-case basis, because there is no "one-size-fits-all" model or scenario for Europe.
Managing the water environment based on uncertainty of projections and scenarios	4. Despite uncertainty in models, 'doing nothing' is not an option. For the next river basin management cycle, accept uncertainty where it is rational to do so and take first actions for adaptation to climate change. 5. Take best available scientific information into account. 6. Use a range of climate projections or scenarios in the analyses for river basin management planning in order to accept and work within the context of an uncertain future. 7. Prefer adaptation options which are robust against a range of future changes or postpone commitment to a particular projection of the future by building flexibility into your system.

II. How to build adaptive capacity for management under climate change?

Issue	*Guiding principles*
Using ongoing research and adaptation activities to increase knowledge at river basin scale	1. Link river basin management adaptation activities to national and regional climate change adaptation strategies and activities. 2. Check existing relevant science and research information on climate change modelling and impacts in the river basin. 3. Make use of good-practice examples coming, e.g. from existing research and implementation experience regarding adaptation strategies and measures. 4. Look beyond the borders of your river.
Data collection and building of partnerships	5. Evaluate coverage of data (e.g. meteorological, hydrological, water quality, soil moisture data, stake, damage cost data, etc.). 6. Use the WFD consultation process (Art. 14) to bring in sector-specific knowledge and data from key stakeholders. 7. Ensure communication and coordination on climate change adaptation issues between different levels of management within an RBD. 8. Work in cross-sectoral partnerships and across administrations. Ensure that climate change aspects are discussed between the relevant public administrations, in stakeholder meetings and discuss how relevant water-related sectors can contribute to adaptation. 9. Make sure to receive information related to the influence of climate change on other sectors which are directly related to water management (e.g. agriculture-water demands, water needs for energy production, etc). 10. Integrate cross-sectoral delivery of adaptation measures and coordinate activities with land use planning.
Broadening the audience and increasing its capacities - Awareness-raising, education and training	11. Include the issue of climate change impacts in the river basin in your RBD awareness-raising activities as part of the WFD public participation process. 12. Establish staff training and capacity building programmes on climate change issues, e.g. to introduce staff to climate change modelling, scenarios and projections.
Looking beyond the borders	13. Develop joint or coordinated adaptation strategies in transboundary RBDs.

III. Water Framework Directive (WFD) and adaptation

Issue	*Guiding principles*
Assessing pressures and impacts on water bodies	1. Assess, over a range of timescales, direct influences of climate change and indirect influences where pressures are created due to human activities adapting 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. 3. Include reference sites in long term monitoring programmes to understand the extent and causes of natural variability and impact of climate change.
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.
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.
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 to the 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 which have the least environmental impact, including GHG emissions.
What to do if other responses to climate change are impacting on the WFD objective of good status?	9. Avoid measures that are counterproductive for the water environment or that decrease the resilience of water ecosystems. 10. Apply WFD Article 4.7 to adaptation measures that are modifying the physical characteristics of water bodies (e.g. reservoirs, water abstractions, dykes) and deteriorate water status. 11. Take all practicable steps to mitigate adverse effects of counterproductive measures.

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IV. Flood risk management and adaptation

Issue	*Guiding principles*
Overall guiding principle on flood risk management and adaptation	1. Start adapting flood risk management to potential climate change as soon as possible, when information is robust enough, since full certainty will never be the case. Follow the guiding principles set out for the WFD.
Preliminary flood risk assessment	2. Understand and anticipate as far as possible climate change impact on flood patterns. 3. Use best available information and data. 4. Homogenize time series, and remove bias as far as possible. 5. Understand and anticipate as far as possible increased exposure, vulnerability and flood risk due to climate change, for establishing areas of potential significant flood risk
Flood Hazard and Risk Maps	6. When identifying the different flood scenarios, incorporate information on climate change 7. Present uncertainties surrounding climate change in maps transparently. 8. Use the 6-year review of flood maps to incorporate climate change information
Flood Risk Management Objectives	9. Incorporate climate change in setting flood risk management objectives 10. Ensure coordination at catchment level, also respecting the Directive's coordination requirements at RBD/unit of management level
Awareness raising, early warning, preparedness	11. Include climate change scenarios in ongoing initiatives and in the planning processes.

Issue	*Guiding principles*
Measures	12. Perform a climate check of flood risk measures 13. Favour options that are robust to the uncertainty in climate projections a. Focus on pollution risk in flood prone zones b. Focus on non-structural measures when possible c. Focus on "no-regret" and "win-win" measures d. Focus on a mix of measures 14 Favour prevention through the catchment approach 15. Take account of a long term perspective in defining flood risk measures (e.g. with respect to land use, structural measures efficiency, protection of buildings, critical infrastructure, etc). e. Include long-term climate change scenarios in land-use planning f. Develop robust cost-benefit methods which enable taking into account longer term costs and benefits in view of climate change. g. Use economic incentives to influence land use [Link insurance] 16. Assess other climate change adaptation (and even mitigation) measures by their impact on flood risk: h. Hydropower and flow regulation i. Link with water scarcity
Links to WFD	17. Pay special attention to the requirements of WFD Article 4.7 when developing flood protection measures 18. Determine on the basis of robust scientific evidence and on a case-by-case basis whether an extreme flood allows for the application of WFD Article 4.6. 19. Pay special attention to the vulnerability of protected areas in view of changed flood patterns

V. Drought management, water scarcity and adaptation

Issue	*Guiding principles*
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 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 WFD Article 4.7 when developing measures to tackle water scarcity under a changing climate and 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. Monitor water demand closely 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 imposed by climate change, in order to detect water scarcity early. 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 resources systems. 13. Engage stakeholders to produce decisive measures to tackle water scarcity. 14. Assess other climate change adaptation and mitigation measures by their impact on water scarcity and drought risks.

7 OVERVIEW OF POSSIBLE CLIMATE CHANGE ADAPTATION MEASURES

Following the UNECE Guidance, when climate change adaptation measures are being planned, climate change impacts on water resources should always be considered together with other pressures or stressors, such as population growth or changing consumption patterns. As a result, adaptation measures with respect to climate change can often build on planned or already implemented water management measures. Adaptation planning in general should consider and prevent possible conflicts and provide adequate trade-offs.

Adaptation should start now with a priority on win-win, no-regret and low-regret measures that are flexible enough for various conditions. The adaptive approaches within the management framework also require flexibility so they can be modified if new information or understandings become available. This way of working has the benefit of increasing resilience and decreasing vulnerability for the whole Danube ecosystem. For a common understanding of some keywords, definitions are provided in *Table 11*.

Table 11

Definition of keywords

Adaptation	Adaptation refers to actions that people take in response to, or in anticipation of, projected or actual changes in climate, to reduce adverse impacts or take advantage of opportunities posed by climate change.
Mitigation	Mitigation refers to actions taken to prevent, reduce or slow climate change, through slowing or stopping the build-up of greenhouse gases in the atmosphere.
Win-win measures	Cost-effective adaptation measures that minimize climate risks or increase adaptive capacity, and which also have other social, environmental or economic benefits; win-win options are often associated with those measures or activities that address climate impacts and also contribute to climate change mitigation or meet other social and environmental objectives.
No-regret measures	Cost-effective adaptation measures that are worthwhile (i.e. they bring net socio-economic benefits) whatever the extent of future climate change is; they include measures that are justified (cost-effective) under current climate conditions (including those addressing its variability and extremes) and are also consistent with addressing risks associated with projected climate changes.
Low-regret measures	Adaptation measures where the associated costs are relatively low and where the benefits, although mainly accrued under projected future climate change, may be relatively large.
Climate-proof	Activities to increase the resistance and resilience of the policies, plans and programmes that wiall be directly or indirectly affected by the impacts of climate change, acknowledging the new conditions where the baseline is inherently unstable and changing, and including climate protection aims.
Resilience	The resilience of a natural system is its capacity to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient system can withstand shocks such as extreme events and rebuild itself. When a system loses resilience, it becomes vulnerable to changes that previously could have been absorbed. In a vulnerable system, even small changes may be devastating. Even in the absence of disturbance, gradually changing conditions such as climate, land use and policies can surpass threshold levels, triggering an abrupt system response. Therefore, managing resilience enhances the likelihood of a sustainable generation of ecosystem services benefiting humans in changing environments where the future is unpredictable and changes are likely.
Improvement of resilience	Improvement of resilience involves increasing the ability of a system to withstand shocks and surprises and to revitalize itself if damaged. An integrated adaptive ecosystem management approach that increases ecosystem stability can improve the resilience of the environment and reduce vulnerability to improve the well-being of societies and ecosystems dependent on natural resources. Flexible sustainable decision-making processes that can accept new information, and that can be modified on the basis of this information, are also important elements in building and/or improving resilience.
Benefit-sharing	Equitable sharing of (economic) benefits from water use or from water-related adaptation measures among individuals, regions and countries

It has to be pointed out that the ICPDR Strategy on Adaptation to Climate Change focuses on basin-wide adaptation measures facing the challenges of climate change of the next decades. However, additional or adapted measures may well be necessary due to local characteristics. The following is an overview of possible adaptation measures. They are classified into five different categories following the UNECE [33] and EEA[34]: preparation measures, ecosystem-based measures, behavioural/managerial measures, technological measures and policy approaches.

- **Preparation measures** aim to support planning processes. This includes monitoring, evaluating changes, identifying risk areas, elaborating on warning systems and emergency plans and supporting further research where needed.
- **Ecosystem-based measures** aim to reduce the negative effects of a changing climate by enhancing the capacity of the ecosystem to adapt to different impacts. These measures help to conserve or restore ecosystems. Healthy ecosystems can thus contribute to increasing resilience to slow changes such as increasing summer temperatures or sudden impacts such as floods.
- **Behavioural and managerial measures** aim to raise awareness about possible future conditions, and to support sustainable management with a focus on the efficient use of water and conservation of good water quality. This includes, inter alia, the elaboration of risk management plans for water scarcity and the propagation of best practices, where the exchange of knowledge plays an important role.
- **Technological measures** aim to help implementing individual projects. The focus is on infrastructure which has to be built or improved, such as dams, reservoirs, fish ladders or water networks.
- **Policy approaches** aim to support the national, international and basin-wide coordination of activities. Common transnational threshold values, limits, restrictions, expansions (e.g. for protection areas or nature reserves), etc. should be considered.

Table 12 provides examples of possible adaptation measures that are valid for almost all impact fields. Numerous discussions with stakeholders and country representatives have revealed the highlighted measures of highest relevance and of highest consensus.

A comprehensive and easy to use toolbox of adaptation measures is provided here: *http://www.icpdr.org/main/climate-change-adaptation-measures-toolbox.*

The toolbox allows the user to obtain detailed information on the measures of interest, which are divided into various groups such as impact fields, relevancy to the WFD, time horizon and others.

[33] UNECE (2009): Guidance on water and adaptation to climate change. United Nations Publication, Geneva.
[34] EEA (2015): The European Environment – State and Outlook 2015: synthesis. European Environment Agency, Copenhagen.

Table 12

Examples for general adaptation measures. Measures of highest relevance are highlighted in blue, measures of highest consensus are written in italics

Preparation measures

- *Additional, intensified monitoring activities to follow and assess climate change and climate change impacts*
- Homogenous data production, digital mapping and a centralised open database for data exchange and comparability among regions and countries
- Identification of potential risk areas and hot spots
- Implementation of forecasting and warning services (e.g. for extreme events such as floods and droughts)
- Development of action plans or integration of specific issues into ongoing planning activities (e.g. to deal with water scarcity and flood situations)
- Further research to close knowledge gaps, determine vulnerability or reduce uncertainty
- Rules for water allocation in case of water scarcity under the aspect of benefit sharing
- Toolbox preparation measures

Technological measures

- Adjustment of (existing) infrastructure, e.g. construction and modification of dams and reservoirs for hydropower generation, agriculture, drinking water supply, tourism, fish-farming, irrigation and navigation
- Development and application of water-efficient technologies
- Installation of alternative industrial cooling processes largely independent of river flow
- Efficient waste- and sewage-water treatment and water recycling
- Usage of innovative technologies to achieve goals

Ecosystem based measures

- Taking environmental implications and the conservation of biodiversity into consideration in all other measures
- Sustainable management of land use practices for improving resilience, and for enhancing the capacity to adapt to climate change impacts
- Implementation of green infrastructure to connect bio-geographic regions and habitats
- Protection, restoration and expansion of water conservation and retention areas
- Rehabilitation of polluted water bodies

Behavioural and managerial measures

- Support education, open access databases, capacity building (financial resources as the most important factor for capacity building), awareness raising, information exchange and knowledge transfer
- Establishment of and support for an integrated risk management
- Support of a water saving behaviour
- Propagation of best practice examples
- Application of sustainable methods (e.g. good agricultural practices)
- Water runoff management
- Sustainable groundwater management

Policy approaches

- Support of an institutional framework to coordinate activities
- Harmonisation of international, basin-wide legal limits and threshold values (transboundary collaboration)
- Implementation of restrictions (e.g. for development in flood risk areas)
- Expansion of protection areas (e.g. for drinking water resources)
- Adaptation of policies to changing conditions
- Guidelines for politics to develop and implement strategies and measures

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8
ICPDR APPROACH FOR INTEGRATING CLIMATE CHANGE ADAPTATION

Climate change is a cross-cutting issue that has impacts upon different sectors on a transboundary scale. The quality of water and its availability are very much at the heart of the expected changes and therefore require coordinated action in an integrative way. Due to the transboundary character of water and its relevance for various issues and water-related sectors such as its role for biodiversity and the ecosystem, energy, transport, agriculture, floods and droughts, integrated river basin management plays a key for role in ICPDR's approach to climate change adaptation.

Building on this basic rationale, work on climate change adaptation is anchored in existing ICPDR structures and planning instruments as well as in the corresponding national institutions and structures, which enables dealing with the significant complexity of this issue.

To adequately integrate climate change adaptation into the ICPDR planning process for the implementation of the European Water Framework Directive and Floods Directive, a range of different actions is required. These include overarching activities such as the development and the update of the ICPDR Strategy on Adaptation to Climate Change as well as tasks outlined in the "Guiding Principles for Adaptation to Climate Change" of section 6 and table 10.

Taking into account the overview of possible climate change adaptation measures referred to in section 7, the following ICPDR approach for integrating climate change adaptation in ICPDR activities can be summarised:

- A joint understanding of scenarios, impacts and adaptation measures and sharing a scientific knowledge base is essential for joint decision making in a transboundary basin such as the Danube River Basin.
- The ICPDR Climate Change Adaptation Strategy does not include a separate programme of measures, but relevant action is incorporated in the Danube River Basin Management Plans and Flood Risk Management Plans.
- Since climate change is a key cross-cutting issue all ICPDR Expert Groups and Task Groups are mandated to fully integrate climate change adaptation in the development of the Danube River Basin Management Plan and the Danube Flood Risk Management Plan.
- The ICPDR Climate Change Adaptation Strategy focuses on issues relevant at the Danube basin-wide level (level A) and needs to be complemented with further detailed planning on adaptation at sub-basin, national and/or sub-unit level.
- Consultation on competing uses and priorities to prevent potential conflicts is needed to take into account potential target conflicts and competition between different water-related users and sectors such as agriculture, navigation, water supply, energy, industry, tourism, environment and nature protection.
- The communication, coordination and stakeholder involvement on climate change adaptation issues between different levels of management in the Danube River Basin is ensured at the national level, through the ICPDR and also through different projects.
- Building resilience against climate change impacts on water resources through capacity building, transboundary cooperation and benefit-sharing is a key priority to address climate change in the Danube River Basin.

9
RELEVANCE, ICPDR ACTIVITIES AND NEXT STEPS

9.1
Relevance of the ICPDR Climate Change Adaptation Strategy

The relevance of the Danube basin wide Climate Change Adaptation Strategy for Danube countries – in addition to national and regional strategies – is in particular seen in the context of promoting action in a multilateral and transboundary context as outlined as one of the key priorities of the EU Strategy on Adaptation to Climate Change.

The ICPDR Climate Change Adaptation Strategy serves as a reference document that influences national strategies and activities in general and more specifically provides input for national RBMPs and FRMPs on possible adaptation measures of relevance for the Danube River Basin. The catalogue of potential adaptation measures identified at the ICPDR level supports and enriches catalogues of national adaptation measures. The strategy guides EU and international funding objectives and instruments and can serve as the basis for prioritizing of projects of Danube River Basin wide relevance (e.g. list of projects identified in DFRMP 2015) in close cooperation with the EU Strategy for the Danube Region. The compilation of existing projects/actions/platforms dealing with climate change adaptation issues in the Danube River Basin is of particular interest for all relevant institutions that deal with climate change adaptation activities in the Danube River Basin.

However, an increasing awareness and thereby improved visibility and effectiveness of the ICPDR Climate Change Adaptation Strategy in Danube countries, in particular as regards the interaction between national strategies as well as RBMPs and FRMPs, are aimed for.

9.2
Activities of Danube basin wide relevance

Serving as a reference document, the ICPDR Strategy on Adaptation to Climate Change is triggering relevant discussions at national and sub-basin levels. To underline the added value of a basin wide strategy, the following ICPDR activities in the context of climate change adaptation at ICPDR level can be identified referring to the "Guiding Principles on Adaptation to Climate Change" as outlined in section 6.

Danube basin wide monitoring activities regularly take place via the ICPDR Transnational Monitoring Network (TNMN) including the monitoring of impacts of climate change; data on the impacts of climate change on water temperature and water quality are compiled by the ICPDR Contracting Parties, where available. The TNMN is an important tool under the Danube River Protection Convention and requires Contracting Parties to the ICPDR to co-operate in the field of monitoring and assessment. Formally launched in 1996, it aims at providing a well-balanced overall view of pollution and long-term trends in water quality and pollution loads in the major rivers in the Danube River Basin.

The scope of the planned Danube Hydrological Information System (HIS) will provide Danube basin wide level basic hydrological and meteorological near real time data in a standard format and, if possible, validated long-term data series, for flood risk management or for any water related scientific activities in DRB. The Danube HIS data will include water level, water discharge, water temperature and precipitation depending upon availability.

In recent years, drought management and water allocation have played a more significant role in transboundary water resources management in the Danube River Basin primarily because of the expected upcoming water quantity challenge due to climate change. Sound hydrological information is essential for agreeing upon effective management objectives and designing appropriate measures. Therefore, there is a need for developing an improved water balance for the Danube River Basin as an element for facing the expected upcoming water quantity challenge. This water balance shall be the basis for any hydrological modelling needed in the frame of the ICPDR activities.

The knowledge and exchange of information on water scarcity and droughts as well as on ice events is expanded; the following reports were published by the ICPDR:

- "The 2015 Droughts in the Danube River Basin"[35] report outlines meteorological and hydrological situation of the Danube River Basin, impacts and measures related to droughts as well as lessons learned and conclusions. The report also includes issues and activities, which are worthwhile to be considered at the national level: drought management, droughts monitoring and forecasting, droughts and agriculture, conjunctive management as well as exchange and cooperation.
- The "Report on the Ice Event 2017 in the Danube River Basin" provides information on basic features of river ice, past ice events in the Danube River Basin, current policy for ice control in the Danube River Basin, a description of the ice event in January/February 2017, lessons learned and recommendations for the future. The report outlines different activities such as applied emergency measures, weather forecast and warning services, ice monitoring and forecasting, ice control measures in the Danube River and in the Danube tributaries.

Other ICPDR activities such as the planned Guidance document on sustainable agriculture in the Danube River Basin will cover climate change aspects.

Close cooperation with the JRC in regional modelling of climate change scenarios for the Danube River Basin is ongoing; the JRC Technical Report on "Impact of a changing climate, land use, and water usage on water resources in the Danube river basin" describes an assessment of the projected future impacts of climate change, land use change and changes in water consumption on water resources in the Danube River Basin.

[35] *https://www.icpdr.org/main/issues/droughts.*

9.3
Next Steps

The step-wise and cyclic approach of the river basin management planning process, for both the Water Framework Directive and Floods Directive, makes it well-suited to adaptively manage climate change impacts. It is therefore essential to adjust adaptation actions in a step-wise manner, hand in hand with subsequent planning cycles, building on increased experience and knowledge gained while taking into consideration climate change scenarios and expected water-related impacts. In order to ensure coherence, it is therefore crucial that awareness of ongoing adaptation processes be raised and that an exchange takes place between experts working on adaptation at different levels, such as at national, sub-basin or international levels. This will be guaranteed through the involvement of national experts in the international working groups of the ICPDR, respectively via existing coordination approaches between the basin wide and the sub-basin level within the Danube River Basin (Sava, Tisza, Danube Delta, Prut).

Apart from the involvement of observer organisations, further targeted exchange on climate change adaptation with specific experts and interest groups outside existing ICPDR structures will be undertaken (e.g. through participation in respective meetings or the organisation of specific workshops on adaptation). Synergies and potential conflicts need to be addressed at an early stage in the planning process and different stakeholders and interest groups need to be involved.

The ICPDR Strategy on Adaptation to Climate Change will be taken fully into account during the next steps of the implementation of the Water Framework Directive and Floods Directive in the Danube River Basin. Closing the knowledge gaps and identifying further research requirements will be constantly aimed for.

ANNEX
LIST OF CASE STUDIES AND GOOD PRACTICE EXAMPLES

The following table shows case studies, projects and good practice examples relevant for the Danube River Basin.

Project/Author	*Project title and description*
ALPFFIRS	Alpine Forest Fire waRning System. Source: ALPFFIRS (2012): Die Waldbrände der Alpen. Vorhersage, Kenntnis und Kooperation zum Schutze unserer Wälder
Bavarian State Ministry of the Environment and Consumer Protection (Bayerisches Staatsministerium für Umwelt und Verbraucherschutz - StMUV)	StMUV (2016): Bavarian Climate Adaptation Strategy 2016 (Bayerische Bayerische Klima-Anpassungsstrategie 2016)
Bisselink, B.et al	Impact of a changing climate, land use, and water usage on water resources in the Danube river basin, EUR 29228 EN, Publications Office of the European Union, Luxembourg
CARPATCLIM	Climate of the Carpathian Region (2011-2013). The main aim of the project is to improve the basis of climate data in the Carpathian Region for applied regional climatological studies such as a Climate Atlas and/or drought monitoring, to investigate the fine temporal and spatial structure of the climate in the Carpathian Mountains and the Carpathian basin with unified methods. http://www.carpatclim-eu.org/pages/home/
CLIMAMAP	Climate Change Impact Maps for Austrian Regions. Source: Provides maps to assess the climate change impacts for communities in Austria. Source:CLIMAMAP (2017): Karten zur Auswirkung des Klimawandels für Gemeinden und Regionen Österreichs
CLIMSAVE	Provides a climate change integrated assessment methodology for cross-sectoral adaptation and vulnerability in Europe. http://www.climsave.eu
CzechAdapt	System for Exchange of Information on Climate Change Impacts, Vulnerability and Adaptation Measures on the Territory of the Czech Republic. The aim of this broad and interdisciplinary project was to create an open and continuously updated online database summarizing information about climate change impacts, risks, vulnerabilities and adaptation measures. Outcomes were prepared for the whole area of the Czech Republic on the basis of best available techniques and cooperation of specialist teams. www.klimatickazmena.cz
Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ	The Vulnerability Sourcebook. It offers a concept and step-by-step guidelines for standardised vulnerability assessments
Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ	Risk Supplement to the Vulnerability Sourcebook. In the IPCC AR5 the concept of vulnerability was replaced by the concept of risk. This supplement is an addition to the vulnerability sourcebook
DriDanube	Drought Risk in the Danube Region. A project within the Interreg Danube Transnational Programme. The main objective of the project is to increase the capacity of the Danube region to manage drought relates risks. www.interreg-danube.eu/approved-projects/dridanube
German Working Group on Water Issues of the Federal States and the Federal Government (LAWA)	LAWA – Bund/Länder-Arbeitsgemeinschaft Wasser (2017): Impacts of Climate Change on Water Management. Stocktaking, Options for Action, and Strategic Fields of Action
German Working Group on Water Issues of the Federal States and the Federal Government (LAWA)	LAWA – Bund/Länder-Arbeitsgemeinschaft Wasser (2018): LAWA-Strategie für ein effektives Starkregenrisikomanagement (LAWA-strategy for an effective management of heavy rainfall effects)
GLOBAL WATER PARNERSHIP	GLOBAL WATER PARNERSHIP (2017): Integrated drought management in Central and Eastern Europe

Project/Author	Project title and description
HABITAT-CHANGE	LEIBNITZ INSTITUTE OF ECOLOGY AND REGIONAL DEVELOPMENT (2013): HABIT-CHANGE - adaptive management of climate-induced changes of habitat diversity in protected areas, www.habit-change.eu/
Harrison & CLIMSAVE - Consortium	Harrison, P. & CLIMSAVE-Consortium (2013): Climate Change Impacts, Adaptation and Vulnerability in Europe: An integrated approach
KLIWAS	KLIWAS (2013): Auswirkungen des Klimawandels auf Wasserstraßen und Schifffahrt – Entwicklung von Anpassungsoptionen KLIWAS (2014): Validierung und Bewertung von Klimaprojektionen – Bereitstellung von Klimaszenarien für den Binnenbereich. Bundesanstalt für Gewässerkunde
MINISTERIUM FÜR VERKEHR, INNOVATION UND TECHNOLOGIE der BUNDES-REPUBLIK DEUTSCHLAND	Aktionsprogramm Donau des BMVIT bis 2022
Pistocchi et al.	Pistocchi, A., Beck, H., Bisselink, B., Gelati, E., Lavalle, C. & Feher, J. (2015): Water scenarios for the Danube River Basin: Elements for the assessment of the Danube agriculture-energy-water nexus
Schmidt, G. & C. Benítez-Sanz	Schmidt, G. & C. Benítez-Sanz (2012): Topic report on: Assessment of Water Scarcity and Drought aspects in a selection of EU River Basin Management Plans. Study by Intecsa-Inarsa for the European Commission (under contract "Support to the implementation of the Water Framework Directive (2000/60/EC)" (070307/2011/600310/SER/D.2)).
German UMWELTBUNDESAMT	Guidelines for Climate Impact and Vulnerability Assessment
UHI	Development and application of mitigation and adaptation strategies and measures for counteracting the global Urban Heat Islands phenomenon (2011-2014). UHI Project aims at developing mitigation and risk prevention and management strategies concerning the urban heat island (UHI) phenomenon. http://eu-uhi.eu/cz/

Project/Author	Project title and description
UNECE	UNECE - United Nations Economic Commission for Europe (2015): Water and Climate Change Adaptation in Transboundary Basins
WATCAP	Water and Climate Adaptation Plan for the Sava River Basin. Source: WORLD BANK (2015): WATCAP - Water and Climate Adaptation Plan for the Sava River Basin - Final Report
WateratRisk	http://www.geo.u-szeged.hu/wateratrisk/?q=en

LIST OF ACRONYMS

AR	Assessment Report
CIS	Common Implementation Strategy for the Water Framework Directive
CLIMATE-ADAPT	European Climate Adaptation Platform
CORDEX	Coordinated Regional Climate Downscaling Experiment
CLIMSAVE	Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe
ClimWatAdapt	Climate Adaptation – modelling water scenarios and sectoral impacts
DRB	Danube River Basin
DFRM Plan	Danube Flood Risk Management Plan
DJF	December/January/February
DRBM Plan	Danube River Basin Management Plan
EC	European Commission
EEA	European Environment Agency
EFD	European Floods Directive
ESPON	European Spatial Planning Observation Network
ETC/CCA	European Topic Centre on Climate Change, Impacts, Vulnerability and Adaptation
EU	European Union
GCM	Global Circulation Model
GHG	Greenhouse gas
ICPDR	International Commission for the Protection of the Danube River
IPCC	Intergovernmental Panel on Climate Change
JJA	June/July/August
LDRB	Lower Danube River Basin
MDRB	Middle Danube River Basin
NAS	National Adaptation Strategy
RBD	River Basin District
RCM	Regional Climate Models
RCP	Representative Concentration Pathway
RBM	River Basin Management
RBMP	Danube River Basin Management Plan
SRES	Special Report on Emissions Scenarios
UDRB	Upper Danube River Basin
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WFD	Water Framework Directive