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Water & Climate Adaptation Plan for the Sava River Basin

FINAL REPORT

August 2015

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ACRONYMS AND ABBREVIATIONS

ANN	Annual Mean Flows
APE	Average Percentage Error
BAP	Best Available Practices
BAT	Best Available Technology
BiH and BA	Bosnia and Herzegovina
BOD	Biological Oxygen Demand
CC	Climate Change
CDF	Cumulative Distribution Functions
CGE	Computable General Equilibrium
CIA	Central Intelligence Agency of the United States
CLC	CORINE Land Cover
CM	Climate Model
CMIP	Coupled Model Inter-comparison Project
COD	Carbon Oxygen Demand
CORINE	Coordination of Information on the Environment
CROPWAT	Decision support tool from Land and Water Development Division of FAO
DC	Danube Commission
DJF	December January February
DRB	Danube River Basin
EC	European Commission
EEA	European Economic Area
EFD	European Floods Directive
EIA	Environmental Impact Assessment
E-OBS	European observation - European daily high-resolution gridded data
ESW	Economic and Sector Work
ET	Evapotranspiration
EU	European Union
EUR	Euro
EUROSTAT	Statistical Office of the European Communities
FAO	Food and Agriculture Organisation
FASRB	Framework Agreement on the Sava River Basin
FD	Floods Directive
FRMP	Flood Risk Management Plans
GCM	Global Circulation Models
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GTAP	Global Trade Analysis Project
GWh	Gigawatt Hour
HBV	Swedish Hydrological Agency's Water Balance Department
HEC HMS	Hydrologic Engineering Centre – Hydrologic Modeling System
HEC RAS	Hydrologic Engineering Centre – River Analysis System
HP	Hydropower
HPP	Hydropower Plant
HR	Croatia
HRK	Croatian Kuna
HV	Hrvatske Vide – Croatia Water
ICPDR	International Commission for the Protection of the Danube River
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISRBC	International Sava River Basin Commission
IWRM	Integrated Water Resources Management
JJA	June July August
KNMI	Royal Netherlands Meteorological Institute
MAM	March April May
MAPE	Mean Absolute Percentage Error
MODIS	Moderate Resolution Imaging Spectro-radiometer
MW	Megawatt
NAS	National Adaptation Strategies
NPP	Nuclear Power Plant

ACRONYMS AND ABBREVIATIONS

NSE	Nash Sutcliffe Efficiency
OECD	Organisation for Economic Cooperation and Development
PBIAS	Percentage Errors in Mean Flows
PDF	Probability Density Functions
PEBLDS	Pan European Biological and Landscape Diversity Strategy
PET	Potential Evapotranspiration
PIANC	The International Navigation Association
PWE	Public Water Enterprise
Q	Discharge
R&D	Research and Development
RBMP	River Basin Management Plan
RCM	Regional Climate Model
RRDISS	Rapid Regional Diagnostic and Investment Scan Study
RS	Republic of Serbia
SCC	Sava Commission Classification
SEE	South East Europe
SEEDRIMI	South East European Disaster Risk Management Initiative
SHPP	Small (Micro) Hydropower Plant
SL	Slovenia
SMA	Soil Moisture Accounting
SON	September October November
SRB	Sava River Basin
TFESSD	Trust Fund for Environmentally & Socially Sustainable Development
TFP	Total Factor Productivity
TNMN	Trans-National Monitoring Network
TPP	Thermal Power Plant
UK	United Kingdom
UN	United Nations
UNECE	United National Economic Commission for Europe
UNFCCC	United Nations Framework Convention for Climate Change
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
WATCAP	Water and Climate Adaptation Plan
WB	World Bank
WBFDI	West Balkan Regional Initiative for Flood and Drought Management
WFD	Water Framework Directive
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organisation
WPP	Water Partnership Program

FOREWORD AND ACKNOWLEDGMENTS

Planning climate adaptation activities at the river basin level is an extremely relevant and important tool for the water resources community at large, as well as for those stakeholders working on more mainstream climate considerations and their planning and management decision making. This Water and Climate Adaptation Plan (WATCAP) for the Sava River Basin (SRB) is an important step in this process, as it provides a sound methodology and guidance for the future.

The WATCAP for the SRB has evolved over a period of three years and was prepared by a technical team comprising a number of external consultants with the financial backing of the Water Partnership Program (WPP), a World Bank multi-donor trust fund, and the Trust Fund for Environmentally and Socially Sustainable Development (TFESSD).

The report has been developed under the overall guidance of global water practice and the direction of Dina Umali-Deininger and Steven Schonberger, Water Practice Managers, by a task team led by David Meerbach, Senior Water Resources Specialist, and with guidance from the International Sava River Basin Commission (ISRBC). The final report was prepared by COWI AS of Norway and includes contributions from multiple authors:

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Ana Vuković (Climate Modeling)
Nikola Zlatanović (Hydrologic Modeling)

Consultations were held with peer reviewers whose comments are incorporated in the main report and the guidance notes. Peer reviewers of the report were: Dejan Komatina (ISRBC); Guy Alaerts, Alejandro Deeb, Winston Yu, Donald F. Larson, and Daniel Gerber (World Bank); and Tarik Kupusović (HEIS, Bosnia and Herzegovina).

Throughout the process of WATCAP preparation, a continual dialogue with the ISRBC was maintained. The WATCAP in its early draft stages was presented at a number of regional workshops and conferences in Zagreb and Belgrade during 2013 and 2014. In July 2014, the draft final version of the WATCAP report was released for general public consultation through ISRBC's website. The report was also distributed to experts in the Sava region, and a workshop was convened on November 10, 2014 at which feedback was provided, followed by a training course on the modeling used in the study on November 11–12. The final WATCAP report was presented at the Fifth Meeting of the Parties in Zagreb, held at the Croatian Water Offices on December 2, 2014.

The study team would like to thank all contributors who assisted in data gathering, analysis, and consultations for their important and relevant contributions and comments. Special gratitude goes to the ISRBC and especially to Dejan Komatina, Secretary of the Commission, Dragan Zeljko, Samo Grošelj, and Željko Milković, who assisted in all phases of the preparation of the WATCAP report.

EXECUTIVE SUMMARY

This report presents the Water and Climate Adaptation Plan (WATCAP) developed for the Sava River Basin (SRB) as result of a study undertaken by the World Bank. The WATCAP is intended to help to bridge the gap between the climate change predictions for the SRB and the decision makers in current and planned water management investment projects that will be affected by changing climate trends. More specifically, the purpose of the report is to:

(i) assist stakeholders and decision makers in assessing and planning for the risks generated by climate change impacts on water resources;
(ii) provide a basis for future plans and studies of adaptation to climate change impacts in the SRB;
(iii) stimulate cooperation and debate across the basin toward additional and more detailed studies on climate change impacts at the regional and basin scale.

BACKGROUND AND INTRODUCTION

The SRB covers an area of approximately 98,000 square kilometers and is one of the major tributaries of the Danube River, accounting for 12 percent of the entire Danube River Basin (DRB) (Exec Figure 1). The SRB is home to almost 9 million people who rely on its waters and natural resources for their daily existence, potable water, hydropower, and agriculture. Furthermore, the Sava River is very important for the overall DRB system and hosts the largest complex of alluvial wetlands located within the Central Sava Basin, together with large lowland forest complexes. These areas are cradles of biological diversity, providing the means upon which countless species of plants and animals depend for their survival. In addition, they are of such special cultural and aesthetic interest that they have been collectively selected as a focal region in the Council of Europe's (CE) Pan European Biological and Landscape Diversity Strategy (PEBLDS).

Source: ISRBC RBMP 2013

Exec Figure 1: Sava River Basin

The Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report[1] from late 2014 confirms previous findings that the Southern Europe region, including the SRB, is highly sensitive to climate change. Recent 1981-2012 trends in annual mean temperature in this region exceed the global mean land trend, and the trends in precipitation suggest more precipitation in winter and less precipitation in summer giving rise to more spring floods and more summer droughts. Among other developments, the recent devastating floods that hit the region in May 2014 bear witness to this fact. Official counts indicate over 1.6 million people have been affected in Serbia, over 1.5 million people in BiH and 0.5 million in Croatia.

The World Bank has responded to climate change concerns by mainstreaming two distinct courses of action: investment financing and analytical work. The former more traditionally addresses mitigation efforts, while the latter deals with adaptation and has become central to the Bank's dialogue on water policy reforms and investment programs with riparian states.

Climate change sensitivities in the SRB are also exacerbated by socioeconomic factors, which have been particularly bad since the 2007 global financial crisis and as a result of steady migration from rural areas to the cities, and by the legacy of the former Federal Republic of Yugoslavia's poor environmental management. Consequently, the SRB must contend with aging infrastructure for water control and use that was poorly constructed and badly maintained, and housing that is ill-suited to cope with storms, floods, or heat waves or to protect people from the impacts of such extreme events.

Assuming no impact from climate change, the SRB is projected to experience small increases in water use by the public water supply, industry, energy, and agricultural/irrigation sectors. However, it is widely expected that new hydropower plants (HPPs) will be constructed in the near future, making energy (primarily through hydropower) the most important water use in the SRB.

OBJECTIVES

In this context, the World Bank undertook this report, the *Water and Climate Adaptation Plan for the Sava River Basin*, with the following objectives:

- Inform government policy and the development community on approaches to adapting water resources management, planning, and operations to the forecasted impact of climate change;
- Enhance the climate resilience of selected water sector investments in the portfolio of international financial institutions and governments;
- Stimulate debate among key stakeholders in the water resources sector in South East Europe (SEE) on climate-related impacts and adaptation strategies.

SCOPE

The above objectives are to be met through the development and dissemination of a WATCAP for the SRB, where existing or planned water management investments supported by the World Bank and national governments are located. The adaptation strategies are sector specific, and the core issues within the SRB that were considered important in the context of climate change are: navigation, flood protection, agricultural water management, and hydropower. The scope of work for the WATCAP therefore consisted of a sequence of consecutive components with five main tasks:

[1] Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

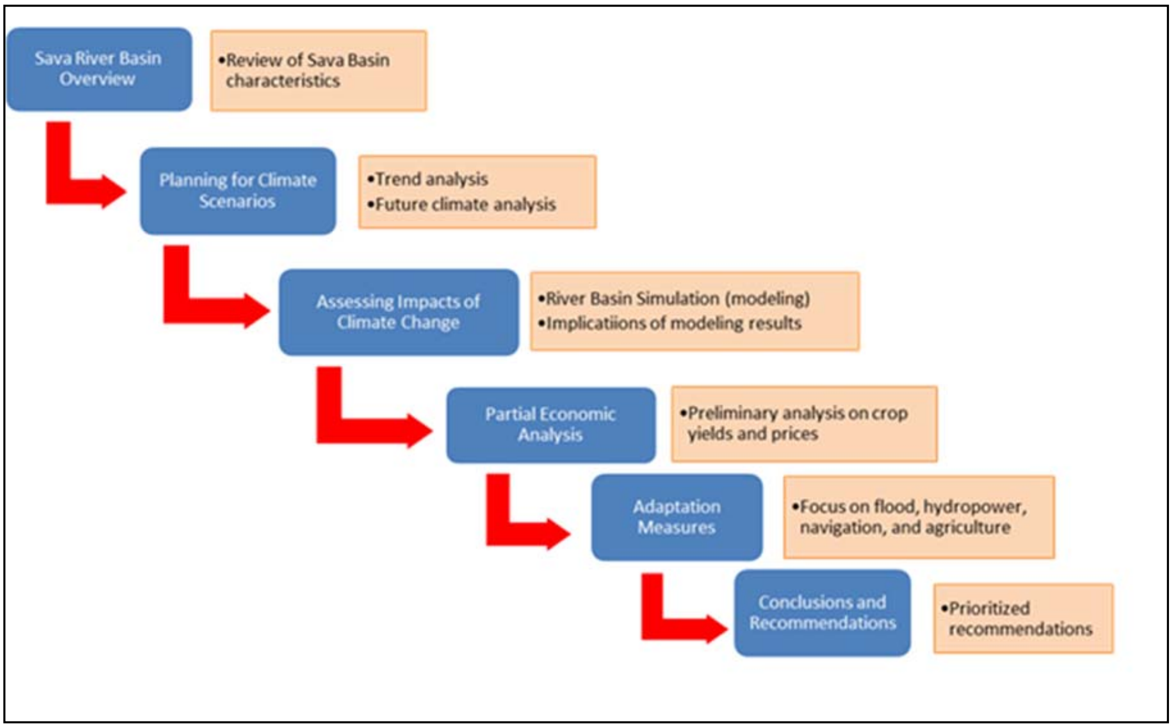
1. A review of historical climate data and an analysis of trends as the means for the characterization of future climate scenarios.
2. The development of future climate scenarios using global and regional climate models (GCMs and RCMs).
3. Preparation of a hydrologic model that included the provision of hydrologic data (river flow, precipitation, temperatures, and evapotranspiration) and a simulation of the basin's response to climate change scenarios.
4. Preparation of guidance notes aimed at disseminating adaptation strategies for specific subsectors within the basin, that is, navigation, floods, hydropower, and agriculture, combined with a preliminary economic evaluation of the impact on crops and crop prices. The guidance notes provide adaptation measures that are based on the results of the hydrologic model simulations, with both historical data and climate change scenarios.
5. Preparation of the WATCAP main report based on the results of climate and hydrologic modeling and the various adaptation scenarios produced in the guidance notes.

PARTNERS

The WATCAP was prepared utilizing a combination of World Bank staff and external consultants. The main beneficiaries for this report are the International Sava River Basin Commission (ISRBC) and the relevant riparian governments of Bosnia and Herzegovina (BiH, involving the entities of Republika Srpska [RS] and Federation BiH [FBiH]), Croatia, Montenegro, Serbia, and Slovenia. Funding for the WATCAP was provided using trust funds from the World Bank Water Partnership Program (WPP) and the Trust Fund for Environmentally and Socially Sustainable Development (TFESSD).

METHODOLOGY

The approach and methodology for the development of the WATCAP is presented schematically in Exec Figure 2, which shows the logical steps undertaken in the preparation of this report. The principal idea was to develop future climate and hydrology scenarios in the SRB that would serve to assess the vulnerability of the selected water sectors to climate change and to propose adaptation measures.



Source: Figure produced by COWI 2014

Exec Figure 2: Flowchart depicting methodology for WATCAP preparation

Trend Analysis

As the first task, an analysis of trends in observed precipitation, temperature, evaporation, and river discharge was provided to identify regional climate behavior. Observed climate tendencies are considered important as the means of projecting future climate developments and verifying future climate trends predicted by climate models. The analysis was based on simple statistical measures and data from national experts, followed by an analysis done within the World Bank.

Climate Modeling

For the 21st century climate predictions, the A1B IPCC/Special Report on Emissions Scenarios (SRES) greenhouse gas (GHG) emission scenario was assumed. This scenario is considered to be a mid-level intensity scenario and is commonly used for the future projection of GHG emissions in many climate change studies. Two different methodologies for developing climate scenarios were applied, both of which relied on an ensemble of GCM outputs. The first approach was based on developing probability distributions of future climate parameters in a Bayesian framework,[2] while the second approach applied RCMs to downscale the GCM outputs in order to derive time series of future precipitation and temperature for locations used in the impact modelling.

The RCM approach was based on a number of suitable GCM/RCM climate simulation chains across the European region, available from the ENSEMBLES project[3] (Exec Table 1). Using this approach, future climate scenarios were developed for two 30-year time frames: 2011–40 (near future) and 2041–70 (distant future). The baseline time frame was 1961–90 as the standard climatological period for which the majority of climate data were available (there are huge gaps in the 1990s data due to the conflicts in the region). These scenarios were adopted for further use in hydrologic and other simulations.

The results of an earlier application based on the same approach by the University of Ljubljana in Slovenia were also used for an assessment of the climate change impacts on floods. In this case, an ensemble of 16 GCM/RCM model runs was used for the same future time frames and additionally for 2071–2100.

Exec Table 1: GCM/RCM model chains used for developing climate scenarios.

Model No.	Institution	GCM	RCM
CM1	KNMI	ECHAM5r3	RACMO
CM2	MPI	ECHAM5r3	REMO
CM3	ETHZ	HadCM3Q0	CLM
CM4	METO	HadCM3Q0	HadRM3Q0
CM5	ICTP	ECHAM5r3	RegCM3

Source: COWI 2014

Impact Modeling

Another important part of the WATCAP was the development of a hydrologic model of the entire SRB with the aim of providing a simulation tool for converting climate scenarios into hydrologic scenarios. For this purpose, the HEC-HMS[4] modeling software was selected in consultation with the ISRBC for three reasons: (1) a preliminary model in HEC-HMS had already been developed for the ISRBC by the U.S. Army Corps of Engineers (USACE), and there was a strong preference within the ISRBC for continuation in this direction; (2) the HEC-HMS can be easily disseminated to users in the SRB as the software is free of charge; and (3) the HEC-HMS model has low data requirements, which is advantageous due to the chronic shortage of data that exist in the SRB.

[2] The framework uses Bayes Theory of the concept of probability.
[3] ENSEMBLES Project, European Union, 2013 (www.ensembles-eu.org).
[4] Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) by U.S. Army Corps of Engineers (http://www.hec.usace.army.mil/software/hec-hms/)

The data needed for model development were collected by individual experts from the SRB riparian countries. Data sets were also collected from the trend analysis, from previous work undertaken on the Vrbas Basin in BiH, and for the Drina River Basin, which was obtained through the ISRBC's direct contact with the Hydro-meteorological Institute of Montenegro.

The results of the hydrologic simulations using the HMS model with baseline and future climate scenarios were used to assess the future mean and low water flows at a multitude of locations along the Sava River and its tributaries. A number of different indicators of the hydrologic regime were developed to support an analysis of the impact of climate change on navigation and hydropower.

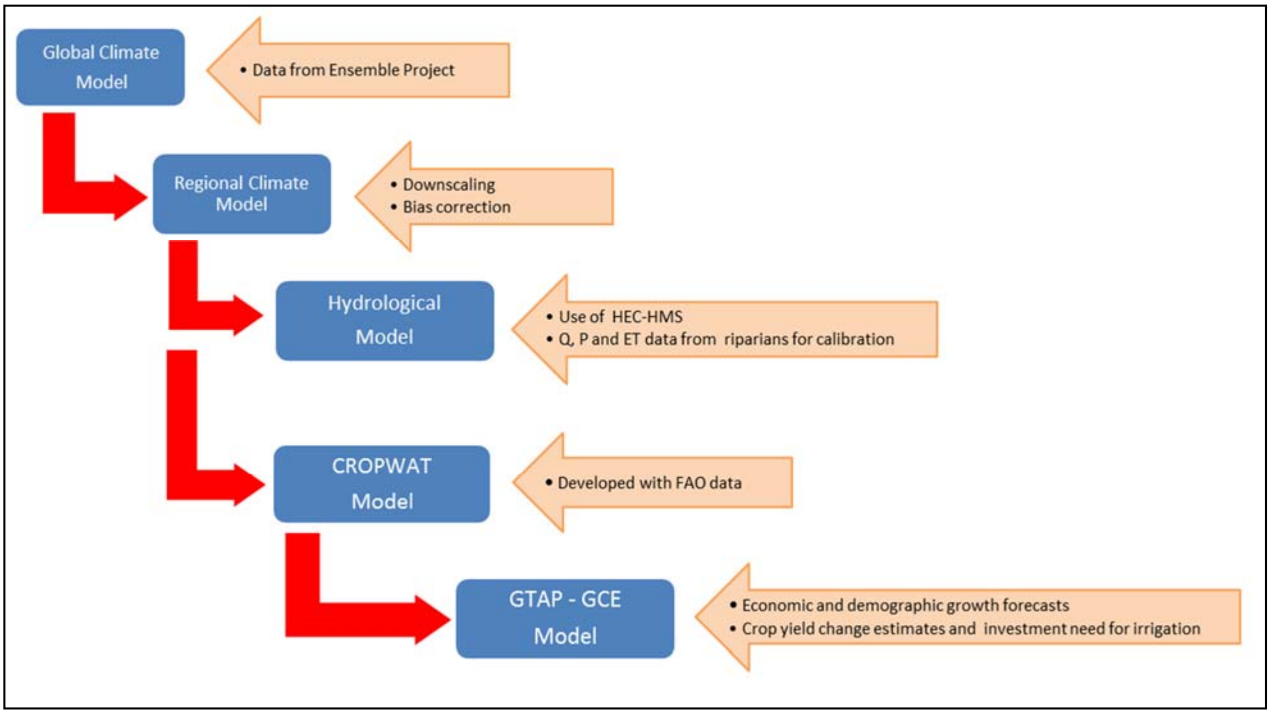
Another hydrologic model developed earlier by the University of Ljubljana using HBV modeling software[5] was also used to simulate climate change impacts on floods in the SRB. Unlike the model developed in HEC-HMS, the HBV-based model was specifically calibrated for flood flows, and its results served to develop the *Flood Guidance Note*.

The analysis of the vulnerability of agriculture to climate change used crop water balance as a tool to determine the water stress and subsequent crop yield changes. This analysis was done for four proxy locations, one for each of the riparian countries (Montenegro was not included), and was based on the future climate scenarios. The crop water balance and yield response for four representative crops in representative soil for each location were calculated using the CROPWAT model from the Food and Agriculture Organization of the United Nations (FAO).[6] The agricultural adaptation measures proposed in this report are based on the outputs of this analysis.

A preliminary economic analysis was conducted to assess the magnitude and distribution of the costs of climate change impacts and the adaptation options under alternative water regime scenarios. This study adopted an integrated approach, combining crop modeling with an economy-wide analysis. For this purpose, an economy-wide model for the SRB countries was first developed to describe the most likely economic growth path for the various regions without taking into account the potential impact of climate change. The economic analysis then focused on the macro-level impacts of climate change through country and inter-regional computable general equilibrium analyses (GTAP/CGE model).

A number of different models utilized in the WATCAP preparation and their different interactions and interrelationships are shown in Exec Figure 3.

[5] Hydrologiska Byråns Vattenbalansavdelning (HBV) is a computer simulation model used to analyze river discharge.
[6] CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO.



Source: Figure produced by COWI 2014

Exec Figure 3: Flowchart depicting model interrelationships

Uncertainties in the projections and limitations of the methodology

The comprehensive modeling chain used in the WATCAP's development is a useful tool for investigating climate change impacts on various aspects of the water regime and water management sectors. At the same time, the models are idealized representations of real systems and are built on limited data and information. The models and their outputs are therefore unavoidably associated with a range of uncertainties. Limitations on the methodology can be summarized as follows:

- Although historical hydro-meteorological data and trends can benefit water management of the SRB in terms of planning for infrastructure and integrated water resources management, the results of the analysis should be treated with care. These results are obtained from the hydro-meteorological records of varying time spans, and hence the consistency of the trends may be of concern.
- An ensemble of five appropriate GCM/RCM model chains (Exec Table 1) from just one GHG emission scenario was used, which provides only a limited insight into the uncertainties related to future tendencies in GHG emissions and to climate modeling.
- The methodology takes into account the climate change impacts only. Demographic, land use, and other anthropogenic changes are not analyzed, as there was no readily available data. However, this approach makes it possible to examine the partial or even marginal effects of climate change on the water sectors, isolated from other effects. This should give a better picture of the climate change threats to the water sectors in comparison to other changes, although the integrated effects of all changes should be considered when devising development strategies for these sectors.
- The hydrologic model is capable of reproducing natural Sava basin runoff but cannot cope with flow regulation by water management facilities such as reservoirs, a consequence of the lack of factual information on current water management operation and practice. This hinders efforts to carry out a comprehensive analysis of the impact of current and potentially adapted water management policies on water sectors such as hydropower production.
- The outcomes of the study are marked with a measure of uncertainty related to both the direction and magnitude of the changes in water quantities and distribution. As such, in

policy making, the outcomes should be considered as possible future scenarios rather than reliable future predictions.

RESULTS OF CLIMATE AND IMPACT MODELING

Historical climate trends

Analysis of the historical climate data generally shows warming trends in temperature, highly variable precipitation patterns, and a changing hydrology. Mean temperature is rising throughout the SRB, a result of the rarer occurrence of colder extremes and more frequent higher temperatures rather than of an exceedance of extreme temperatures. Long-term trends in precipitation are small or negligible, but a long-term oscillation in precipitation exists and produces a sequence of short-term trends with opposite directions. Seasonal patterns of precipitation and temperature also exhibit evolution over time, with varying trend magnitudes in different seasons. Evaporation and evapotranspiration show increasing trends.

River discharge is declining noticeably even though precipitation is declining little or not at all. The decline in discharge seems to be a consequence of increased evapotranspiration resulting from rising mean temperature and reforestation. Discharge also manifests multi-decade oscillations in mean flow and seasonal distribution, as do temperature and precipitation.

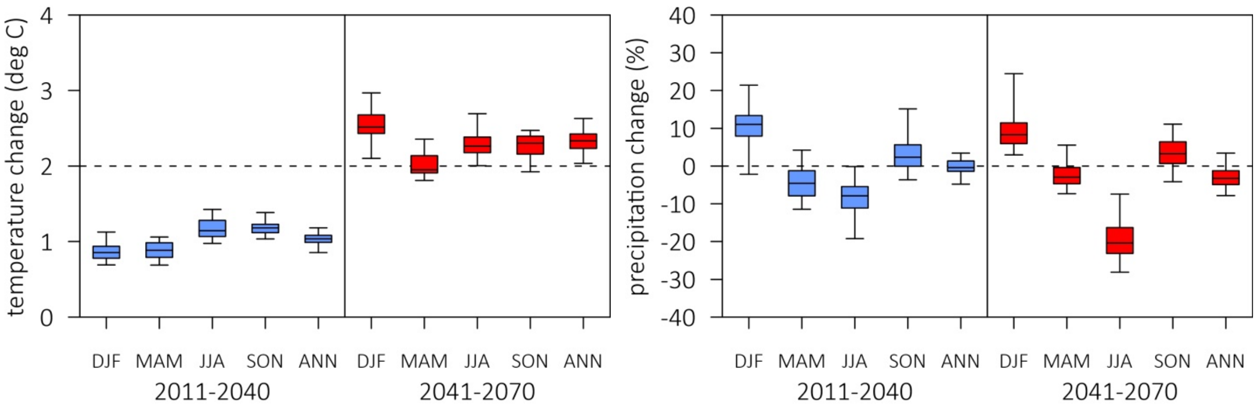
Climate modeling and future climate scenarios

The future climate analysis based on the probability distributions developed in the Bayesian framework found that future precipitation exhibit changes consistent with those found in other climate change studies and in the observed historical data. At the same time, modeled temperature and evapotranspiration proved to be completely out of the observed climate variability range. That approach was therefore not found to be useful for further analysis.

The results of the RCM approach for the future climate scenarios were analyzed on a seasonal and annual basis for the two future periods outlined in the report: 2011–40 and 2041–70 (Exec Figure 4). All five GCM/RCM models showed a temperature increase across the SRB, with larger values apparent for 2041–70. Precipitation change is, however, more complex. Although it shows only a slight decrease on the annual level, seasonal changes are more pronounced; despite a lot of spatial variation, precipitation generally shows an increase during the winter and a decrease for the summer months. The summer precipitation deficit is more pronounced for 2041–70 than for 2011–40.

Very similar conclusions were drawn from the separate study by the University of Ljubljana that was based on 16 GCM/RCM model chains from the same gas emission scenario (A1B IPCC SRES). This set of climate model outputs was also used to analyze changes in maximum daily precipitation across the basin as one of the indicators of flood hazards. The maximum daily precipitation in the autumn season was analyzed, since autumn precipitation has proven to produce the largest floods. The analysis showed that the maximum daily precipitation in autumn will increase until the end of the 21st century on average by 22 percent for the 20-year return period and by 32 percent for the 100-year return period. However, the percentage increases seem to be randomly distributed over the SRB; higher values are characteristic for the edge of the basin from the northwest to the southeast and in the area of the Dinaric Mountains, and lower values for the central part.

The historical trends in temperatures agree with those predicted by GCM outputs only in trend direction (rising temperatures), but the two approaches quantify this increase differently. Precipitation tendencies as given by trends and by GCM outputs do not correlate highly. However, the spatial patterns of these tendencies across the basin as inferred from both trends and GCMs are quite variable, thus indicating the presence of a very high uncertainty in future precipitation.



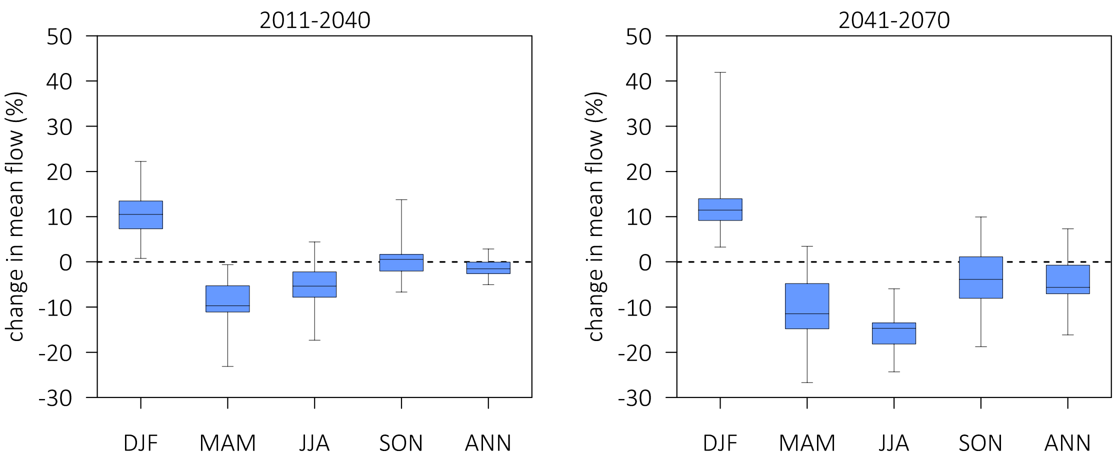
Source: Figure produced by COWI 2014

Exec Figure 4: Change in ensemble median values of mean seasonal (DJF, MAM, JJA, SON) and annual (ANN) temperature (left) and precipitation (right); box plots indicate variation across the basin

Hydrologic simulations – mean flows

Calibration and verification of the hydrological model developed in HEC-HMS proved that the model can reproduce month-to-month or year-to-year runoff variations reasonably well at most hydrologic stations. Poorer results are related to those locations where there are doubts about the validity of measurements and/or a good representation of precipitation over the sub-basin, or where complex geological structures such as karst[7] would require more complex runoff estimation methods.

Hydrologic simulations with the future climate ensemble from the GCM/RCMs showed that a change in the hydrologic regime corresponds to the projected changes in precipitation and temperature. The most notable change in both the near and distant future is the predicted increase in runoff in the winter season, as a result of an increase in precipitation and a significant rise in temperatures. The higher temperatures and increased precipitation in the winter season suggest that there would be either a smaller share of snow compared to rainfall or more snowmelt, but both alternatives lead to greater winter streamflow. This increase is evident in the results from all five climate scenarios in both time frames and over the whole basin (Exec Figure 5).



Source: Figure produced by COWI 2014

Exec Figure 5: Change in ensemble median values of mean seasonal (DJF, MAM, JJA, SON) and annual (ANN) runoff; box plots indicate variation across the basin

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[7] Karst is a landscape formed from the dissolution of soluble rocks including limestone and dolomite. It is characterized by sinkholes, caves, and underground drainage systems

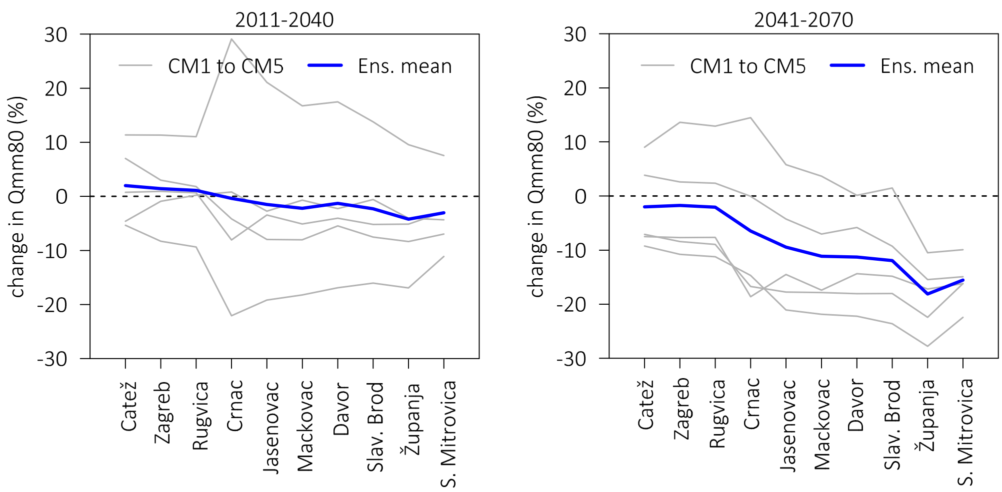
A substantial decrease in river flows is expected in the spring and summer seasons but somewhat differently when considering the near and distant future. The spring decrease is clear in both the near and distant future over the whole basin, though it is projected to be greater in the distant future with more substantial variation across the basin. Summer runoff is expected to decline in the near future according to four climate models (CM1–CM4) and increase according to one (CM5). This behavior is generally following the pattern of decreased precipitation and higher temperatures projected by the climate models, except that the near future summer runoff reduction is less pronounced, despite a greater reduction in precipitation.

The autumn season exhibits a very small change on average for both the near and distant future. The overall change in annual runoff is therefore small as a result of opposite winter and spring/summer trends, with both the negative and positive changes effectively canceling each other out.

In terms of high and low annual flows, the results indicate that low annual flows are projected to decline somewhat, meaning that the proportion of very dry years would slightly increase. On the other hand, high annual flows show a greater reduction, indicating that the proportion of very wet years would decrease.

Hydrologic simulations – low flows

The change in the frequency of low flows, which are an important factor for navigation and water supply, was assessed by looking into probability distributions of minimum mean monthly flows. The 80 and 95 percent probability quantiles (Qmm80 and Qmm95) as typical low-flow measures are used as indicators.[8] The results revealed great variation among the climate models (Exec Figure 6) but on average, Qmm80 is not likely to change in the near future, while a significant decrease could be expected in the distant future downstream of Sisak in Croatia (i.e., downstream of the confluence of the Kupa and Sava Rivers—see map in Exec Figure 1). The results for Qmm95 are similar.



Source: Figure produced by COWI 2014

Exec Figure 6: Change in minimum mean monthly flow of 80% probability of exceedance (Qmm80) in near future (left) and distant future (right) along the Sava River

Hydrologic simulations – flood flows

Based on the output of hydrologic modeling using the HBV model, the probability distributions of future floods were derived for hydrologic stations along the Sava River in order to estimate future

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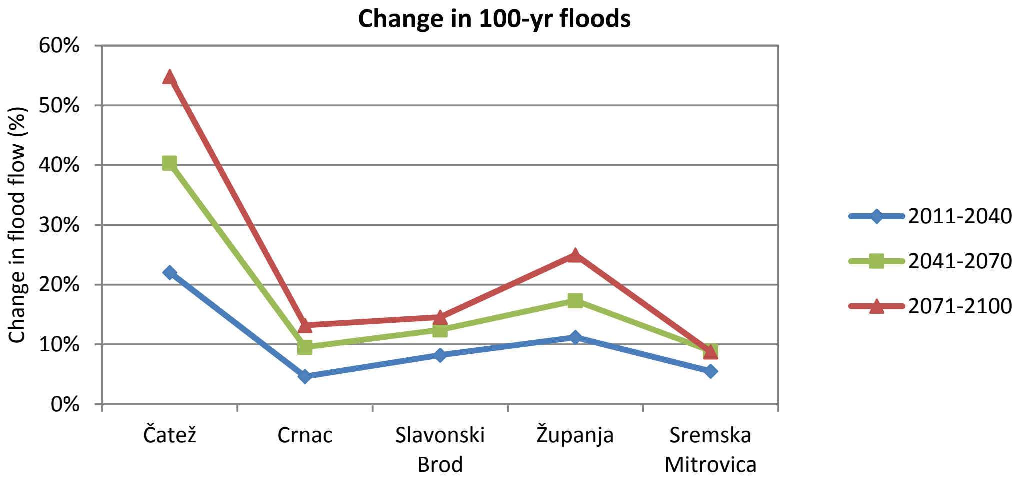
[8] Quantiles are values taken from the inverse of the cumulative distribution function (CDF) of a random variable. Qmm80 and Qmm95 are the minimum monthly river flows exceeded each year with a probability of 80 percent and 95 percent, respectively. In other words, each year there is a probability of 20 percent and 5 percent that the minimum monthly river flows will be below Qmm80 and Qmm95, respectively.

floods with a return period of up to 1,000 years. The hydrologic projections plainly indicate that floods will increase in the future due to climate change. The increase was shown to be greater for 100-year floods than for the 20-year events, thus suggesting an overall increase of the flood risk.

The greatest increase in floods is expected in the head part of the SRB, that is, in Slovenia (the Čatež hydrologic station) and in the main right tributaries (Kupa, Una, and Bosna). By the end of the 21st century, the 100-year floods along the Sava River will increase as shown in Exec Figure 7. The results also demonstrated that the predicted floods on the Drina River and in the lower Sava downstream of Sremska Mitrovica (in Serbia) will be smaller for the late 21st century than for the middle period; however, this could be a result of the fact that fewer precipitation projections were used for 2071–2100.



Source: Figure produced by COWI 2015

Exec Figure 7: Change in flood flows of 20-year (left) and 100-year (right) return period along the Sava River

CLIMATE CHANGE IMPACTS ON WATER SECTORS

Flood Management

Current flood protection in the SRB is insufficient for effective flood management for many reasons, including inadequate infrastructure, poor maintenance, the lack of coordination in the basin in terms of monitoring, forecasting, and warning systems, and so on. This was starkly evident during the destructive floods of May 2014, which were assessed as some of the worst on record. Keeping in mind the flood protection system's poor status currently, it would be very difficult to look only into the marginal effects of climate change on flood management.

The main predicted impact on future flood management is not only climate related, but associated also with future social, economic, and infrastructure development. Without a doubt, the impact that climate change will have on flooding in the future is significant and should not be underestimated, since the flood hazard is increasing. Although the modeling results indicate that the climate-induced impact will be smaller in the downstream plains than in the upstream mountainous regions, the role of flood protection infrastructure even in the downstream plains should not be ignored, as the infrastructure protecting the upstream regions is at the same time increasing the downstream risk.

In Croatia, for example, the May 2014 floods proved that the existing natural retentions have a limited capacity to accept major flooding, thereby emphasizing the need to increase this means of flood protection to complement the aging and insufficient system of embankments. The middle Sava valley (Central Posavina) in particular is an extremely important flood retention area that needs to be protected from further development.

Since the modern era, there has been a general migration of people from rural to urban areas in the SRB countries, which is a global tendency for countries in transition. This urbanization trend can be expected to continue in the future, thus increasing the vulnerability of the capitals built along the Sava River (Ljubljana, Zagreb, and Belgrade) and also to the smaller towns, such as Sisak, Slavonski Brod, Brčko, etc., that are all prone to flooding when the river and its tributaries rise. The May 2014 flood proved that the urban areas are at greatest risk; flood protection for these areas, including for critical infrastructure (e.g., roads, railway, pipelines, etc.), should therefore be prioritized. This implies that outlays for flood protection will need to increase in the future, possibly at the expense of protection for agriculture areas, which should be reduced if it is deemed necessary. Clearly, carefully designed adaptation measures for long-term flood planning must be developed.

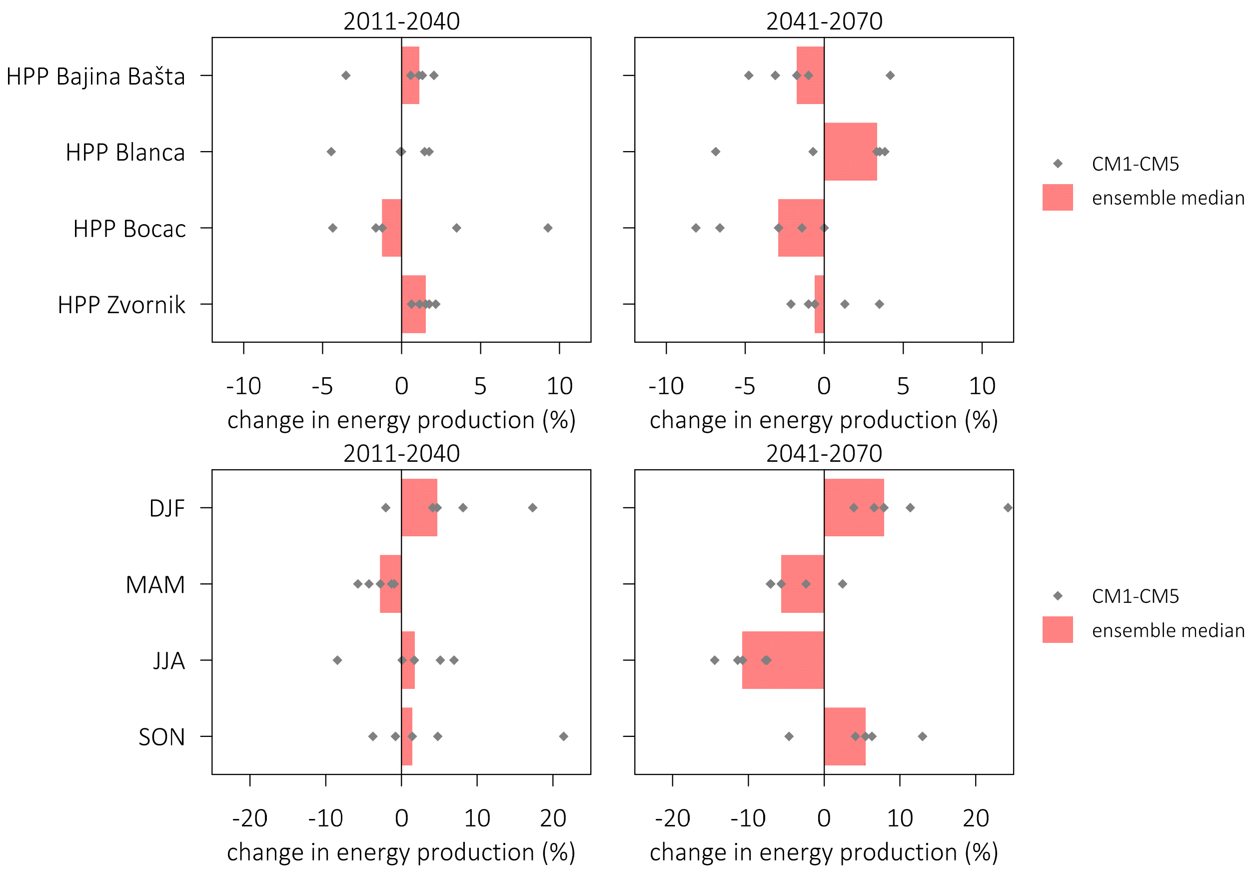
Hydropower

The impact of climate change on hydropower is principally associated with direct effects on power generating potential. There will also be indirect effects, however, involving an increased demand for energy for heating and cooling due to the projected higher and lower temperatures.

A decrease in river runoff would affect power generation through a reduction in the amount of water available at all HPPs, but would particularly affect run-of-the-river schemes that are solely dependent on river runoff. Floods in the autumn/winter and droughts in the spring/summer would also mostly affect run-of-the-river HPPs, as well as those with small reservoirs. With increasing evaporation due to future rising temperatures, hydropower production is expected to decrease in the reservoir and pumped storage–type facilities that have a high storage area/volume ratio and small reservoirs. Other types of HPPs would face smaller effects but still experience a decrease in hydropower generation.

Hence, it is expected that power generation from the hydropower sector in the SRB will be lower in the future. Case studies were made at four HPPs (one in Slovenia and in the Vrbas sub-basin and two in the Drina River Basin) that were chosen for their significance in the power sector and their close proximity to existing hydrological stations with reliable data. (It should be pointed out here that the hydropower operators in question were generally reluctant to share their operational data with water agencies, thus creating an impediment to the overall results of the modeling work.) The case studies showed negligible or small changes (less than ±5 percent) in average annual energy production potential in the near future for all HPPs except for Bočac in BiH, where one climate model predicts an increase of 9 percent (Exec Figure 8). Changes are somewhat more pronounced in the distant future, with larger variation among the climate models, where again the most notable changes are at HPP Bočac. The general trend in most cases, however, is decreasing hydropower production.

An analysis of the seasonal energy production at HPP Bajina Bašta in Serbia shows a general trend of more energy available in the near future in winter and autumn and a small decrease in spring (see also Exec Figure 8). For the distant future, a greater production decrease can be expected for the spring and summer seasons (4% and 10% on average, respectively) and an increase in winter and autumn (11% and 5% on average, respectively). It should be noted, however, that currently, power companies in the region generally fail to carefully optimize the operation of reservoir-type HPPs, and the projected magnitude of decrease in power production might be compensated for by an increase in production under well-optimized operational rules.



Source: Figure produced by COWI 2014

Exec Figure 8: Relative change in annual energy production (top) and seasonal production at HPP Bajina Bašta (bottom) according to climate models CM1-CM5 for near/distant future

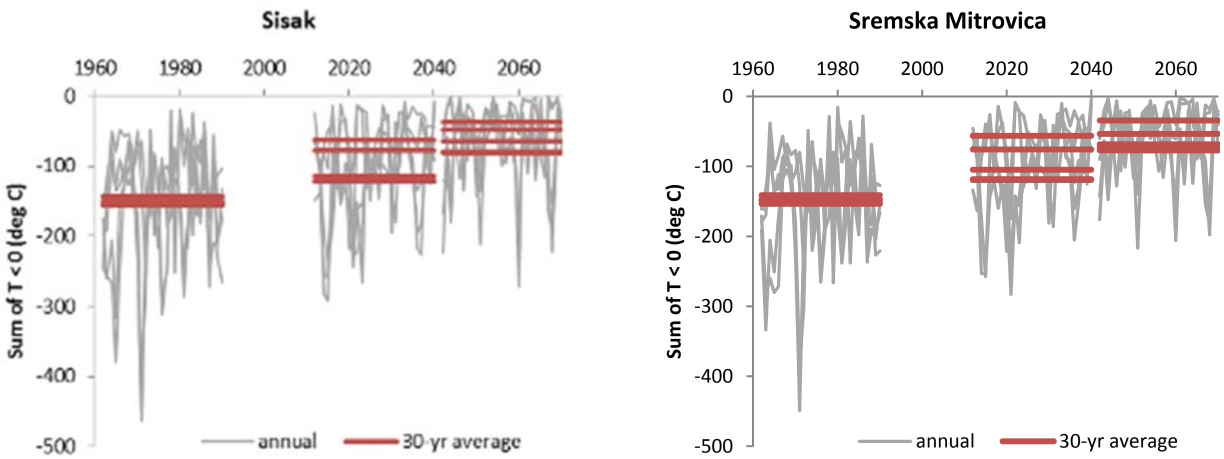
Navigation

The impacts of climate change on navigation were considered by evaluating the changes in three indicators: low flows, high flows, and river ice.

Low-flow thresholds for the Sava River are associated with two target water depths that facilitate navigation with a maximum and a reduced draft; a maximum draft must be possible for 65 percent of the time and a reduced draft for 95 percent. The modeling results indicate that virtually no change in the low flows corresponding to these two water depths, Q65 and Q95, is likely to occur in the near future, while a modest decrease can be expected in the distant future, which will be more significant downstream of Sisak. In addition, the number of days with flows below the current (or baseline) Q65 and Q95 is likely to increase very little in the near future (on average for three days and two days, respectively), but a significant increase can be expected in the distant future downstream of Sisak (on average for 13 and eight days, respectively). Therefore, restrictions on the number of navigable days could be much more pronounced in the distant future.

High flows, which were assessed as the flows exceeded for 1 and 3 percent of time during a year, do not exhibit significant changes in the future. They are therefore not likely to have additional implications on the navigation sector in terms of the number of days that navigation would be restricted or suspended due to high flows compared to current conditions.

Given the general trend in rising temperatures that all climate models predict, a reduced potential for ice formation along the whole navigable part of the Sava River can be expected. This is shown for two stations on the Sava River (Sisak and Sremska Mitrovica) in Exec Figure 9 below. This, of course, would have a beneficial impact on inland navigation, since the number of days per year that navigation would be suspended due to ice is expected to decrease.



Source: Figure produced by COWI 2014

Exec Figure 9: Change in the sums of negative daily temperature in the November–March season at two locations along the Sava River waterway as an indicator of the potential for ice formation (horizontal bars indicate average values for 30 years from different climate models)

Agriculture

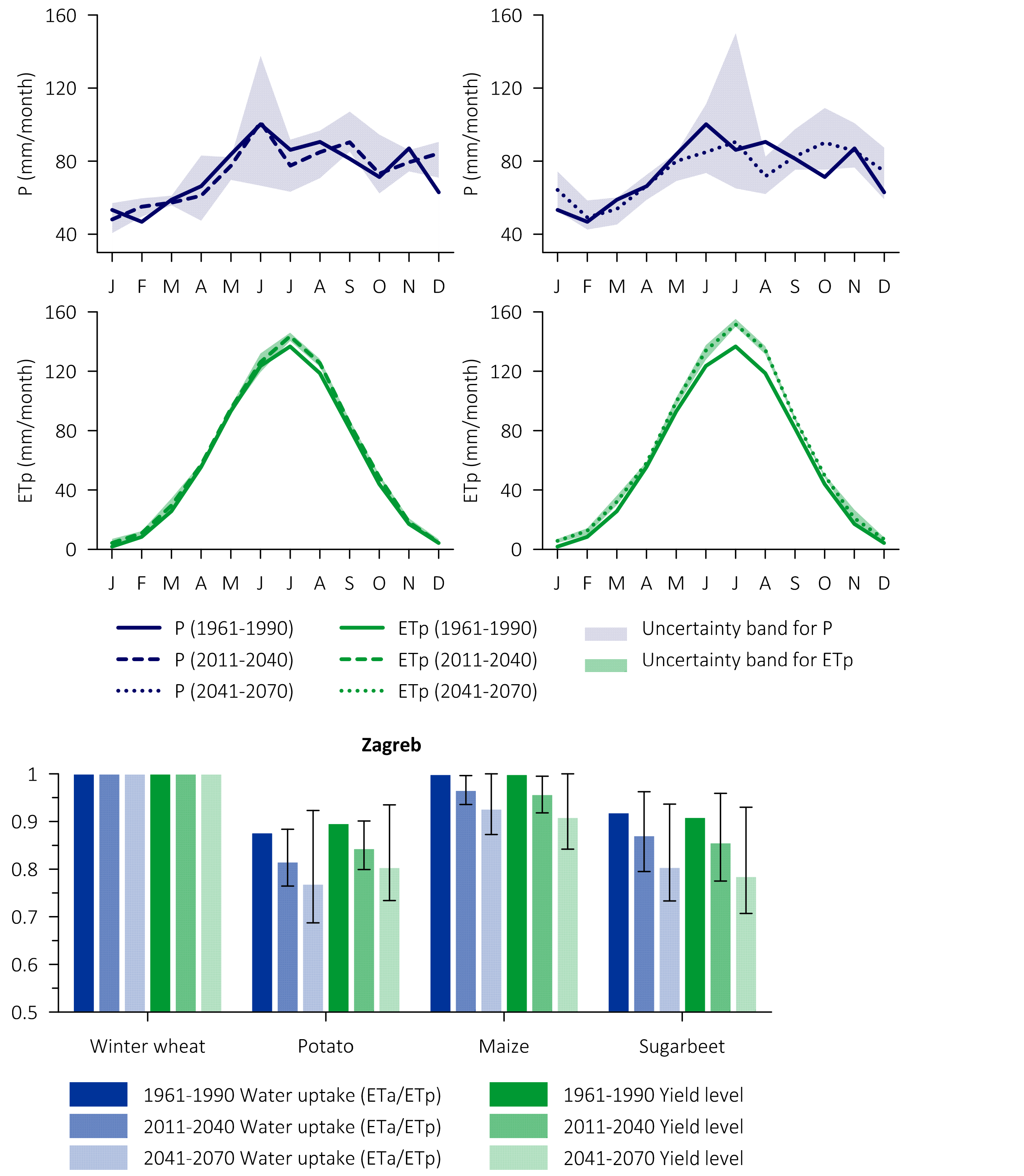
The SRB's food sector lags behind the rest of the economy in growth terms largely because it is undercapitalized, fragmented, and dominated by small producers. In addition, irrigation in the SRB accounts for less than 1 percent of total water withdrawals. A vulnerability analysis was undertaken to assess the impact of a changing climate on crop water status and crop yields using the crop water balance to determine the water stress and subsequent crop yield changes.

A selection of four representative crops were used for each of the four main riparian states (Montenegro was excluded), with case studies being made for Ljubljana (Slovenia), Zagreb (Croatia), Banja Luka (entity of RS in BiH), and Sremska Mitrovica (Serbia).

The general consensus was that extreme events will occur more often or with more intensity, which will test the current systems and have a substantial impact on the economy of SRB countries. The resulting evaporation from temperature rises will create more aridity and increase the probability of forest fires; higher temperatures will also affect crop development, cause heat stress in livestock, and increase the likelihood of pests and diseases in crops and animals. There might additionally be phenological changes leading to the altitudinal and latitudinal shifts of plant ranges.

Predicted lower flows will also have a stronger impact on agriculture, as they will result in more stress on irrigation and a higher probability of drought and frost. The impacts of this vulnerability will increase further south and east within the basin.

An example of the analytical results for Zagreb is shown in Exec Figure 10. Zagreb currently has what can be considered moderate rainfall, with an average of 888 millimeters per year (mm/year) (1961–90), which is lower in the winter months and higher in the summer months. Climate scenario modeling shows that precipitation will increase very slightly to 890 mm/year (2011–40) and to 894 mm/year (2041–70), with a slight increase in winter precipitation and a slight decrease in summer precipitation. Overall evapotranspiration is projected to change more significantly than rainfall, increasing from 710 mm/year (1961–90) to 748 mm/year and 794 mm/year, respectively, for the 2011–40 and 2041–70 time frames. Almost all of this increase would occur in the summer months. However, there is a high uncertainty in future precipitation that is especially pronounced in the summer months whilst the uncertainty for evapotranspiration is much smaller.



Source: Figure produced by COWI 2015 Error bars indicate uncertainties

Exec Figure 10: Climate projections, water uptake (ETa/ETp) and yield levels for Zagreb with uncertainties

Model projections indicate that impacts are likely to be pronounced in the crop water balance due to changes in precipitation and evapotranspiration. Surplus rainfall in winter gets stored in the root zone that suits winter wheat, so there is some storage buffer, but toward the end of the growing season, the summer crops will be experiencing water stress. Some water stress is already being experienced by the potato and sugar beet crops as a result of their relatively shallow root zone compared to winter wheat and maize, and water stress is projected to become more pronounced as the evapotranspiration increases in summer, with significant yield reductions as a result.

However, due to high uncertainty in future precipitation, the crop modelling results need to be viewed with caution, especially for the distant future.

On a positive note, the predicted temperature rises might expand the growing season across the basin, with longer summers and warmer winters that might potentially provide an increase in agricultural production for selected crops that require less watering.

Economic evaluation of climate change impacts on agriculture

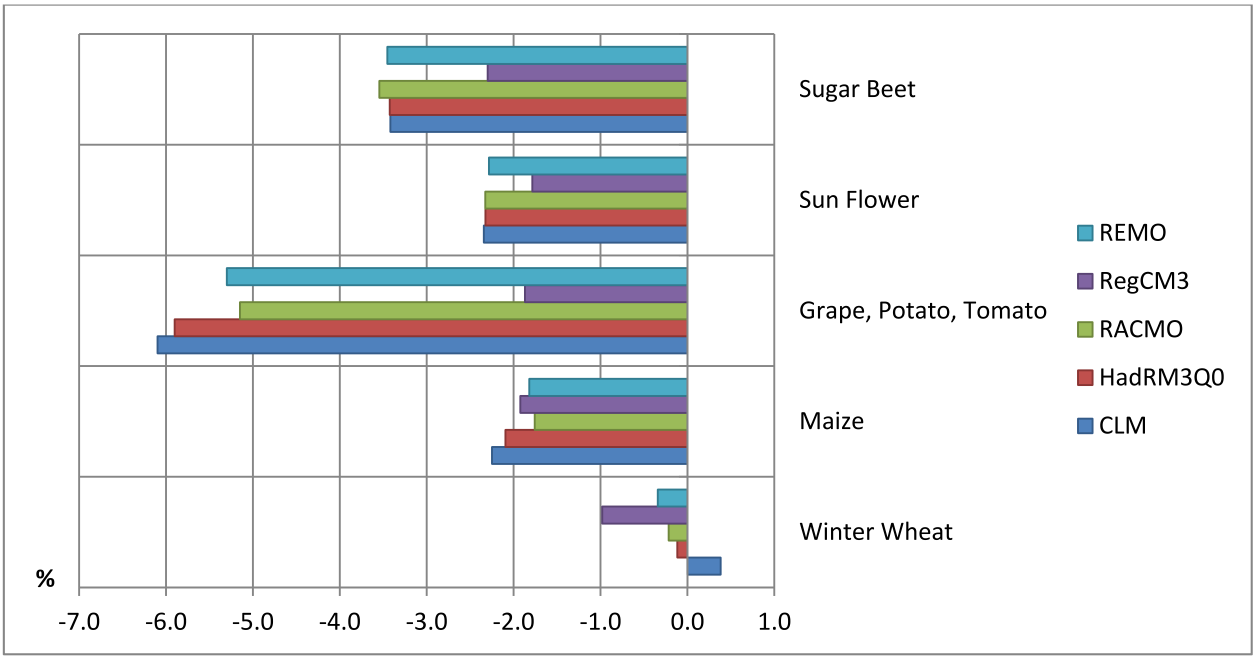
A preliminary economic evaluation was carried out, combining crop modeling with an economy-wide analysis, to measure the expected economic costs of climate change impacts on selected crops and adaptation options under alternative water regime scenarios at the sector and economy-wide levels. Data were obtained from a variety of sources, including the Global Trade Analysis Project (GTAP), International Monetary Fund (IMF), U.S. Department of Agriculture (USDA), FAO, etc., as well as national statistics centers in the riparian states. GTAP and CROPWAT models were used together with the five GCM/RCM scenarios shown in Exec Table 1.

Countries facing severe impacts from climate change on the agricultural sector will witness rising agricultural prices that will be reflected in higher consumer prices. Rising prices will negatively affect consumers' disposable income and likely motivate them to substitute the consumption of agricultural goods with less expensive commodities or imported agricultural products.

Simulation results for yields from a 2007 baseline show a marked variation depending on the GCM/RCM scenario used. Results indicate yields may vary from the baseline from -6 to +3.5 percent for each crop and producing country through time.

Among SRB countries, the agriculture sectors of Serbia and BiH are estimated to be the most vulnerable to climate change. Grape, tomato, and potato yields are predicted to decline by around 6 percent by 2070 compared to a baseline scenario in which climate impacts are not taken into account. For sugar beets, sunflowers, and maize, loss estimates are -2 to -3.5 percent from the baseline. The predicted impact on winter wheat is lower and varies from +0.5 to -1 percent. These crop loss estimates are illustrated in Exec Figure 11.

Simulated results for crop prices show a rise with respect to the baseline scenario except for winter wheat. Again, Serbia and BiH are the most vulnerable, as these countries are where price hikes are predicted to be the highest. The CGE model signals different price changes according to the choice of the GCM/RCM climate model. The lowest and highest values are predicted as 8–18 percent for winter wheat; 15–80 percent for potatoes, grapes, tomatoes, maize, and sunflowers; and 5–100 percent for sugar beets. Thus, the predicted price variation between regions is the highest for winter wheat and the lowest for sugar beets. For a majority of the crops, the price changes vary between 15 and 80 percent compared to their 2010 prices, according to the CGE model simulations.



Source: Figure produced by World Bank 2014

Exec Figure 11: Serbia and BiH - Crops in 2070 (% change from the baseline scenario)

ADAPTATION

Policy frameworks for adaptation

An assessment of the various analyses undertaken clearly points to a need for the SRB's key stakeholders to consider and act upon climate change adaptation. Although the process of adaptation to changes in climate is not new, the analytical work carried out in this study shows that the pace of change and the scale of impacts, including from extreme events, are unprecedented and are likely only to get worse, especially in the latter part of the 21st century. Consequently, climate risk–based approaches that address climate variability and climate change need to be integrated into water policy frameworks in the SRB riparian states.

Two key framework policies for the SRB that are highly relevant to climate change adaptation are the European Union's (EU) Water Framework Directive and its Floods Directive. EU countries such as Slovenia and recently joined Croatia already comply with such legislation; the other SRB states, BiH (RS and FBiH), Montenegro, and Serbia, also recognize these EU policies in their own national legislation under their EU *acquis communautaire* plans.

Furthermore, the National Adaptation Strategies (NAS) developed under EU auspices focus on assessing the current situation and on the additional requirements needed to contend with climate change. Among the SRB countries, an NAS is in preparation in Slovenia, BiH, and Serbia, while there is currently no NAS in Croatia and Montenegro.

In terms of European policy, the EC White Paper on Adaptation,[9] together with the United Nations Economic Commission for Europe (UNECE) Guidance on Water and Adaptation to Climate Change,[10] are important documents in the effort to address climate change concerns. The latter in particular offers useful support to decision makers by providing advice on the challenges that climate change will bring to water management and water-related activities and on the development of adaptation strategies.

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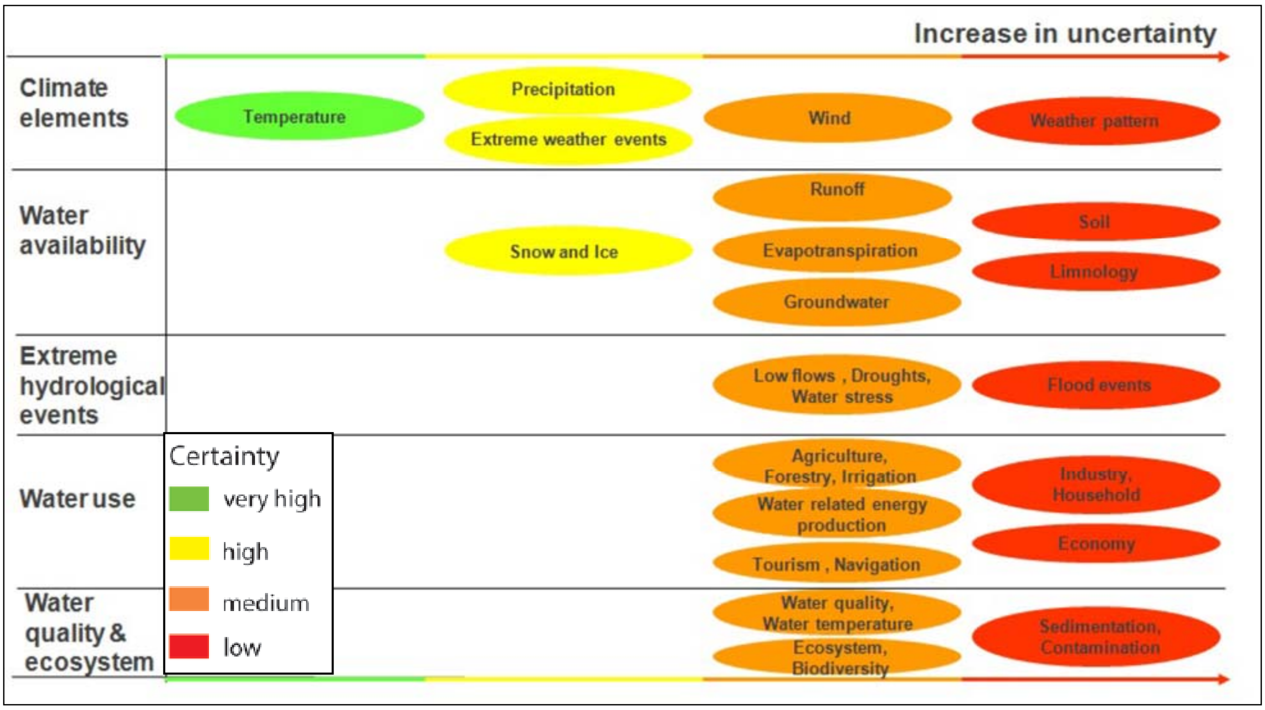
[9] European Commission (2009) White Paper: Adapting to climate change: Towards a European framework for action.
[10] United Nations Economic Commission for Europe (2008) Guidance on Water and Adaptation to Climate Change.

Dealing with uncertainty

The uncertainties surrounding the impact of climate change are an important issue. This report recommends that the SRB's key stakeholders follow the lead of the International Commission for the Protection of the Danube River (ICPDR),[11] which has mapped out the expected impacts and uncertainties experienced in the Danube River Basin that are of direct relevance to the SRB. These are shown in Exec Figure 12 below.



Source: ICPDR Strategy on Adaptation to Climate Change

Exec Figure 12: Uncertainty of climate elements and main impacts due to the four certainty categories

Among climate parameters, changes in temperature are classified with very high certainty (green), because many studies predict increases in the mean annual and seasonal temperature, and this has been confirmed from both the trend analysis and the climate modeling. The certainty of the future development of precipitation is also high (yellow), though this is not as reliable as temperature changes. Similarly, extreme weather events are classified with a high certainty and are likely to show more variability in quantity, seasonality, and space.

In terms of water availability, the certainty of changes in water storage from snow and ice is high due to predicted changes in winter precipitation from snow to more rain, but projections in quantity are less reliable. Runoff, evapotranspiration, and groundwater are all rather uncertain and classified with a medium (orange) certainty. Changes in water availability depend largely on precipitation and evapotranspiration, both of which show a declining trend in the SRB. There are only a few reliable findings on changes in the water content in soil and lakes; hence, these impacts were classified with low certainty (red).

Projections of extreme hydrological events are more uncertain than the changes in the mean water availability. Climate change impacts on low flows, droughts, and water scarcity have a medium rating but are considered more reliable than flood events, which have a low certainty. As previously mentioned, navigation could benefit in winter due to a decrease in the ice levels, but in summer, shipping might be restricted due to more days with low water conditions. Similarly for hydropower production, power generation might possibly increase in winter with greater water availability and decrease in summer, which has been demonstrated by the assessment in the *Hydropower Guidance Note*.

[11] International Commission for the Protection of the Danube River (2013) Strategy on Adaptation to Climate Change.

Uncertainties related to climate change impacts on agriculture are embedded into the models by using estimates of climate induced crop yields from five different climate model chains. The uncertainty from temperature and precipitation projections propagates to the crop yield projections and can therefore be classified as medium uncertainty (orange). Additional uncertainty is introduced in the economic evaluation of the impacts in agriculture from the assumed economic parameters, resulting in very high (red) uncertainty class.

Recommended adaptation measures

One of the prominent outcomes of the study is an outline adaptation plan covering the sectors included in the guidance notes: floods, navigation, hydropower, and agriculture. The adaptation measures have been prioritized under a scoring system using three levels—high: 1; medium: 2; and low: 3—by WATCAP study team members and a selection of stakeholders from SRB country ministries, hydro-meteorological institutions, and nongovernmental organizations (NGOs). An average score was then obtained from the combined scores to establish the final list of recommendations for the guidance notes. The recommendations of the main WATCAP study have also been prioritized in the same manner.

The recommended adaptation measures are described in boxes 1 through 4 for the four water sectors.

Box 1. Recommended Adaptation Measures for Floods

- *The development of flood forecasting and warning systems* is considered a top priority for the management of the increasing flood risk in the SRB. This is also closely related to improving monitoring networks through expanding and modernizing monitoring equipment, developing hydrologic and hydraulic simulation models, strengthening institutions responsible for forecasting and emergency response, and improving cooperation between the riparian countries on the operational level.
- *The development of strategic documents* and policies is also considered of high importance, including those related to flood risk management and implementation of the EU Flood Directive, as well as national and other plans and strategies on climate change.
- The *Flood Guidance Note* as well as the stakeholders emphasize the need to *give more space to rivers*, especially by using the natural wetlands and floodplains for both flood control and biodiversity conservation and also by deepening and/or widening the river channels. Introducing flood hazard maps into the spatial plans and prohibiting or controlling development in flood plains are also of primary importance. The *Flood Guidance Note* also recommends increasing the level of protection of towns along the Sava River that are facing heightened risk due to migration and urbanization.
- As learned from the damaging impact of the May 2014 floods and from the *Flood Guidance Note*, there is need to *ensure that infrastructure has adequate capacity* to deal with the full range of precipitation levels that have been seen in the past 40 years and that are predicted in the future. Furthermore, all infrastructure prone to flooding should be inspected and adequate measures taken to strengthen its ability to deal with extreme events. Lessons learned from the flooding in May 2014 should be a guideline for improving all flood control and response measures.

Box 2. Recommended Adaptation Measures for Hydropower

- *Reducing the impact of hydropower schemes on ecosystems* is recognized as a top priority in this sector. Multiple stakeholders have confirmed this necessity, which should include the formation of guidelines and criteria for integrating environmental standards into hydropower development, limiting hydropower schemes in streams with first-class water quality, ensuring adequate environmental flows at all times, and assessing the consequences of hydropower schemes' tendency to neglect the impact of small- and medium-scale floods, which are often ecologically the most important.
- Although *risk assessment with regard to the effects of climate change* for the hydropower sector is also considered to be important, the stakeholders assign a relatively low priority to proposed structural and nonstructural measures for coping with a decreasing supply of water for hydropower (such as enhancing hydrological forecasting to improve operational rules and the utilization of HPP capacity, building robust dams with large reservoirs that can cope with extreme events, ensuring flexible design for installed capacity, etc.). Low priority was also given to a reduction in energy demand and a consideration of alternative energy sources.

Box 3. Recommended Adaptation Measures for Navigation

- *Better monitoring* of river water levels and meteorological parameters related to ice and fog formation (air temperature, air humidity, wind, water temperatures) and *improved hydrological forecasting* are considered the most important measures, followed by the development of River Information Systems.
- *Water management* is generally considered important for navigation, including improving reservoir management to promote low-flow augmentation, combining increased water storage for navigation with habitat creation initiatives, and encouraging ship waste management based on the "polluter pays" principle.
- Measures related to the *adaptation of transportation and fleet* proposed in the *Navigation Guidance Note* (e.g., making better use of the season with high river flow, supporting container shipping with shallow draft vessels) were given low priority by stakeholders.
- *Structural measures* also proposed in the *Navigation Guidance Note*, involving dredging to ensure sufficient water depth and upgrading and expanding river and port infrastructure, were given the lowest priority by stakeholders.

Box 4. Recommended Adaptation Measures for Agriculture

- *Drought management* is the top priority for agriculture. The establishment of early warning systems for droughts and other extreme climate episodes is considered of greatest importance, followed by the need to promote water retention in drought-prone agricultural areas.
- *Policy measures* that would introduce sustainable resource and land management systems are also considered a top priority, followed by the need for increased coordination between water and agricultural policies.
- A more detailed *assessment of vulnerability to climate change* for agriculture is needed, including improvements in climate modeling and scenarios and in evaluations of climate change impact on droughts.
- Adaptation in *agricultural technology* is seen by stakeholders as encouraging more environmentally compatible farming methods to preserve and improve biodiversity rather than as selecting more resilient crop species or adapting sowing patterns and harvest dates to changing climate conditions.
- Due to the poor current status of *irrigation* schemes, the stakeholders do not recognize them as an adaptation measure. However, the analytical work has indicated that irrigation is an adequate adaptation mechanism to mitigate water stress induced by climate changes.

It is important to emphasize that many of the recommended adaption measures listed in Boxes 1-4 above are not dependent upon future climate prediction; hence, there is no reason to delay their implementation. This is especially true for flood prediction and flood management measures. Since the devastating May 2014 floods, the IFIs including the World Bank and the EU have planned and started implementation on projects valued at more than Euro 410 million (DG ELARG 2014) in the West Balkans. This includes an enhanced flood prediction and weather forecasting system for the ISRBC for the SRB, flood risk mapping and flood hazard mapping projects in BiH, Croatia and Serbia along with a number of initiatives on improved flood protection and flood management.

Uncertainty related to the climate change impacts introduces some level of risk to implementation of the adaptation measures. This is especially true for the long-term measures, the effects of which extend to the distant future where the uncertainties are the highest. The uncertainties are therefore an important factor for decision making about the irreversible investments in the adaptation measures. For example, there might be a smaller investment risk for flood management by providing additional storage for excess water in the natural retention areas than by building man-made reservoirs. However, with the improved climate and impact modelling over time, and with some measures already in effect, the uncertainties could be reduced. Therefore, an important point is that adaptation planning must be regularly reassessed, so that any new developments and new modelling work are taken into consideration.

Recommendations related to knowledge about the basin

The consultation process during the preparation of the WATCAP report also resulted in a number of general recommendations for the SRB that are not necessarily associated with climate change. Nevertheless, these recommendations address well-known and important problems for integrated water resources management in the basin and consequently for its overall development.

Hydro-meteorological and water resources data. The improved organization and coordination of data records, collection, analysis, and storage are needed. Substantial historical data exist from the past century that have not been digitized, such as data in the hydrologic yearbooks of the former Federal Hydro-meteorological Service of Yugoslavia. These data are valuable for investigating climate and hydrology in the region, especially given that large data gaps during the 1990s prevent the compilation of continuous records of acceptable lengths. In order to make this information available for various analyses, it needs to be digitized. A possible solution could be the provision of a central repository for the data, possibly with the ISRBC, which could be accessible online to users for a small fee to cover upkeep of the website and maintenance of the data records.

In addition, data on water resources management, such as withdrawals, discharges, reservoir levels, and releases, are extremely difficult to collect, which hinders any water balance assessments in the basin. Data and information from hydropower operators are also important for flood forecasting.

The riparian countries should build on the existing valuable data record by promoting mandatory reporting procedures (even through a legislative process) for essential data from riparian governments. For example, hydropower operators should be required to provide all their operational data so that modeling tasks can be successfully completed. This could be implemented by inviting HPP owners/operators to join a working group to study, analyze, plan, or mainstream climate change considerations in their business operations. The ISRBC could facilitate the institutional space for such an exchange of experiences and technical economic and policy options to incorporate the perspectives of power plant operators. Furthermore, the provision of hydropower operational licenses could be tied to the provision of operational data to the ISRBC and others.

New hydrological study. A new hydrological study of the basin should be undertaken that should use longer time series, including recent years. The results of such a study will be of invaluable importance for water balance analysis and water management studies.

Hydrologic modeling. The HEC-HMS hydrological model developed for the WATCAP has been distributed among the riparian countries and could be further developed by undertaking modeling of the tributaries to the Sava River. This work needs to be coordinated by the ISRBC with the planned utilization of the USACE in the further development of the hydraulic (HEC-RAS) model for the Sava River.

CONCLUSIONS

The impacts of climate change on the four important water sectors (floods, navigation, hydropower, and agriculture) in the SRB have been evaluated and are presented in this report. In addition, adaptation measures have been prioritized and recommended and many can be implemented without delay.

There is obviously a need to effectively plan for the climate-induced changes in the basin. Rising mean temperature has a very high certainty of occurring. Precipitation that is highly variable across the basin and seems to have a changing seasonal distribution brings a measure of uncertainty into the hydrologic trends within the basin. Therefore, options to reduce the severity of the impacts associated with rising mean temperatures and variable precipitation need to be identified by careful planning and by promoting adaptation measures than can cope with such changes. In this regard, the results of this study should provide a basis for stakeholders and decision makers for future developments in the basin.

In the adaptation process, improved management and coordination (institutional strengthening) would be beneficial for institutions and stakeholders within the basin that understand the specific details of climate change and its effects and what explicitly can be done to manage and adapt to these changes.

While there is no doubt that the four sectors could be heavily affected by climate change, this study should also be used to gain an insight into the uncertainties associated with such a comprehensive methodology and to understand how these uncertainties can be dealt with on both a planning and an operational level. The results presented here are therefore not intended for use in detailed design projects, but rather as a resource to support further decisions about the scope and extent of the analyses that will need to be carried out in specific future projects.

1 Introduction

In 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded in their 4th Assessment Report that there is evidence of increased hydrologic variability and climate change is occurring. The region of southern Europe was identified as one of the global regions that are highly sensitive to climate change. The earth's climate is changing at an unprecedented rate and human activities are in part responsible (IPCC, 2007). The current IPCC assessment (5th Assessment Report) released in late 2014 has not moved from this conclusion. The recent devastating floods that have hit the Sava River Basin in May 2014 are testament to this fact.

There are two interlinked courses of action in responding to climate change; one of mitigation and the other of adaptation. Mitigation is primarily concerned with control and reduction of greenhouse gas emissions; whilst adaptation attempts to reduce the vulnerability of human livelihoods, economies, and natural systems to the impact of climate induced changes.

Addressing climate variability through mitigation has been, and continues to be, a key priority for the World Bank and many project initiatives have been; and are being implemented. However, more recently the focus has also turned to adaptation practices. Recognizing water as a key affected sector, the impact of climate change and potential adaptation strategies have become central to the dialogue on water policy reforms and investment programs with client countries (World Bank, 2008).

The World Bank has assessed many examples of climate adaptation activities that include: reducing the risk of floods through improved storage and infrastructure management, increasing the resilience of the agricultural sector to droughts, and protecting freshwater ecosystem services by integrating environmental flow requirements in infrastructure planning, design and operation (World Bank, 2009).

Climate impacts will have significant consequences on investments in water systems – from infrastructure to institutions – associated both with delivering water services and managing water. Water systems for delivering services include, among others, urban water supply and sanitation, irrigation and drainage, and ecosystem services. Systems for managing water resources include those for delivery of bulk water to urban, rural and agricultural water use centers, as well as multi-purpose systems (often including inland navigation and hydropower) and flood control. Extreme variability and/or reduced supplies could stretch the infrastructural and institutional limits of systems that manage water across sectors and even national boundaries (World Bank, 2009).

Climate change is therefore a global phenomenon with regional and local implications of different intensity. The urgency of addressing the climate change agenda in the countries of South-Eastern Europe (SEE) was acknowledged recently by a number of institutions. The 2007 Green Paper of the European Commission on adapting to climate change highlighted that especially the SEE countries below the 40^{o} latitude are at considerable risk (European Commission, 2007). The 2009 White Paper built upon this initiative and set out a framework to reduce the EU's vulnerability to the impact of climate change (European Commission, 2009).

In addition, at a conference held in November 2008, the Ministers responsible for environment in Albania, Bosnia and Herzegovina (BiH), Macedonia, Montenegro and Serbia (Joint Statement, 2008) acknowledged that climate change in the region:

"is projected to worsen conditions by the increased frequencies, magnitudes and damages caused by floods, droughts, forest fires, heat waves and other climate related hazards, reductions in crop yields, decreased water availability, reduced hydropower potential, increased number of people exposed to vector and water-borne diseases, etc. Adaptation could significantly reduce these effects."

There is a concern in the SEE region that recent growth in key economic sectors and livelihoods of the general populations may be constrained by climate change impacts. It is acknowledged at the same time that climate change adaptation planning is generally limited – modeling of climate and subsequent impacts on hydrological regimes in specific river basins is still at an early stage. In this context, the World Bank has undertaken this study utilizing external consultants and with the support of the International Sava River Basin Commission (ISRBC). Financing was provided from multi donor trust funds from the World Bank's WPP and the Trust Fund for Environmentally & Socially Sustainable Development (TFESSD). The intent is to fill the knowledge gap on the impact of climate change on the water sector in the SEE region and to inform decision making by World Bank client governments and the development community on how to increase the climate resilience of critical water management infrastructure investments and of integrated water resource management (IWRM) in the region. [12]

The study meets the objective through the development and dissemination of a Water and Climate Adaptation Plans (WATCAP) for a regional river basin where existing or planned water infrastructure investments supported by the World Bank and national governments are located. The Sava River Basin (SRB) has been selected as one such area. The WATCAPs combine general analysis on the river basin level with more detailed analysis on these investments and the climate change adaptation measures needed. On the basis of that work, guidelines will be prepared to advance water and climate change adaptation in SEE, including potential adaptation investments. The aim would be that these guidelines would then be available for use in other regions as well.

In the development of WATCAPs, current modeling efforts on climate, sector impacts and adaptation alternatives are assessed and opportunities for further applied research identified. Since much of this analytical work is relatively recent, a review of the feasibility of the application of current methodologies (instead of focusing on developing new methodologies at increasing levels of sophistication) will be an important outcome. The study adopts an action research approach (learning-by-doing), conducted in close consultation and cooperation with local institutional counterparts and research institutes.

Consequently, the primary purpose of this report is to present the WATCAP developed for the SRB. The Sava River is a high priority since regional climate modeling suggests an overall reduction of around 15% to 30% in mean annual runoff by the middle of this century which could be challenging for all investments undertaken in this basin.

This report concludes the first task of the above mentioned study (Mainstreaming climate change adaptation in World Bank financed investments in the SRB). The WATCAP presented for the Sava Basin herein therefore has two primary goals:

i. *To inform on the possible climate change adaptation measures for existing and planned projects in the SRB; and*
ii. *To build on and complement the recently completed Sava River Basin Management Plan (RBMP), funded by the EC. Any changes necessary to the RBMP based on the WATCAP findings would be integrated into the next RBMP which is scheduled to be prepared on a six-yearly basis.* [13]

The following graphic (Figure 1-1) presents the logic of how the work was undertaken on the WATCAP.

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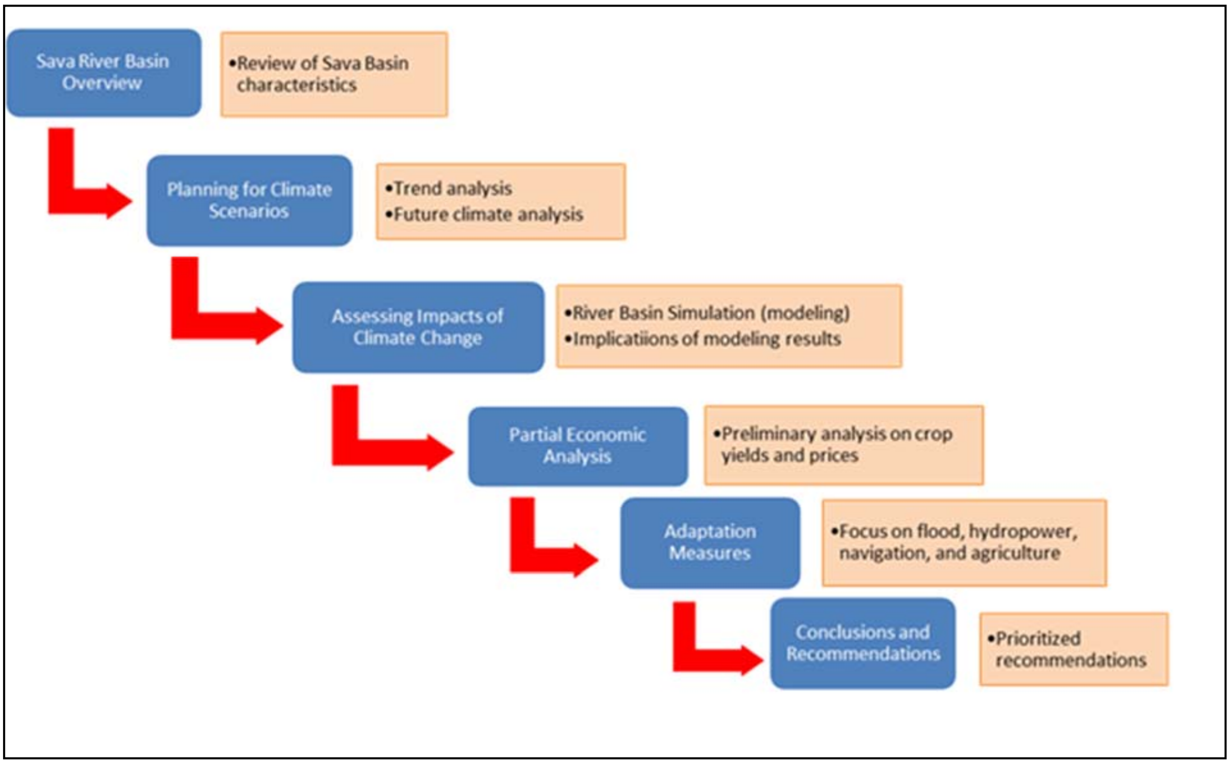
[12] The World Bank has committed itself to becoming a "global knowledge bank", using knowledge to improve the development effectiveness of its work. Two of the analytical and advisory ways the Bank provides knowledge to its client countries are *economic and sector work* (ESW) and non-lending *technical assistance* (TA).

[13] The final draft Sava RBMP was submitted to the riparian countries in March 2013, for national procedures that are necessary for Plan adoption. The RBMP is expected to be 'endorsed' at the ministerial meeting planned to be held in November 2014.



Source: Figure produced by COWI 2014

Figure 1-1: Flowchart depicting logic of WATCAP preparation

Consequently, following this introduction, Chapter 2 sets the outline and presents an overview of the current status of water resources and their management in the SRB. The chapter especially focuses on the analysis on the agriculture, navigation, hydropower and floods sectors with some projections concerning the future[14].

Chapter 3 is a first step forward on the actual analysis of trends for the SRB and for individual member countries as it looks at past climate. After climate modeling in Chapter 4, hydrologic modeling is presented in Chapter 5, which includes a description of the model used, calibration and verification issues, model set up and performance. Complete details of the hydrological modeling work are also presented in a separate report (Annex 1).

With the achieved climate and hydrologic modeling results, Chapter 6 then provides a review on the implications of these results through a characterization of the future hydrologic regime in the SRB. The chapter then speculates impacts due to climate change on other selected water sectors in the Basin. This chapter is supported by separate guidance notes on floods, navigation, hydropower and agriculture (Annex 2, 3, 4 and 5, respectively).

With the implications of these climate change impacts, Chapter 7 then provides a partial and preliminary economic evaluation of the SRB with an aim to measure the magnitude and distributional costs of climate change impacts and adaptation options under alternative water regime scenarios in the SRB. This analysis adopts an integrated approach combining crop modeling with economy-wide analysis. The chapter is supported by a separate guidance note on the economic evaluation (Annex 6).

With the climate change impacts identified and in some cases quantified and the partial economic evaluation completed, Chapter 8 provides climate adaptation strategies for the SRB, presenting overall strategies and suggestions for the Basin taken from the above mentioned guidance notes. The chapter also addresses the main framework policies for the Basin and how to deal with elements of uncertainty when predicting climate change. Sector specific adaptation measures are

[14] This is mostly based on the documentation contained in the Sava RBMP from ISRBC.

then presented covering the topics from the guidance notes as well as other extreme hydrological events such as droughts and low flows, effects on groundwater, snow and ice. Adaptation procedures are subdivided into general adaptation measures; ecological based measures, management measures and technological measures before finally, consideration of the policy approach is made.

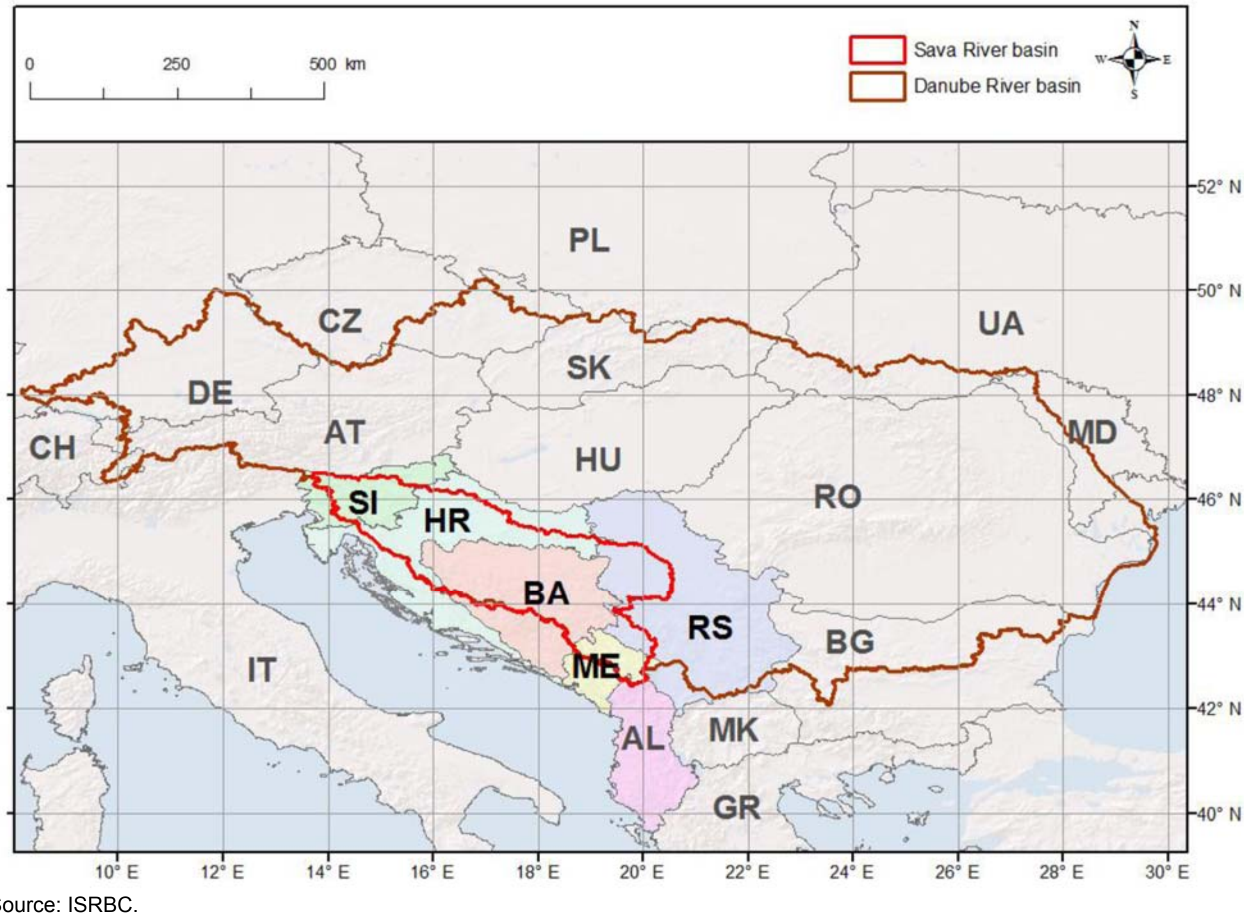
Finally in Chapter 9 the results and conclusions of the WATCAP study are provided with prioritized recommendations of future analysis.

2 Water Resources Overview for the Sava River Basin

2.1 Brief Social and Economic Characteristics of the Basin

Before discussing the water resources of the basin it is necessary to characterize briefly the river basin's profile in terms of some basic social and economic indicators. . The data were collected from the Sava River Basin Management Plan prepared by the International Sava River Basin Commission (ISRBC, 2013).

The SRB covers an area of approximately 98,000 km² and is one of the major tributaries of the Danube River system accounting for 12% of the entire Danube Basin. The SRB (Figure 2-1) is located between geographical co-ordinates 13.67 ºE and 20.58 º E longitudes and 42.43 ºN and 46.52 ºN latitude.



Source: ISRBC.

Figure 2-1: Country Overview of the Sava River Basin

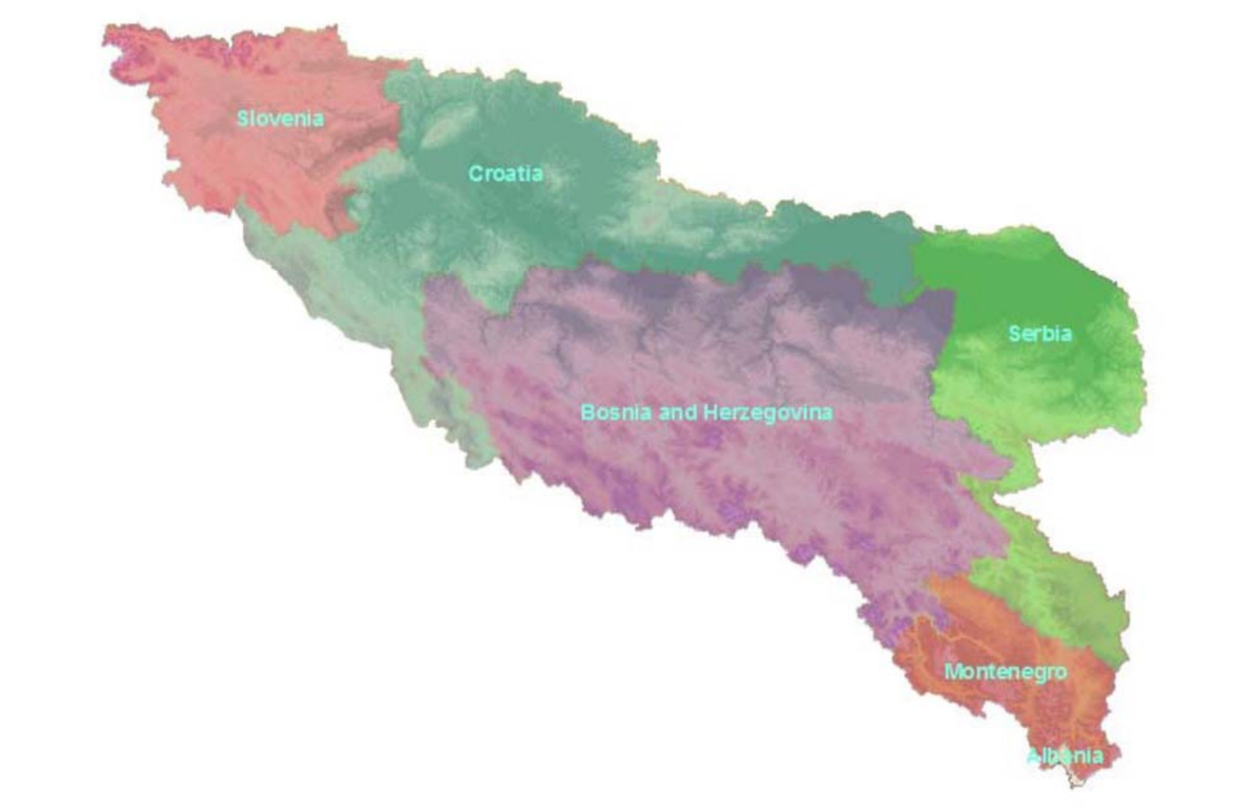
The Sava River is very important for the Danube River Basin (DRB) system, for its outstanding biological and landscape diversity. It hosts the largest complex of alluvial wetlands in the DRB (Posavina - Central Sava Basin) and large lowland forest complexes. The Sava River is a unique example of a river with some of the floodplains still intact, thus supporting biodiversity and the flood alleviation in the natural retention areas.

The SRB area is shared by six states as subdivided in Table 2-1 below and as shown graphically in Figure 2-2.

Table 2-1: Share of Countries belonging to the Sava River Basin

SRB Country	Slovenia	Croatia	Bosnia and Herzegovina	Serbia	Montenegro	Albania
Total country area [km^2]	20,273	56,542	51,129	88,361	13,812	27,398
Share of national territory in SRB [%]	52.80	45.20	75.80	17.40	49.60	0.59
Area of the country in the SRB [km^2]	11,734.8	25,373.5	38,349.1	15,147.0	6,929.8	179.0
Share of SRB [%]	12.01	25.97	39.25	15.50	7.09	0.18

Source: ISRBC.



Source: ISRBC.

Figure 2-2: Geographic Share of Countries in the Sava River Basin

The respective proportions of land areas for the SRB countries are as follows: Slovenia (12%), Croatia (26%), BiH (39.25 %), Serbia (15.5%), and Montenegro (7 %), while a small part of the basin area also extends into Albania (0.18%).

The first four countries are currently members of the ISRBC, while Montenegro cooperates on the technical level. The four countries signed the Framework Agreement on the Sava River Basin (FASRB) which emphasizes the importance of transboundary cooperation of governments, institutions and individuals for sustainable development of the SRB.

One of the main goals of the process of transboundary cooperation is the establishment of sustainable water management, including the cooperation on management of the SRB water resources in a sustainable way, in a manner that would provide:

- Water in sufficient quantity and of appropriate quality for the preservation, protection and improvement of aquatic eco-systems;
- Waters in sufficient quantity and of appropriate quality for all kinds of water utilization;

- Protection against detrimental effects of water (flooding, excessive groundwater, erosion and ice hazards);
- Resolution of conflicts of interest caused by different uses and utilizations; and
- Effective control of the water regime.

The co-operation between the riparian countries is based on the following principles:

- Sovereign equality, territorial integrity, mutual benefit, and good faith;
- Mutual respect of national legislation, institutions and organizations;
- Co-operation in line with the EU Water Framework Directive (WFD) and other related Community legislation;
- Regular exchange of information within the basin on: water regime, navigation regime, legislation, organizational structures, administrative and technical practices;
- Securing the integrity of the water regime in the basin; and
- Reduction of transboundary impacts caused by economic and other activities.

By signing the FASRB, the Parties expressed their commitment to prepare a joint Sava River Basin Management Plan (RBMP) as mentioned above. The strategy on the implementation of the ISRBC was prepared in 2008 and this was subsequently upgraded with an accompanying Action Plan for the period 2011-2015 (adopted in 2011). The Final Draft of the RBMP was prepared in March 2013.[15]

The population of the SRB is distributed by country as shown in Table 2-2. As can be seen some 47.7% of the population of the four ISRBC member states and Montenegro live within the SRB, but spatial distribution is variable with 88.4% of BiH population living within the SRB as opposed to 26% of Serbia's population. The share of the population in Table 2-2 excludes Albania, as the area of territory is very small, nor Kosovo. There are about 2.6 million people employed in the basin, or about 29% of the population of the SRB. This is relatively low compared with the EU27 countries employment rate of 64%.[16] The unemployment rate does not show great divergence within the SRB countries.

Table 2-2: Population in the Sava River Basin

Name of Country	Country Population (in millions)	Population within SRB (in millions)	Percentage of population within SRB
Bosnia and Herzegovina	3,815,297	3,373,951	88.4%
Slovenia	1,978,000	1,030,116	61%
Croatia	4,437,460	2,213,337	50%
Serbia (without Kosovo)	7,498,001	1,947,322	26.0%
Montenegro	627,428	195,300	31.1%
All countries (combined)	18,356,186	8,760,026	47.7%

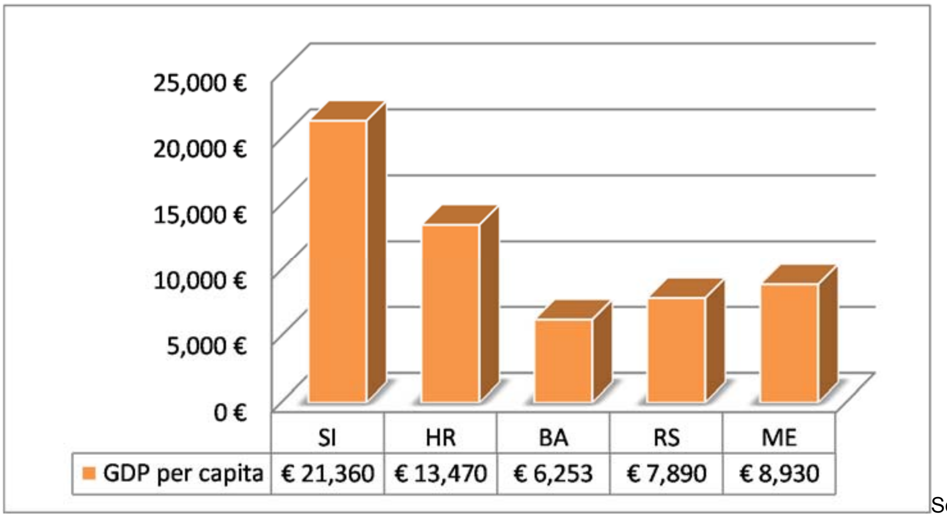
Source: ISRBC, 2013.

The division of employment in the SRB is as follows:

- 11% of people employed work in the agricultural sector,
- 25% in industry,
- 1% in the energy sector,
- 27% in public services, and
- 36% in other activities (construction, wholesale/retail trade, hotel and restaurant services, transport, storage, communication, etc.).

[15] Updated Strategy and Action Plan available from the website: http://www.savacommission.org/basic_docs
The RBMP is available from the website: http://www.savacommission.org/srbmp/en/draft
[16] EUROSTAT Information

The socio-economic situation as measured by Gross Domestic Product (GDP) per capita shows great extremes in the SRB. The difference in GDP per capita between the lowest (BiH) and the highest (Slovenia) value is more than threefold.



Source: ISRBC.

Figure 2-3: GDP per capita in the countries of the Sava River Basin in 2012

GDP in 2012 in the SRB was as follows[17] (Figure 2-3): Slovenia 21,360 €/person, Croatia 13,470 €/person, BiH 6,253 €/person, Serbia 7,890 €/person and Montenegro 8,930 €/person.

As the previous paragraphs have indicated; the economic situation in the SRB countries varies very markedly and it is an important factor that must be taken into consideration in the Water and Climate Adaptation planning effort. Especially difficult is the situation of Serbia, Montenegro and BiH, which together occupy more than 50% of the SRB area but are not member states of the EU and thus do not have the financial support that EU countries enjoy. In many reports and publications it is stated that current financing of water resources development as well as operation and maintenance of existing water infrastructure is dramatically insufficient. Under such circumstances, overall economic development and improvement of the current financing systems in the SRB countries seems to be one of the most important climate change adaptation measures.

There are strong changes in social structure in the region, due in part to the conflicts in the region during the early 1990's; BiH alone lost about 20% of its population. Further, there are certain dynamics in the structure of the labor force (based upon CIA data; Table 2-3). Agricultural lands are also becoming depopulated and this trend seems to be continuing in BiH and Serbia.

Table 2-3: Labor force by occupation in the Sava River Basin

Labor Force - By Occupation (%)			
Country	**Agriculture**	**Industry**	**Services**
Slovenia	2,2	35	62,8
Croatia	2,1	29	69
Serbia	21,9	19,5	58,6
BiH	20,5	32,6	47
Montenegro	6,3	20,9	72,8

Source: CIA website: https://www.cia.gov/library/publications/the-world-factbook/fields/2048.html

[17] CIA World Fact Book in 2012.

2.2 Current Status of Water Resources

2.2.1 General Characteristics of the Basin

The climate in the SRB varies markedly over the basin as a result of proximity to land and sea as well as of various orographic features. There are three principal climatic zones: (i) Alpine, (ii) Moderate – continental, and (iii) Moderate – continental (mid-European). The dividing lines between these climatic zones are not distinct, and various other factors influence and determine the climate. There are three main elements of the climate that significantly affect water availability, water use and conservation: most notably air temperature, precipitation and evapotranspiration.

Alpine climatic conditions prevail in the upper SRB in Slovenia. A more moderate continental climate dominates in the right tributaries' catchment areas within Croatia, BiH, Serbia and Montenegro, while a moderate continental (mid-European) climate primarily features in the left tributaries' catchment areas that belong to the Pannonian Basin, which is principally Croatian and Serbian territory.

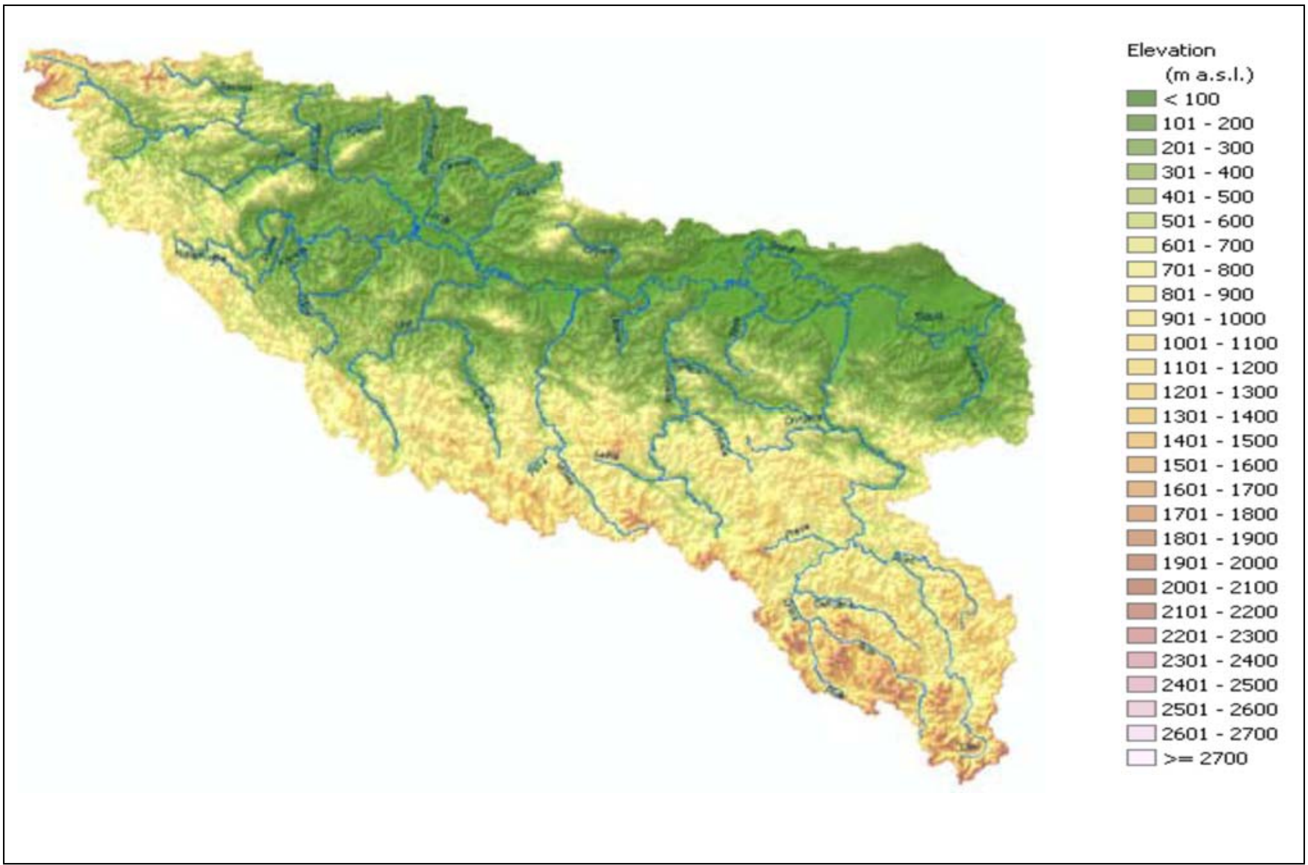
Mean annual air temperature for the whole SRB is estimated to be around 9.5°C. Mean monthly temperature in January falls to approx. -1.5°C, whilst in July it can reach almost 20°C. The precipitation amount and its annual distribution are fairly variable within the basin. The average annual rainfall over the SRB is estimated to be approximately 1,100 mm, whilst the average evapotranspiration (ET) for the whole catchment area is approximately 530mm/year.

In terms of hydrology, the Sava River average annual discharge at the confluence with the Danube (located at Belgrade, Serbia) is about 1,700 m^3/s which results in the long-term average unit-area-runoff for the complete catchment of about 18 $l/s/km^2$. The 945-km-long Sava River is the Danube's longest right-hand tributary and the second longest after the Tisza River. However, the Sava River is the largest tributary in terms of water flow within the Danube River system. To the north, the Sava Basin borders with the Drava River Basin, where the Drava River is also a tributary of the Danube River. The watershed between the southern part of the SRB and the Adriatic Sea catchments goes over relatively high and rugged mountains.

Rugged mountains of the Alps and the Dinarides (see Figure 2-4) dominate the entire upper part of the basin which belongs to Slovenia. In the lower parts of the basin, the southern (right) side of the basin is remarkably different than the northern (left) one. The most important right-bank tributaries are the Kupa, Una/Sana, Vrbas, Bosna and Drina Rivers and the upper parts of their basins are as rugged as the Slovenian part of the Sava basin.

The lowland areas extending along the Sava River and in the lower reaches of its tributaries belong to the low-lying fertile agricultural areas of the Pannonian Plain and Vojvodina flatlands. The left-hand tributaries, except in the upper part of the catchment (in Slovenia), drain mostly flat areas and low hills of the Pannonian Plain. Consequently, the slopes and flow velocities are less and the streams are meandering. The most important rivers are the Krapina, Lonja and Orljava in Croatia, and the Bosut in Croatia and Serbia (see Figure 2-5).

The water resources of the Sava Basin constitute close to 80% of the total freshwater resources of the four SRB countries.



Source: ISRBC.

Figure 2-4: Sava River Basin and relief characteristics

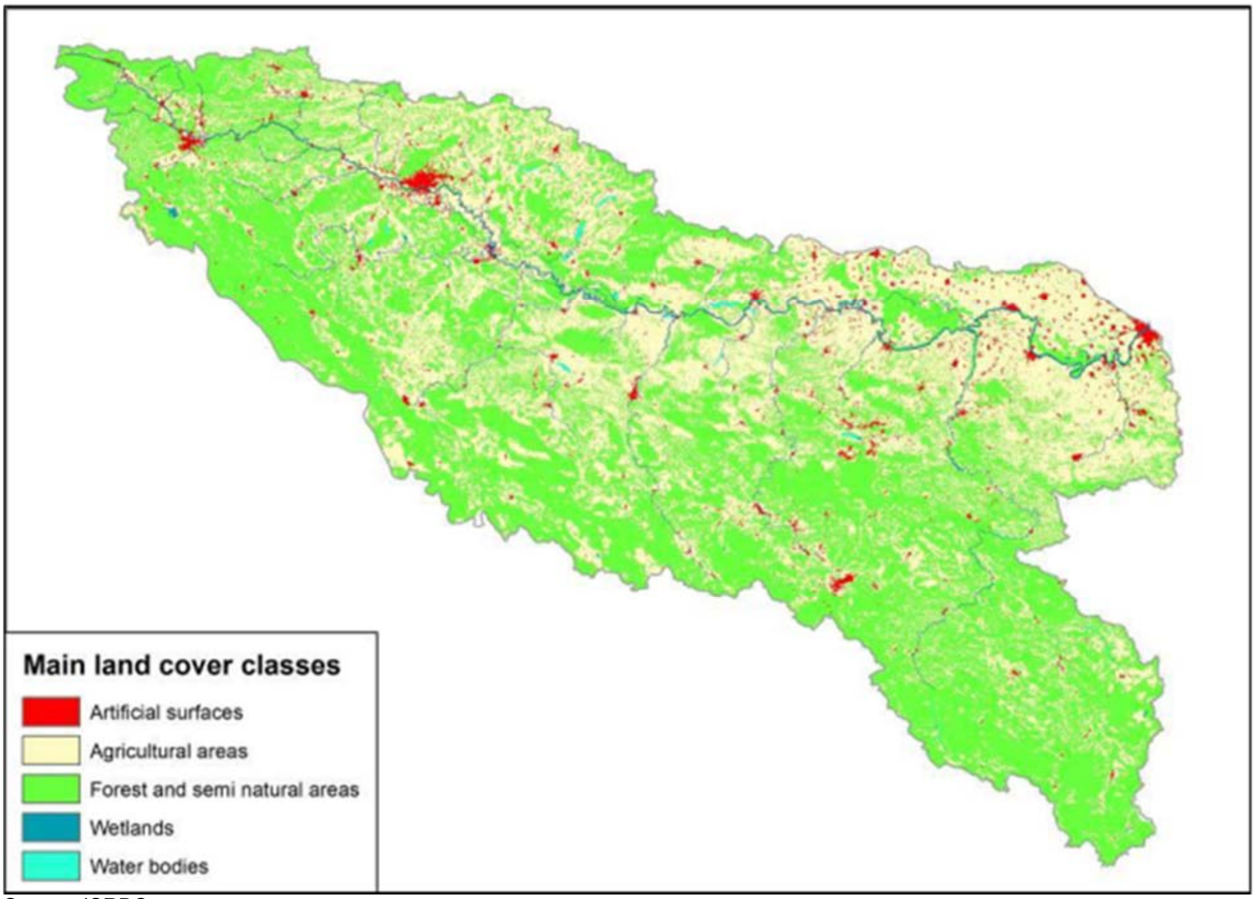
Source: ISRBC.

Figure 2-5: Sava River network and main tributaries

2.2.2 Land Use

For an overview of the land cover/land use in the SRB, the EEA CORINE land cover 2000 (CLC)[18] database for Europe was used and prepared by ISRBC for the entire area of the SRB as shown in Figure 2-6 below.

There is a clear domination of forest and semi-natural as well as agricultural areas. More details on the land classes and land use in the SRB are given in Figure 2-6, Figure 2-6: Distribution of main land cover/land use classes in the Sava River Basin
Table 2-4 and Table 2-5.



Source: ISRBC.

Figure 2-6: Distribution of main land cover/land use classes in the Sava River Basin

Table 2-4: Distribution of main land cover class in the Sava River Basin

CORINE 2000 Land cover class	Area (km²)	Share %
Artificial surfaces	2,179.00	2.23
Agricultural areas	41,381.50	42.35
Forests and semi natural areas	53,458.90	54.71
Wetland	78.20	0.08
Inland water (water bodies)	615.60	0.63
Total	**97,713.20**	**100.00**

Source: EEA CORINE Land Cover database, 2000.

Table 2-5: Distribution of main land use class in the Sava River Basin

CORINE 2000 Land use class	Km²	%
Discontinuous urban fabric	1708.650	1.75
Industrial or commercial units	169.310	0.17

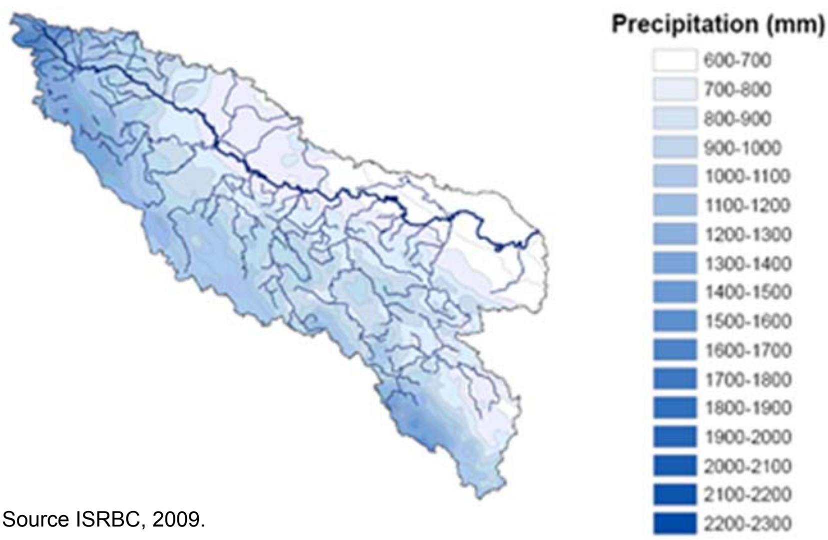
[18] CORINE land cover 2000 (CLC 2000) is the year 2000 update of the first CLC database which was finalized in the early 1990s as part of the European Commission programme to Coordinate Information on the Environment (CORINE). It provides consistent information on land cover changes during the past decade (32 countries).

CORINE 2000 Land use class	Km^2	%
Mineral extraction sites	133.710	0.14
Non-irrigated arable land	6162.430	6.32
Permanently irrigated land	0.280	0.00
Vineyards and fruit trees	187.390	0.20
Pastures	5875.410	6.03
Complex cultivation patterns	16990.640	17.43
Land principally occupied by agriculture, with significant areas of natural vegetation	12068.440	12.38
Broad-leaved forest	29596.930	30.37
Coniferous forest	5384.240	5.42
Mixed forest	9376.860	9.62
Natural grasslands	23636.110	2.38
Moors and heathland	295.410	0.30
Transitional woodland-shrub	5874.040	5.92
Bare rocks	200.370	0.21
Sparsely vegetated areas	449.500	0.46
Burnt areas	2.360	0.00
Inland marshes	81.260	0.08
Water courses	375.620	0.39
Water bodies	233.880	0.24
Other	185.770	0.40
Total	**97713.200**	**100.00**

Source: EEA CORINE Land Cover database, 2000.

2.2.3 Precipitation, Evapotranspiration and Runoff

As reported in the Sava River Basin Analysis Report (ISRBC, 2009), the amount of precipitation and its seasonal distribution are very variable within the SRB (see Figure 2-7 and Figure 2-8). Generally, most precipitation occurs either in the summer season or during the autumn. However, a significant proportion of precipitation falls in the form of snow later in the year, so that relatively long periods with snow cover are a common characteristic for the whole basin. This causes relatively high spring- to early summer runoff.



Source ISRBC, 2009.

Considerable more precipitation takes place in the mountainous parts of the basin due to orographic effects. For example, the mean annual precipitation over the SRB is estimated at 1100 mm/year, but it varies from around 3000 mm/year in the mountain zones in the far west of the SRB in Slovenia to about 600 mm/year at the most eastern part. The Slovenian part of the basin, however can receive noticeably larger precipitation in some wet years.

Figure 2-7: Mean annual precipitation in the Sava River Basin

Precipitation in the mountainous headwater part of the Drina River basin, in Montenegro, is also very important not only for the Drina River runoff generation, but also for the flood risks in the Sava River most downstream from the confluence with the Drina River. Unlike the rest of the basin, precipitation in this part is considerably greater in both autumn and winter, while is the smallest in summer.

As previously stated, a part of the SRB situated north of the Sava River, which constitutes a smaller part of the basin, belongs to the Pannonian plains. Climatic conditions in this region are governed not only by orographic features but also by the proximity and openness to the central- and east European part of the Continent. The Pannonian climate, with hot summers and cold winters, prevails in Slavonia and Vojvodina whose smaller part is drained towards the Sava River. This climate also extends south of the Sava River course into northern BiH and Serbia to the far southern and western edges of the Basin. Precipitation in this region is relatively low. It ranges from about 650 mm/year to 1000 mm/year in areas with somewhat higher altitudes that occur on the southern and western edges of the Basin. More precipitation occurs during the warmer parts of the year (mainly in summer and autumn which is the main growing season) than in the colder periods. This characteristic is favorable to agricultural activities. Snow fall is regular feature every year.

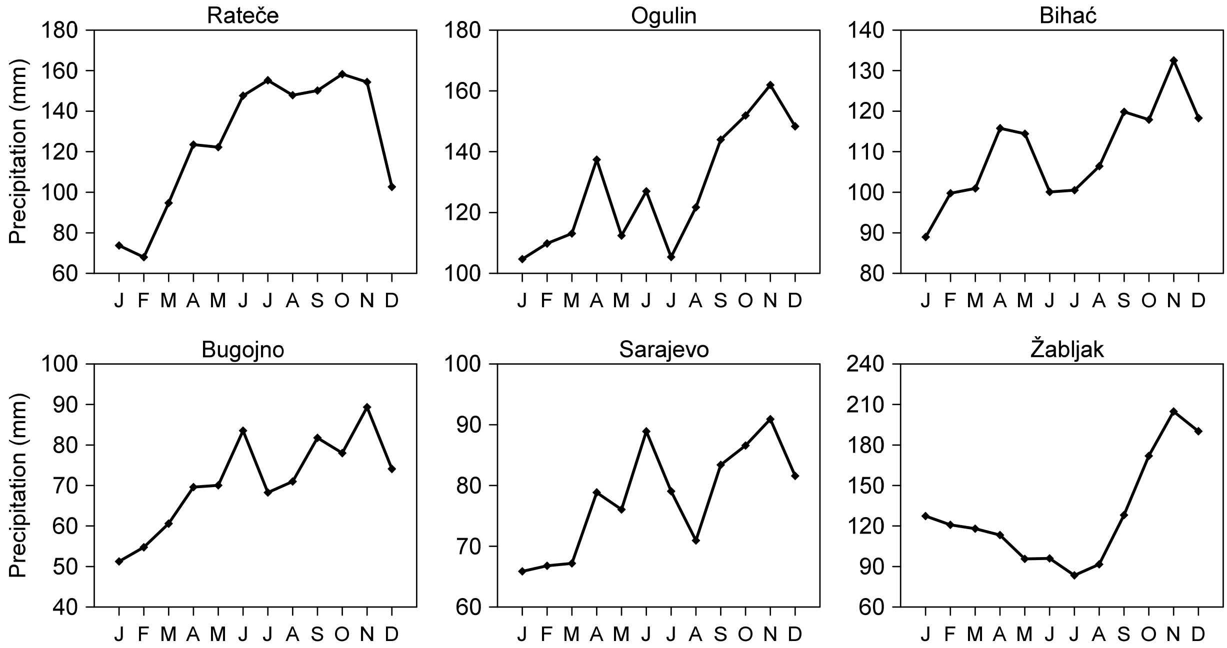
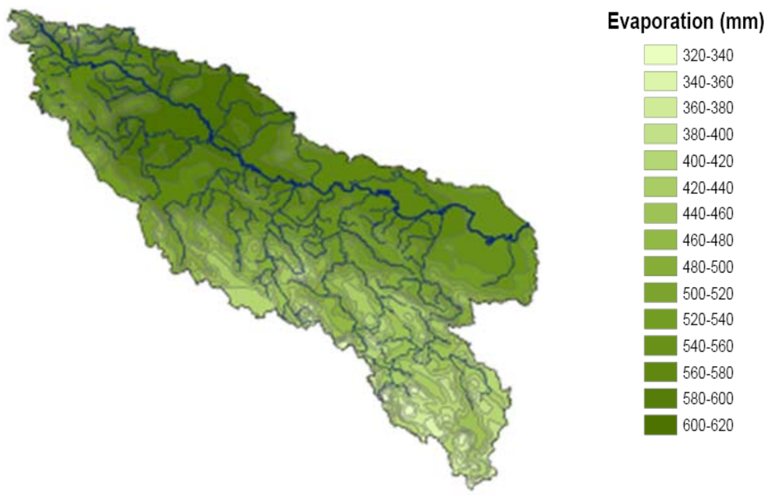


Figure 2-8: Seasonal precipitation patterns at selected locations in the Sava River Basin for 1969-2009.

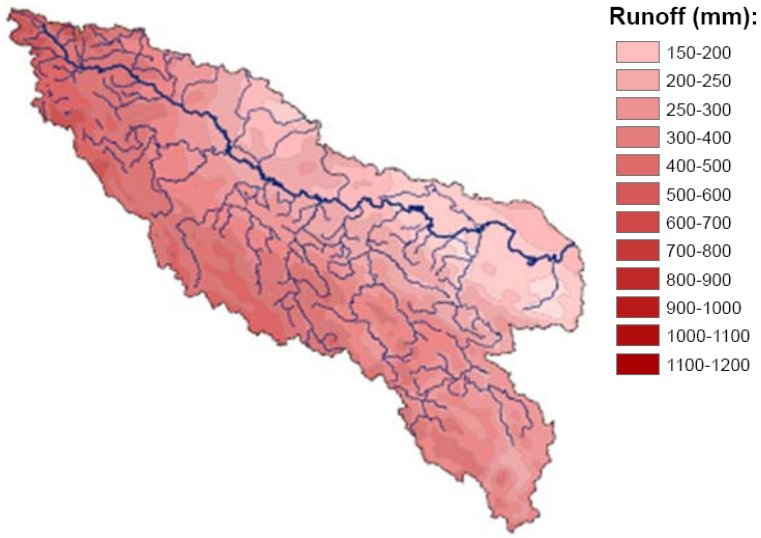


Evapotranspiration (ET) in the SRB is relatively high owing to high summer temperatures and ample water availability (Figure 2-9).

Based on the simple comparison of mean annual values of precipitation (1100 mm) and runoff (570 mm) for the entire basin, mean annual ET for the same area is about 530 mm/year. In the upper SRB mean annual ET is estimated to range between 500 and 600 mm/year.

Source: ISRBC, 2009.

Figure 2-9: Mean annual evaporation in the Sava River Basin



Due to previously stated precipitation and ET characteristics the contribution of the northern part of the SRB to the Sava River flow is much less significant than that coming from the mountainous regions which are present in the upper and southern parts of the basin (see Figure 2-10).

Source: ISRBC, 2009.

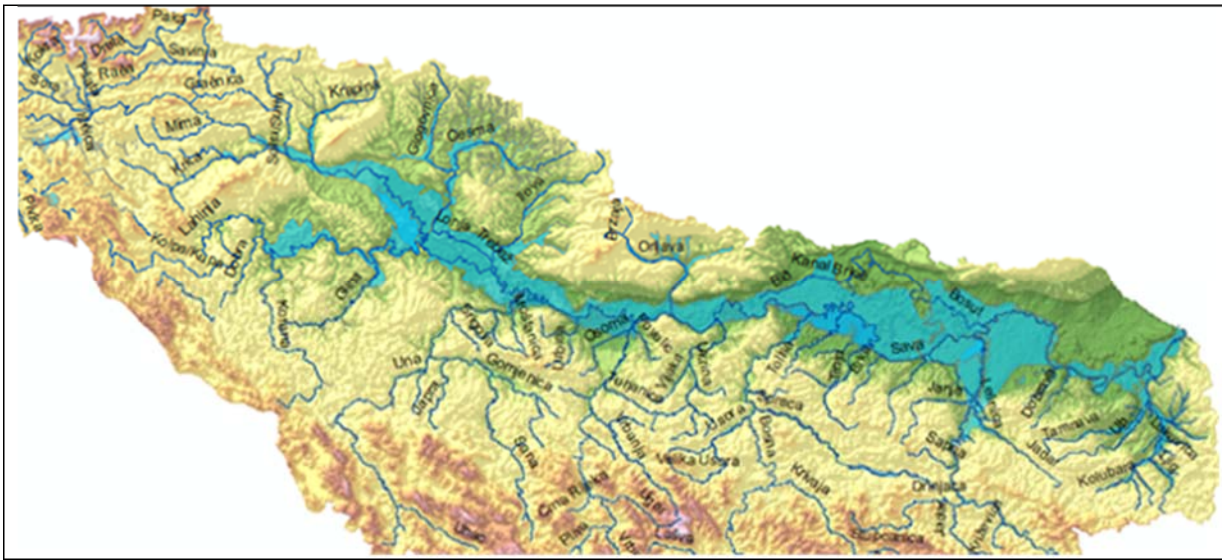
Figure 2-10: Mean annual runoff in the Sava River Basin

2.2.4 Hydrological Regime

Hydrological characteristics of the Sava River and its basin have been extensively studied in the past, with hydrologic measurements beginning in the 19th century. Unfortunately the war activities in the early 1990s interrupted practically all hydrologic monitoring and analytic activities. The long-term time series of average annual and monthly flows for the Sava River and its main tributaries are generally available, however for the last 25 years there are considerable data gaps. The report by Prohaska (2009) reviews the existing hydrologic studies of the Sava River basin. Among these studies, only a few are basin-wide and they originate from more than 30 year ago. The following description of the hydrologic regime is based on the studies reviewed by Prohaska (2009).

The SRB; especially its middle part (from Zagreb to Županja) and the lower part (downstream of Županja), as well as the downstream sections of the Sava tributaries; are prone to flooding. The floods occur generally in spring, after the snow melt, and in autumn, after the heavy rainfall. The wide flood plains of the Sava River and the natural lowland areas act as detention areas and retentions of the flood waves.

Spring floods last longer and their maximum discharges are relatively low, while the autumn floods exhibit very high peak flows of short duration. However, they often overtop the river banks and inundate very large floodplain areas which remain under water for a long time. The location of important flood-prone areas in the SRB is shown in Figure 2-11.



Source: IRSRB, 2009.

Figure 2-11: Indicative map of important flood-prone areas in the Sava River Basin

Coincidence analysis indicates that floods on the right tributaries of the Sava River occur generally earlier than on the Sava River itself. The lead times vary from one to less than three days. Flood duration depends on the flood volume hydrograph and the size of the catchment. Flood duration of the Sava River near Zagreb is 10-20 days and 40-70 days near Sremska Mitrovica. A significant difference in the flood travel time on the Sava River between the earliest (1933, 1934) and subsequent (1962, 1964) floods are noticed. Former floods have routing periods of 8-9 days, while subsequent ones have considerable shorter travel time—only 4-5 days. Shorter routing periods are the result of embankment construction along the Sava River, which led to a reduction in the upstream flood retention areas, shorter concentration times and larger maximum discharge in the channel.

The headwater part of right tributaries of the Sava River, from Slovenia to Montenegro, is a well-known karst region with a specific water regime. Water is stored in the karst areas longer and is released much slower than from non-permeable soils; consequently, flood peak discharges can be up to four times lower due to the impact of karst.

By reviewing the data from the flood hydrographs it can be confirmed that intensive floods occur over limited space**.** Most flood prone areas are within the regions of Donje Posavlje, downstream of Županja; Srednje Posavlje, from Zagreb to Županja; and upstream from Zagreb. The only floods ever to overtake the whole region from Belgrade to Zagreb occurred in 1933, 1937, 1940, 1947, and in 2014. The most severe floods occurred in 1932, 1942, 1970 and 2014 in the Lower Sava region and in 1937, 1944 and 1974 in the Middle Sava region. These data are for constant durations of 60 days. However, for other durations, floods are different in terms of their significance, which must be kept in mind for future hydrological research.

Floods on the downstream part of the Sava River are closely related to the Drina River. There were significant floods in 1896, 1974, 2010 and 2014. In 1896 the flood was produced by a combination of snowmelt and precipitation and was almost equal to the estimated probable maximum flood. During the 1974 flood event, the Sava River discharge downstream of the confluence with the Drina River was greater than the 100-year flood. The maximum precipitation in the Drina River Basin occurred two days later than the maximum precipitation in Slovenia, which is further west, leading to a coincidence of the flood peaks in the Sava River and in the Drina River downstream of their confluence. In the late 1970's, Mratinje dam on the Piva River in Montenegro was constructed which controls about 50% of runoff from the Montenegrin part of the basin causing the flood peaks to drop down significantly in the upper Drina watershed. Nowadays, operation of the series of the reservoirs on the Drina River crucially affects the conditions for flood generation along this river. The lower part of the Sava River is under the influence of back water effect from the Danube River caused by the Iron Gate dam.[19]

The heavy rainfall experienced in the SRB in 2010 particularly within the Drina River Basin and the subsequent floods led to loss of life and substantial damage to infrastructure. In February 2011, the World Bank held discussions with the four riparian governments in Sarajevo, Belgrade, Podgorica and Tirana that confirmed the need for a comprehensive regional program approach, encompassing the assessment of the natural resources potential of the Drina River Basin with focus on concrete measures to mitigate risks of floods and droughts at local (municipality) level, and sustainable water resources management at basin level, particularly with regard to hydropower generation. The ICPDR and the ISRBC also expressed strong support for such an approach. This led to the establishment in late 2011 of the West Balkan Regional Initiative for Flood and Drought Management (WBFDI) with focus on the Drina River Basin (World Bank 2012 Sucur-Ploco, Tomin, Klemm, and Ivanovic). One of the outputs of the WBFDI was the Rapid Regional Diagnostic and Investment Scan Study (RRDISS).

Five issue papers were also prepared under the initiative, supplementing the RRDISS: This included: i) Agreements and memoranda of understanding (MOUs);ii) data and information management; iii) hydropower - environment nexus; iv) hydropower plant, reservoir operation and flood management; and v) sediment management. The objectives of these issue papers were to present the findings of an identified, discussed and analyzed set of issues; to conclude the needs for action; and to recommend short- and long-term measures to overcome deficiencies and bottlenecks preventing sustainable water resources management to the benefit of the population living in the Drina River Basin.

In May 2014, multiple floods affected a large area of South Eastern and Central Europe. A low-pressure area named "Yvette" brought the worst of the flooding from 14–16 May, following three previous significant events starting from mid-April which resulted in a high degree of soil saturation in the valleys of the main Sava course and its tributaries.[20] Rainfall in BiH and Serbia was the heaviest in 120 years of recorded weather measurements; precipitation in the most affected areas was in the range from 100 to 300 mm during less than 72 hours (Plavsic et al, 2014). Quick and wide hydrologic response that was due to both heavy precipitation and an unusual amount of antecedent precipitation brought record flood levels at many hydrologic stations, both at small torrential streams and along the major rivers. The valley of the Bosna River, including towns of Maglaj and Zavidovići, suffered immense damage, but the most difficult situation was in the downstream town of Doboj where the water depth and the number of casualties were the greatest. The town of Obrenovac in Serbia was the most heavily struck with a high number of casualties, where the high water levels remained in town for several weeks after the rainfall event. By 20th May, at least 48 people had died as a result of the flooding, and 30,873 people in Serbia alone have been forced from their homes. Official counts indicate over 1.6 million people have been affected in Serbia, over 1.5 million in Bosnia and 0.5 million in Croatia.[21] The Moderate Resolution Imaging Spectro-radiometer (MODIS) on NASA's Aqua satellite captured an image of flooding in Croatia, Serbia, and BiH on May 19, 2014. The second image shows the same area one year ago during a more typical spring (See Photo 1 and Photo 2).

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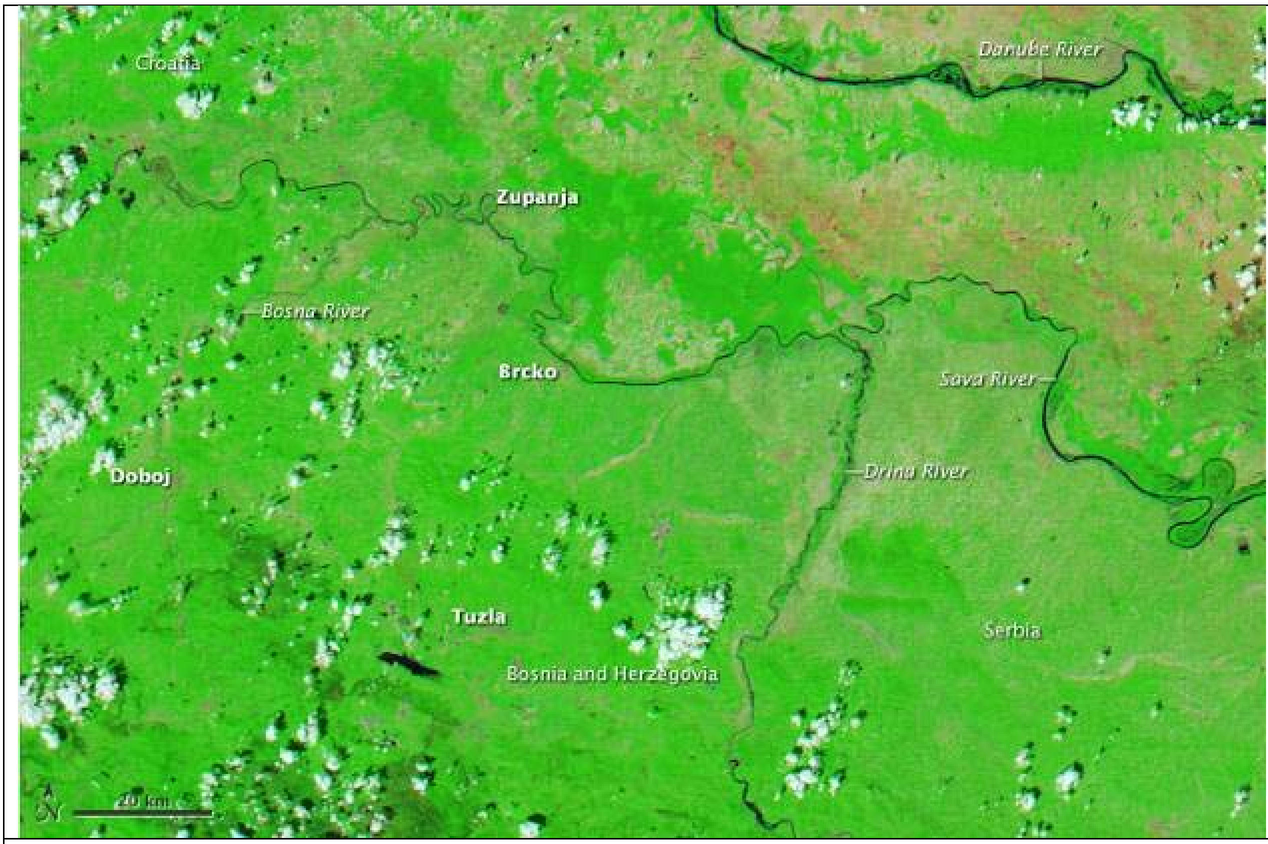
[19] The Iron Gates system has transboundary effects. Located where the Danube forms the boundary between Romania and Serbia, the dam affects the Danube as far upstream as Novi Sad. Among major environmental impacts is the interruption of the river and habitat continuity, hindering fish migration. The reservoirs trap some 20 million tonnes of sediment/year, but the corresponding absence of natural sediments downstream has been creating erosion problems since the dam was put into operation. In some areas surface water and groundwater levels have dropped by up to 4 metres, greatly affecting the ecological conditions in the area's wetlands.

[20] This cyclone is called "Tamara" in BiH, Croatia and Serbia

[21] Obtained from multiple sources of information

Source: NASA 19/05/2014 http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=83697&eocn=home&eoci=nh

Photo 1: NASA image of Sava Region obtained 19/5/2014



Source: NASA 18/05/2013 http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=83697&eocn=home&eoci=nh

Photo 2: NASA image of Sava Region obtained 18/5/2013

A recent paper prepared by the Royal Netherlands Meteorological Institute (KNMI, May 2014, G.J. Van Oldenborgh) addressing the May 2014 floods finds no evidence that the generally accepted warming trend has contributed significantly to the severity of the precipitation leading to the floods in this area; hence the KNMI paper concludes that "the Sava region" is not very sensitive to IPCC climate change projections. However, the results from hydrological modeling in this study suggest that the probability of exceedance of floods on the SRB rivers can decrease, rather than increase, due to climate change.

Droughts are non-homogenous over the complete Sava River catchments since they cover only certain sub-regions. Nevertheless, as compared to floods, the droughts have larger spatial coverage, which implies that they are governed by global causes and have a multidimensional character which gives them larger scale. The most severe historical droughts in the SRB occurred in 1946, 1947, 1949 and 1950. The last significant drought happened in 1971, in the upper part of the Sava catchment. From that, it should not be concluded that there has been no droughts since then. Actually, there is a strong feeling that very severe droughts have also occurred in the last twenty years. However, droughts were not comprehensively analyzed since 1974. Keeping in mind that it has been 35 years since the last data were analyzed, it is clear that a new hydrological study of historical droughts should be undertaken. It should use longer time series, including recent years. The results of such a study will be of importance for water balance and management analyses.

Considering floods and droughts in the SRB, the South East European Disaster Risk Management Initiative (SEEDRMI) study is of importance for the project reported herein (Andjelić and Roškar, 2007). The SEEDRMI was initiated by the World Bank, UN International Strategy for Disaster Reduction, WMO, and international partners to reduce vulnerability of South Eastern Europe to disasters caused by natural hazards, among them floods and droughts. This initiative is to form the foundation for regional- and country-specific investment priorities (projects) in the area of early warning, disaster risk reduction and financing. Component 1 of the SEEDRMI Hydromet Initiative strengthened hydro meteorological services, data sharing and early warning systems in South Eastern Europe. Component 2 of the SEEDRMI Hydromet Initiative is to strengthen hydrological flood warning and forecasting capabilities of the National Meteorological and Hydrological Services of the Sava riparian states in line with the EU Flood Directive, WMO Flood Forecasting Initiative and WHYCOS program, and the ICPDR action plan for sustainable management of floods. This will be achieved not only through the improvements in data collection and data management system in the SRB, but also through development and use of state-of-the-art hydrological river flow and flood forecasting models.

2.2.5 Groundwater

The territory of the SRB is distinguished by diverse geological structure and a complex tectonic setting under which two main geologic units and associated aquifer types stand out (ISRBC, 2009). Those are the *Pannonian basin* with dominant inter-granular aquifers and *Dinarides* with limestone aquifers mostly. The border between the Pannonian basin and Dinarides extends, approximately, along the route *Celje-Zagreb-Karlovac-Prijedor-Stanari-Zvornik-Valjevo*.

Pannonian basin, in the northern part of the SRB, forms a clearly defined and extensive depression, complemented by new sediments of great thickness. It is characterized by two main types of aquifers:

- Block of deposits of Pliocene age, and
- Fluvial deposits of the Sava River and its tributaries.

Aquifers of the *Pliocene complex* occupy a large area and have artesian character and relatively limited yield to wells. Wells are important for potable water supply due to their size and almost complete protection against pollution from the surface terrain.

Major aquifers are present in the fluvial deposits of the Sava River and in the downstream sections of its tributaries, the Ljubljanica, Krka, Kupa, Una, Vrbas, Ukrina, Bosna and Drina, with well yields of more than 100 l/s (8,640m^3/day). The water supply of all bigger settlements in the alluvial plains is based on these aquifers.

This highlights the need of studying the impact of climate change on groundwater, as it is the most common source of potable water.

The Exterior Dinarides mainly belong to the Adriatic basin, while the more extensive Interior Dinarides belong to the SRB. The Interior Dinarides have more heterogeneous lithological composition, but they are composed of highly carbonate rocks, where fractured aquifers are formed. The leading aquifers of this region are the karstic limestone of the mountain massifs and karst areas. In Slovenia, a large volume of groundwater is accumulated in the limestone aquifers of the Julian Alps, Savinja Alps and Karawanken chain; in Croatia, in the Kapela massif, Kordun region, Zagorska and Zvečajska Mrežnica, Dobra River and especially in the Kupa River basin; in BiH, in numerous limestone massifs occupying large areas in the eastern and north-western parts of the country; and in Serbia, in the western Serbian karst. Huge volumes of groundwater are discharged through the very strong flowing karst springs. For example, there are about 125 larger karst springs in Slovenia with average discharges of about 35 m^3/s that drop to about 27 m^3/s in dry periods (Komac, 2000). The level of exploitation of this source of high quality water is still relatively low, although it provides water for most of the population and industry. For example more than half of Slovenia's population is supplied with water from karst springs (Komac, 2000). Thanks to the inaccessibility of many karst terrains, the degree of pollution of these water bodies is negligible. However, unconfined aquifers are highly polluted from activities on the land surface. The expert institutions of all countries in the SRB have distinguished such aquifers over their territories. Defining such aquifers has been undertaken consistently within the principles of the EU WFD and with the current degree of knowledge of the hydrogeological conditions prevailing in each country (ISRBC, 2013). The reported groundwater bodies are shown in Figure 2-12 below.

Concerning Figure 2-12, the expert institutions of all SRB countries have distinguished 41 main groundwater bodies of basin-wide importance over their territories (Slovenia – 11, Croatia – 14, BiH – 7,Serbia – 5, and Montenegro – 4). These groundwater bodies were identified following the principles of the EU WFD (article 5 and Annex II of the WFD) and the current degree of knowledge of hydrological conditions of the territory. A total of 20 of these main groundwater bodies have important transboundary characteristics. It should be recognized, however, that about 80% of the groundwater bodies are judged to be at no risk concerning available water quantity. For the remainder, groundwater levels are being lowered, not from over-abstraction, but more from lowering of river levels, caused by river bed regulation, hydropower plant construction, gravel dredging, etc.

Source: ISRBC, 2013.

Figure 2-12: Reported main groundwater bodies in the Sava River Basin

2.2.6 Water Quality

There are 90 surface water quality monitoring stations in the SRB, measuring a combination of physical, organic, nutrients, heavy metal and microbiologic parameters. Physical parameters are measured at 90, organic at 68, nutrient at 68, heavy metals at 55 and microbiologic at 52 water quality monitoring stations (ISRBC, 2009).

In this context, the operation of the Trans-National Monitoring Network (TNMN) is aimed to contribute to implementation of the Danube River Protection Convention and is in operation since 1996. Water quality data from the monitoring program are regularly gathered by Danube/Sava countries, merged at a central point at the Slovak Hydro-meteorological Institute, processed by using agreed procedures and provided to the ICPDR information system. The TNMN builds on the national surface water monitoring networks.

Twelve (12) TNMN stations are operating in the SRB, among them 9 TNMN on Sava (Jesenice-SI, Jesenice-HR, Jasenovac-HR, Jasenovac-BA, Županja-HR, Jamena-RS, Sremska Mitrovica-RS, Šabac-RS, Ostružnica-RS) and 3 TNMN on Sava main tributaries (Modrica-BA-Bosna, Kozarska Dubica-BA-Una, Razboj-BA-Vrbas, Badovici-RS-Drina).

The Environmental Impact Assessment (EIA) report (Pacific Consultants International, 2008) for the Sava Waterway Rehabilitation Project provided data on the quality of water of the Sava River from the water quality monitoring network. The quality assessment is based on the EU Water Classification Act, according to which water is divided into five classes, depending on the borderline values of different water quality parameters. Assessment of water quality is performed on water streams that are being used or are intended to be used for public water supply, on water in national and nature parks, on the parts of the water streams where important state and cross-border waters merge, on the rivers where industrial and/or urban wastewater is discharged, and in the areas where water resources are used or are intended to be used for some economic purposes (irrigation, fish farms, etc.).

The EU Water Quality Classification serves international purposes for the presentation of current status and improvements of water quality and is not to be a tool for implementation of national water policy. Five classes are used for assessment, with target value being the limit value of class II. The class I should represent reference conditions or background concentrations. The classes III – V are on the "non-compliance" side of the classification scheme and their limit values are usually 2-5-times the target values. They should indicate the seriousness of the exceedance of the target value and help to recognize the positive tendency in water quality development.

For the characterization of the water status evaluation physical parameters (temperature, pH, and suspended solids), organic substances (dissolved oxygen, BOD_5 and COD-Cr) and nutrients (NH_4, NO^2, NO^3, and PO^4) have been taken into consideration. The classification scheme for the selected parameters is presented in Table 2-6.

Table 2-6 Water quality classification concerning oxygen/nutrient regime for TNMN purposes

Determinant	Units	Class				
		I	II	III	IV	V
Oxygen/Nutrient Regime		**Class limit values**				
Dissolved oxygen	$mg.l^{-1}$	7	6	5	4	< 4
BOD5	$mg.l^{-1}$	3	5	10	25	> 25
COD-Cr	$mg.l^{-1}$	10	25	50	125	> 125
Ph	-		> 6.5 to < 8.5			
Ammonium-N	$mg.l^{-1}$	0.2	0.3	0.6	1.5	> 1.5
Nitrite-N	$mg.l^{-1}$	0.01	0.06	0.12	0.3	> 0.3
Nitrate-N	$mg.l^{-1}$	1	3	6	15	> 15
Ortho-phosphate-P	$mg.l^{-1}$	0.05	0.1	0.2	0.5	> 0.5

Source: ISRBC, 2009.

The mean annual water quality data (Pacific Consultants International, 2008) are given for 13 monitoring stations located in the Sisak-Račinovci section of the Sava River (including the 9 TNMN stations) for the years 2004, 2005 and 2006. Although one cannot generalize these data for the entire basin, it is interesting that physio-chemical indicators are always in Class I (the best class), oxygen regime indicators in Class II to III, nutrients in Class III to IV, and indicators showing microbiological contamination in Class IV to V.

The RBMP for the SRB prepared by the ISRBC (2013), presents also the results of an analysis of the current situation of water quality (surface waters and groundwater) and the related ecosystems in the SRB, carried out according to the requirements of the EU WFD (refer to Maps 14-17 of the Sava RBMP). The report includes identification of significant pressures (including hydro-morphological alterations), assessment of impacts, risk assessment for the heavily modified water bodies and groundwater bodies, information on water quality monitoring, and general information on gaps and uncertainties.

Risk analysis indicated that about 83% of the Sava River water bodies are “at risk” due to hydro morphological alterations and/or pollution by hazardous substances, nutrients, and organic pollutants. The situation on the Sava tributaries is better, only 33% of them are judged to be “at risk”. Most urban settlements do not have advanced wastewater treatment plants, and currently are disposing sewage water mainly to the surface water bodies. However, as part of the process of EU accession, countries are seeking to meet the WFD requirements, and are planning on installing treatment plants in line with the WFD.

The driving forces related to settlements, industry, agriculture and waste management have been considered as key elements that exert or may exert significant pressure on the quality of surface water bodies in the SRB. The main point sources of pollution in the SRB come from the population through municipal wastewater and from industrial activities. Point pollution sources include public drainage systems as well as all the settlements that do not have wastewater and sewage disposal systems, and the settlements and industrial facilities that discharge their wastewater into drainage systems and natural recipients. Waste disposal sites are one of the most significant uncontrolled sources of water pollution in the SRB. The greatest pressure from diffuse points of pollution comes from agriculture (nutrients from fertilization and plant protection products).

Data gaps and uncertainties for the identification of significant pressures relevant on the SRB scale have been identified for Croatia, Serbia and Slovenia. The data gaps have not been analyzed in BiH, where the situation is most difficult in that respect. Generally there is no reliable knowledge concerning a number of water and related ecosystem parameters, e.g. the data on aquatic macrophyte and fish which are not routinely monitored. Assessment of impact from different sources of pollution is based mainly on the status of physical and chemical parameters of water quality only. The analysis of risk on failure to reach the environmental objectives of the WFD in the SRB is under development.

As far as the groundwater quality is concerned, the most important chemical pressures are identified as:

- Use of natural and artificial fertilizers in agriculture,
- Discharge of wastewater from towns and industry, as well as farm wastewater through septic tanks and wells,
- Discharge of wastewater from towns and industry, as well as farm wastewater into surface waters that feed aquifers, or into the sinking streams (in Karst regions),
- Leakage waters from waste dumps (towns and industry), which do not fulfil even minimum sanitary requirements for waste depositing, and
- Waters from mines and coal separation.

Unfortunately, except for Slovenia and Croatia there is no organized monitoring of polluters, as well as of groundwater quality, with data necessary for forecasting influence of these polluters on ecosystems. Therefore, risk assessment of not reaching aims for certain groundwater bodies was performed mostly during usage of that water, and based on available data and investigation works, which defined protection measures for groundwater. However, the overall assessment is that about 70% of groundwater bodies are considered “at no risk” from the point of view of chemical water quality concerning water quality parameters (ISRBC, 2009).

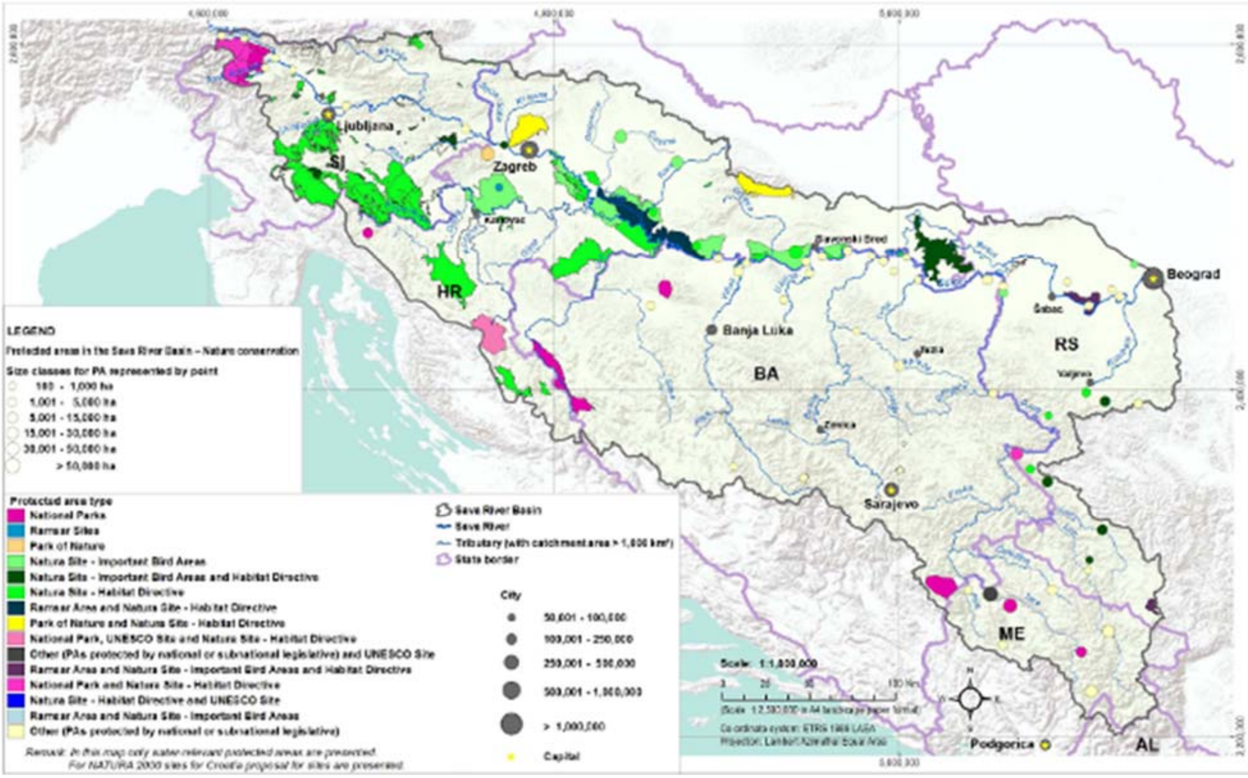
2.2.7 Wetlands and Ecosystem Services

The SRB is of great significance also because of its outstanding biological and landscape diversity (ISRBC, 2013). It hosts the largest complex of alluvial wetlands and large lowland forest complexes. Some of these floodplains are still intact and support at the same time flood alleviation (mentioned in Section 0) and various ecosystem services. Wetlands are cradles of biological diversity, providing the water and primary productivity upon which countless species of plants and animals depend for survival. They support high concentrations of birds, mammals, reptiles, amphibians, fish and invertebrate species. Wetlands are also important storehouses of plant genetic material. In addition, they have special attributes as part of the cultural heritage of humanity related to religious and cosmological beliefs, constitute a source of aesthetic inspiration, provide wildlife sanctuaries, and form the basis of important local traditions. These areas are so important that they have been considered as one of the “crown jewels” of European nature and have been selected as a focal region in the Pan European Biological and Landscape Diversity Strategy (PEBLDS) of the Council of Europe.

Due to the above mentioned ecological and cultural values of these wetlands, the Sava riparian countries have designated six sites in the SRB under the *Convention on Wetlands of International Importance,* the so-called “*Ramsar” Convention.* The list includes the following wetlands which are shown in Figure 2-13 below and cover an area of approximately 78 km^2:

- Bardača Wetland, BiH, 3500 ha, important bird area;
- Lonjsko Polje and Mokro Polje, Croatia, 50560 ha, nature park, ornithological reserve;
- Crna Mlaka, Croatia, 625 ha, ornithological reserve;
- Obedska Bara, Serbia, 17501 ha, nature reserve;

- Zasavica, Serbia, 1913 ha, important bird and plant area, nature reserve; and
- Cerkniško Lake, Slovenia, 7250 ha, ecologically important area, regional park.



Source: ISRBC, 2013.

Figure 2-13: Designated Ramsar Sites within the Sava River Basin

Alluvial forests are one of the most species rich habitats in Europe. They are under the strict protection of the EU Habitats directive. They play a key role in the control of the structure and function of ecosystems along the lowland rivers in the SRB. Alluvial forests are one of the most valuable, but also one of the most endangered habitat types in Europe. They play a vital role in the filtration and cleaning of water and also replenish groundwater and prevent erosion. The central Sava Basin includes the largest complex of alluvial hardwood forests of oak and ash not only in Europe, but also in the Western Palaearctic.[22]

2.3 Institutional Arrangements for Water Resource Management – Sava River Basin States

2.3.1 Bosnia and Herzegovina

According to the Constitution of BiH, water management is in the jurisdiction of entity-level ministries of Agriculture, Water Management and Forestry. Concerning the Federation of Bosnia and Herzegovina, the Sava River Watershed Agency in Sarajevo is responsible for water management, while in the Republika Srpska that responsibility is given to the Republic Water Agency for Sava River District in Bijeljina. At the state level, the Ministry of Foreign Trade and Economic Relations BiH is responsible for coordination of activities and harmonization of plans between different bodies of entity governments as well as international institutions concerned with natural resources, environment protection, agriculture and energy. The Ministry of Communications of BiH, also at the state level, is in charge of inland and sea navigation.

[22] The Western Palaeartic is one of eight ecological zones that divide up the earth's surface.

Although BiH is not a member of the EU, and has no obligations to implement the EU regulations, BiH and both of its two entities have chosen to implement the EU WFD. This intention is expressed by transposition of the WFD basic principles and goals into new entity Water Laws.

2.3.2 Croatia

In Croatia, water management is the responsibility of the Ministry of Regional Development, Forestry and Water Management, but the key development issues (water supply, wastewater management and flood protection) are handled by its agency for water management, Hrvatske Vode (HV). The HV is the key player in water management with 900 employees versus about 40 to 50 in the Ministry. HV collects water charges and distributes funds to 120 municipal water supply companies (there is no private sector in that field). The bodies authorized and responsible for water management are the Croatian Parliament, the National Water Council, the Government of the Republic of Croatia, the Ministry of Regional Development, Forestry and Water Management and other state administration bodies, local and regional self-government units, and HV as a national water management agency. Following severe droughts in 2003 and 2005, Croatia developed a National Irrigation Strategy which together with Financing Act of 2005 makes a good mechanism for regular maintenance of the related water management infrastructure. A new national Water Management Strategy was recently developed by HV and adopted by the Croatian Parliament (HV, 2009a).

The Ministry of Regional Development, Forestry and Water Management have the Directorate for Water Management and the Directorate for Water Policy and International Projects.

2.3.3 Serbia

In Serbia, water management is the responsibility of the Ministry of Agriculture and Environment Protection, Directorate for Water. The Directorate is responsible for water resources management policy, multipurpose water usage, maintenance of water regime, protection against floods and droughts, and maintenance of water management infrastructure. The operational issues are in the hands of the Public Water Enterprise (PWE) Srbija vode and PWE Vode Vojvodine (similar to HV in Croatia) and their regional offices. The basic water management problem is inadequate financing of the water sector, both for investments in new infrastructure and for maintenance. Some earlier estimates from 2006 (now outdated) claim that about 900 million EUR were needed, while the existing sources at all levels yield about 250 million EUR (Marjanovic, 2006). After the devastating floods in May 2014, it can be assumed that the discrepancy between the funds needed and allocated for water management would be much greater in time to come.

Although Serbia is not a member of the EU, it has chosen to implement the EU WFD. That intention is expressed by transposition of the WFD basic principles and goals into Serbia's new Water Law (2012).

2.3.4 Slovenia

In Slovenia, water management is the responsibility of the Ministry of Agriculture and Environment. Specific tasks are delegated to departments within the Ministry, to the Slovenian Environmental Agency and to the Inspectorate for the Environment. The expert assignments are carried out by the Institute for Water and the Geologic Survey.[23]

The Ministry of Agriculture and Environment is in charge of preparing fundamental documentation relevant to the implementation of the water management policy. Its responsibilities include preparation of various regulations, governmental acts determining water use and water protection, as well as coordination and harmonization of policies and other water related issues at the level of the EU.

[23] Information obtained from official pages of the Slovenian Environmental Agency (ARSO) on http://www.arso.gov.si/en/.
The Institute for Water is abbreviated as IZVRS from http://www.izvrs.si/?lang=en and
Geologic survey is http://www.geo-zs.si/podrocje.aspx?id=0&langid=1033

The Slovenian Environmental Agency operates in accordance with the territorial principles. It is responsible for database maintenance, monitoring of the status of water (quantity, quality and ecological status), preparation of administrative acts related to water protection, use of water resources, water management, public water management services and hydrologic forecast of natural disasters. The Inspectorate is responsible for controlling the implementation of the relevant legislation. The Institute for Water carries out the activities related to surface waters and groundwater (monitoring and management). The Geologic Survey (GZS) carries out the activities related to groundwater (geologic research).

2.3.5 Montenegro

In Montenegro, water resources management falls under the responsibility of the Ministry of Agriculture and Rural Development, but strategic planning and environmental protection fall under the responsibility of the Ministry of Sustainable Development and Tourism and the Environmental Protection Agency. Energy policy and strategy (including hydropower) falls under the Ministry of Economy. The country is well advanced for EU integration having adopted the key principles and goals of the EU WFD into its water and environmental policy. Notwithstanding, preparation of river basin management plans is delayed and this is now hampering progress in infrastructure development projects including several planned hydropower developments.

2.3.6 International Sava River Basin Commission

The International Sava River Basin Commission (ISRBC) has been established upon signing of the Framework Agreement on the Sava River Basin (FASRB) at Kranjska Gora (Slovenia), on December 3rd 2002, between Slovenia, Croatia, BiH and Serbia. A Memorandum of Understanding (MoU) on cooperation between the ISRBC and Montenegro was also signed in 2013, providing the basis for full cooperation at the technical level. However, their full membership will become possible, once Montenegro becomes a Party to the FASRB.

The FASRB emphasizes the importance of transboundary cooperation of governments, institutions and individuals for sustainable development of the SRB. Its three main goals are:

- Establishment of an international regime of navigation on the Sava River and its navigable tributaries, which includes provision of conditions for safe navigation on the Sava River and its tributaries;
- Establishment of sustainable water management, which includes cooperation on management of the Sava River Basin water resources in a sustainable manner, including integrated management of surface and ground water resources;
- Undertaking of measures to prevent or limit hazards, such as floods, ice, droughts and accidents involving substances hazardous to water, and to reduce or eliminate related adverse consequences.

2.4 Core Water Management Issues

The Sava River and its tributaries are important sources of water needed for the development of the SRB countries. In the following, some of the water management issues especially important in the context of climate change adaptation in the SRB are discussed.

2.4.1 Navigation

This section is based primarily on the Sava River Basin Analysis Report (ISRBC, 2009) and the later Draft Sava RBMP (Background Paper No 9) both prepared by the ISRBC on the navigation issues.

The Sava River is centrally located in the east-west and north-south Core Transportation Network for South East Europe (SEE) and could better complement the road and rail corridors as well as the European waterway corridor focusing on the Danube River. Transport on the Sava River was around 9.5 million tons in 1982 and decreased to 5.7 million tons in 1990. The war of the early 1990s destroyed economic activities and the river (and port) infrastructure. For this reason, the cargo handled in the Serbian ports of the Sava River in recent years was down to less than 25 thousand tons and in the ports of BiH and Croatia to less than 1 million tons.

Clearly action was needed to regenerate river navigation and to invigorate use of the Sava River as a sustainable, more environmentally friendly and energy efficient form of transportation. Recognizing the potential conflict between the development of inland waterway transport and EU WFD implementation the ISRBC, together with the Danube Commission (DC) and ICPDR was involved in the implementation of the Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin. This document was adopted in December 2007 (by the ICPDR, DC) and in January 2008 (by ISRBC).

The 'Joint Statement' is a guiding document for development of the 'Programme of Measures' requested by EU WFD, for the maintenance of current inland navigation, and for planning and investments in future infrastructure and environmental protection projects.

Low performance of cargo transport along the Sava River is a direct result of the current very poor status of the waterway. In addition, the waterway infrastructure suffers from aging, lack of maintenance and incompleteness. The actual classification of the Sava River from Belgrade to Sisak (586 km) is 50/50 Class III and Class IV. The quality of the Sava River as a transport mode mostly depends on the availability of sufficient depth for navigation. In line with Sava Commission Classification (SCC) regulations, the Sava Commission applies two standards:

- Navigation must be possible with a reduced draft 95% of the time; and
- Navigation with maximum draft must be possible 65% of the time.

According to the SCC, the fairway for Class IV waterways should have a depth of 2.3 m, 95% of the time, and a depth of 3.3 m, 65% of the time. The width of the fairway for two-lane traffic should be 55 m in straight sections and 75 m in curves, measured along the river bed center line of the curve. The design requirements for improving the Sava River to a SCC Class Va waterway are almost similar to the design requirements for a SCC Class IV waterway. The differences are:

- The depth of the fairway is 2.4 m for SCC Class Va and 2.3 m for SCC Class IV (at low navigable water level);
- The width of the waterway in bends is 90 m for SCC Class Va instead of 75 m for SCC Class IV; and
- The horizontal clearance below bridges is 55 m for SCC Class Va and 45 m for Class IV.

The situation in the field is far from meeting the requirements for Class IV and Va waterways. The ISRBC aims at rehabilitation and development of the waterway, improving the Sava River between Belgrade and Sisak to minimum Class IV waterway and to Class Va on sectors where it is possible and feasible. The current navigation conditions are poor and unfavorable mostly due to: (i) limited draft over long periods, (ii) limited width of the fairway, and (iii) sharp river bends limiting the length and width of vessels and convoys.

The conclusion of the Feasibility Study and Project Documentation for the Rehabilitation and Development of Transport and Navigation on the Sava River Waterway is that Sava should be improved to Class Va whose design requirements are almost similar to a class IV waterway. The Feasibility Study recognized that 21 stretches of the river require dredging and training works and 20 stretches require river bend improvements, three bridges have to be reconstructed, and marking systems has to be completed (between 335 to 150 river km), with a total cost of about 86 million EUR.

According to the Feasibility Study, rehabilitation and improvement of the Sava River waterway seems to be a project with clear positive socio-economic effects. However, due to the fact that the project has environmental implications, there is a need to carry out environmental impact assessments (EIA) before decisions are made. This is required by the appropriate EU directives for qualifying the projects.

According to the ISRBC, the Sava River navigation project is implemented in two parts (i.e. on two sections): moving progressively upstream from the confluence with the Danube, these are sections 0 to 211 river km and 211 to 594 river km. The EIA study has been completed for the upper section (211-594 river km). Given some concerns expressed by environmental NGOs, additional environmental considerations will be made in the framework of the detailed design of the waterway, which is currently under development. For the lower section (0-211 river km), the EIA study is being prepared in parallel with the development of the detailed design which is still in process. The timing of the EIA study was intentionally aligned with the detailed design work.

2.4.2 Flood Protection

The existing flood management system in the SRB is very complex and includes a large number of flow regulation and protection structures as well as about 1,600 km of flood dikes (HV, 2009b). Notwithstanding, the flood protection system in the Central and the Lower SRB relies mostly on the natural retention areas and the flood protection levees. Generally, the main levees are designed for the 100-year return period floods, while in urban settlements for the 1000-year flood. The Sava River flood protection system is significant for the rarely preserved large natural retentions (Lonjsko Polje, Mokro Polje, Kupčina, Zelenik and Jantak) which have, together with the system of relief canals, a large positive impact on the flood regime in Croatia as well as in the downstream countries. At the same time, the Nature Park and Ramsar site Lonjsko Polje, covering some 500 km^2 is of great ecological value, while Obedska Bara in the Lower Posavina is one of the biggest wild bird nature reserves.

The history of flood protection works in the SRB goes back to the 18th century. The Grubar channel was constructed for flood protection of the Ljubljanko Barje large semi-karst polje upstream of the Ljubljana. Significant river regulation works were done on the Ljubljanica River and its tributaries after the 1932 flood. The floods in the 1960s helped to develop the integrated Central Posavina flood control plan based on the World Bank project (Polytechna-Hydroprojekt-Carlo Lotty, 1972). The proposed solution was based on the imitation of the centuries-old natural flood processes in the Central Posavina, whose lowest parts are naturally suitable for flood retention. The core of the solution, which is located in the Croatian part of the SRB, was flood storage in the Kupa and Sava lowlands, three relief canals (Odra, Lonja-Strug, and Kupa-Kupa), and about 15 structures for water distribution control under flood conditions. The system was designed to provide protection from the predicted 100-year flood, whereas larger urban centers were defended from the 1000-year flood. The value of constructed Central Posavina flood defense system facilities is approximately 40% of the total value of the investment. Due to unfavorable economic conditions, in the years 1990-2005 available funds were insufficient even for regular maintenance of the existing elements of the system. The consequence of such conditions is the current unfavorable status of protection against adverse effects of water, "which is characterized by high flood risks in some areas, numerous incomplete or inadequately maintained protection and amelioration systems, and only partially repaired war damages."

It should also be recognized that the recently completed World Bank funded "Inland Waters Project" in Croatia includes a sub-component on flood protection (World Bank, 2013). This sub-component supports implementation of flood protection measures in the Central Posavina area. The investments will increase flood management coverage through the rehabilitation and expansion of dikes, canals, and channels. Six investments are implemented, two of which are in Lonjsko Pole (designated Ramsar wetlands). Through the investments, the volume of flood water retained will increase from 600 to 720 million m^3.

Concerning the Sava River tributaries, it should be underlined that land uses in valleys of the main river and tributaries are different. Numerous urban and rural settlements are developed in the riverine lowlands along the Sava, which are predominantly used for agriculture. Along the tributaries forests and barren land prevail and the number of settlements is much smaller. Due to the land use, the most significant are flood risks in the Sava lowlands, while hilly and mountainous basins of the tributaries are endangered by torrent floods and associated phenomena. Standard flood defense systems along major tributaries (e.g. Drina) are mostly levees built to protect the larger settlements, where significant industrial facilities are located. Protection of agricultural land is present only at the most downstream sections of the Sava tributaries. Dams and storage reservoirs built on the Sava tributaries play also an important role in the flood risk management systems. The inundated area on the right bank of the Sava River, between the Una River mouth and the Drina River mouth, in a total length of 332 km, is in the responsibility of Bosnia and Herzegovina. The very fertile area is protected by several independent systems of levees and pumping stations (23 in total).

The flood protection systems discussed herewith are closely related to the large scale drainage systems built in the lowlands, especially in Croatia and Serbia, for the purpose of rapid and efficient drainage of excess water from agricultural and other lowland areas. In Croatia the total area of the drainage system partially constructed is about 350,000 ha, while such drainage is needed on about 1 million ha. According to HV, rehabilitation of the first and second category already built drainage canals and reconstruction and construction of pumping stations call for investment of about 20 million EUR (HRK 116 million), with annual maintenance costs in the order of 7 million EUR. In Serbia, just to indicate the scale of the problem with very substantial financial needs, the total capacity of the existing pumping stations is about 550 m^3/s (ISRBC, 2009). Further details are provided in the Guidance Note on flooding, which is provided as an Annex 2 to this report.

2.4.3 Agricultural Water Management

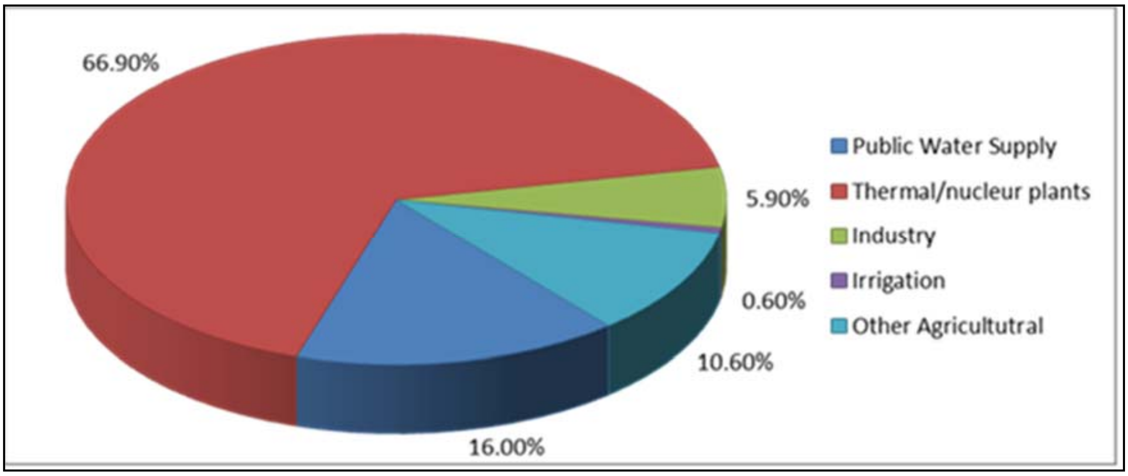
Although at different stages of development, all SRB countries face several challenges in transforming and modernizing their agricultural food production sectors to become competitive in regional and European markets. The agrifood sectors generally lag behind the rest of the economy in growth; they are undercapitalized, fragmented, and dominated by small producers. But agriculture and rural development as sources of growth, employment and food security now need to be taken seriously (Lampietti et al., 2009). The current irrigation coverage is very low and irrigation water use is responsible for 0.6% of the total water withdrawals in the SRB only (annually BiH – 6.2 million m^3, Croatia – 3.1 million m^3, Serbia – 14.4 million m^3, and Slovenia – 4.4 million m^3; ISRBC, 2009). At the same time, however, rapid and efficient drainage of excess water from agricultural lowlands is one of the fundamental problems of agricultural water management in Croatia, Serbia and BiH. For example, in Serbia 2 million ha are under drainage systems and total capacity of drainage pumps is more than 550 m^3/s (Marjanovic, 2006). In Croatia similar drainage systems are fully or partially built on almost 350,000 ha. These drainage systems are generally in poor condition because of the inadequate funds for maintenance of the related infrastructure and unresolved land use structure. Further details are provided in the Guidance Note on agriculture, which is provided as an Annex 5 to this report.

2.4.4 Water Supply and Water Use

Shallow groundwater aquifers are the main source of water supply for most of the urban settlements along the Sava River, including the capital cities of Ljubljana, Zagreb and Belgrade, which are located on its banks (Brilly et al., 2000). To identify the current water use in the basin, a rough estimate was made on the basis of data supplied by the SRB countries (ISRBC, 2009). The level of confidence of those data is relatively low, because of the still prevailing problems with data gathering. Nevertheless, this analysis is an important step towards identification to what extent consumptive water use is a significant water management issue in the SRB. Currently, the total annual water use in the SRB is estimated at about 4.9 billion m^3/year. The sectoral breakdown of this water use is shown in Figure 2-14. Data from 2005 that appears in the draft Sava RBMP showed water use at 4.1billion m^3/year, which indicates a rise of some 20% within a five year period.

Thermal and nuclear power plants account for about two thirds of this amount. The total annual use of water for public water supply (households, industry connected to municipal water systems, etc.) is ~783 million m^3/ year (760 million m^3/year in 2005); and most (approx. 77%) comes from groundwater sources.

The total annual use of water by industrial plants having their own water intakes is approximately 289million m^3/year. The fact that industrial water use is relatively low represents the ominous economic situation in most of the countries of SRB.



Source: ISRBC, 2009.

Figure 2-14: Estimation of current water use in the SRB

As mentioned above, thermal power plants (TPP) and nuclear power plants (NPP) cooling represents the major water abstraction in the SRB—about 3.3 billion m^3/year. Major plants in the SRB are: NPP Krško in Slovenia and TPP Obrenovac 1 and 2 and TPP Nikola Tesla A, in Serbia etc. It should be recognized, however, that the consumptive water use of thermal and nuclear power plants is usually no more than 5% of the volume abstracted – in case of the SRB assumed to be equal to about 164 million m^3/year. Most of the cooling water comes from rivers and reservoirs and it should be taken into account that in spite of small consumptive water use large volumes of water must be abstracted. The capacity of these rivers and reservoirs as sources of cooling water may be adversely affected by climate change. It should be recognized also that thermal pollution of the rivers downstream of major power plants could be a problem in the low water periods.

Irrigation is also a major consumptive use of water in the world, but in the SRB the total annual use of water for irrigation is less than 30 million m^3, accounting for about 0.6% of the water withdrawals in the Basin. The reason for this very small use of irrigation in SRB in comparison with other river basins is the generally inadequate status of agriculture in most of the basin countries. In contrast, the use of water for other agricultural uses in SRB (fish production, livestock farms, or other uses) is relatively high (518 million m^3, this was shown as 600 million m^3/year in 2005), but most of the water is used for fish production.

Data for the use of water for other purposes (tourism, recreation, etc.) are scarce. Since such water uses are basically of non-consumptive character, the only limiting factor for them is water quality.

According to the draft Sava RBMP the average water use per capita in SRB, calculated from the public water supply component, is 238 l/person/day. However, it varies from 140 l/person/day to 328 l/person/day. Public water use includes drinking water for households, industrial and institutional water use, as well as internal use and losses of the service provider.

Comparing the current water use in the SRB with minimum flows and related water supply, it can be concluded that such water use levels can be satisfied even under the low flow conditions. Hence it can be concluded that the current problems are primarily due to the degradation of water management infrastructure and water quality in the last 20 years.

2.4.5 Hydropower

There are 20 hydropower plants in the SRB with an installed capacity larger than 10 MW. In Slovenia most of the plants are located on the Sava River, but in the other SRB countries on major tributaries (e.g. Drina, Vrbas, etc.). The largest plant in terms of annual production is the Bajina Bašta reversible hydropower plant (see Photo 3). Furthermore, in Slovenia there are a large number of small and micro hydropower plants (SHPP). The total installed capacity of the plants is about 2449 MW with yearly production of about 6445 GWh/year (see Table 2-7).

Source: Radomir Kapor

Photo 3: Bajina Bašta Hydropower Plant

Traditionally hydropower facilities integrated with flood protection structures. Future hydropower development in the Slovenia and Croatia downstream up to the Sisak, will manage flood protection also. There is also significant impact on flood protection by Mratinje power plant in Montenegro and other hydropower reservoir on the Drina River such as Zvornik dam and HPP in Serbia (see Photo 4). More recently, there are substantial hydropower developments on the upper Drina River Basin which are at an advanced design stage.

Source: Andrija Nedeljkovic

Photo 4: Zvornik Dam and HPP during 2009 flood

Further details are provided in the Guidance Note on hydropower, which is provided as an Annex 3 to this report.

Table 2-7: Core Data on Hydropower in the SRB

No	SRB Country	Name of the Hydro Power Plant	Name of River	Installed Capacity 2005 (MW)	Installed discharge (m3/s)	Average yearly production [2005-2007] (GWh/year)	Countries share in average total production	Countries share in installed capacity
1	SI	Moste/ Završnica	Sava	21	35	64	9%	8%
2		Mavčiče	Sava	38	260	62		
3		Medvode	Sava	26.4	150	77		
4		Vrhovo	Sava	34	501	116		
5		Boštanj	Sava	33	500	115		
6		Blanca	Sava	43	500	160		
7	HR	Gojak	Donja Dobra	55.5	57	192	4%	4%
8		Lešće	Dobra	42	2x60 +2.7	94		
9	BA	Bočac	Vrbas	110	240	308	29%	21%
10		Višegrad	Drina	315	800	1,120		
11		Jajce I	Pliva	60	74	259		

No	SRB Country	Name of the Hydro Power Plant	Name of River	Installed Capacity 2005 (MW)	Installed discharge (m3/s)	Average yearly production [2005-2007] (GWh/year)	Countries share in average total production	Countries share in installed capacity
12		Jajce II	Vrbas	30	80	181		
13	RS	Zvornik	Drina	96	620	515	46%	52%
14		Uvac	Uvac	36	43	72		
15		Kokin Brod	Uvac	21	37	60		
16		Bistrica	Uvac	103	36	370		
17		Bajina Bašta	Drina	360	644	1,691		
18		Potpeć	Lim	51	165	201		
19		RHE Bajina Bašta*	Drina	614	129	n/a		
20	ME	Piva	Piva	360	240	788	12%	15%
Total SRB 2005				**2,449**		**6,445**	**100%**	**100%**

*Reversible Hydropower Plant

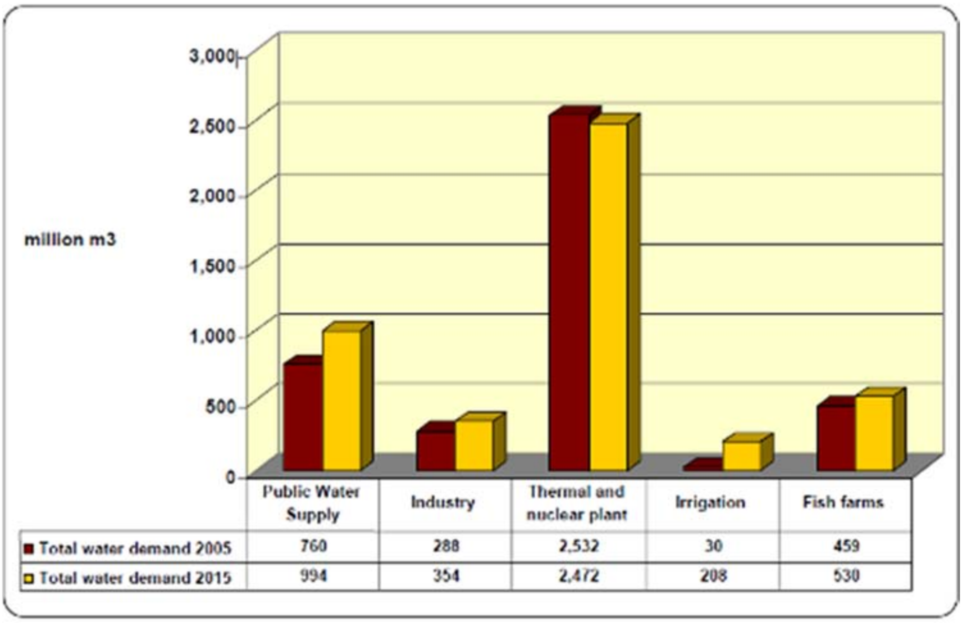
Source: ISRBC, 2013.

2.5 Future Projects Assuming No Climate Change

Assuming no climate change, the difference between the current status of water resources in the SRB and the status projected for 2030 can be due only to the water-related impact of demographic and socio-economic changes. Unfortunately there are no data or information available about such changes that might be expected in 2030. Under such circumstances, only preliminary estimates from water use in 2015 and new planned hydropower plants are given based on the preliminary results of work done by the ISRBC on the Sava RBMP.

2.5.1 Water Use in 2015

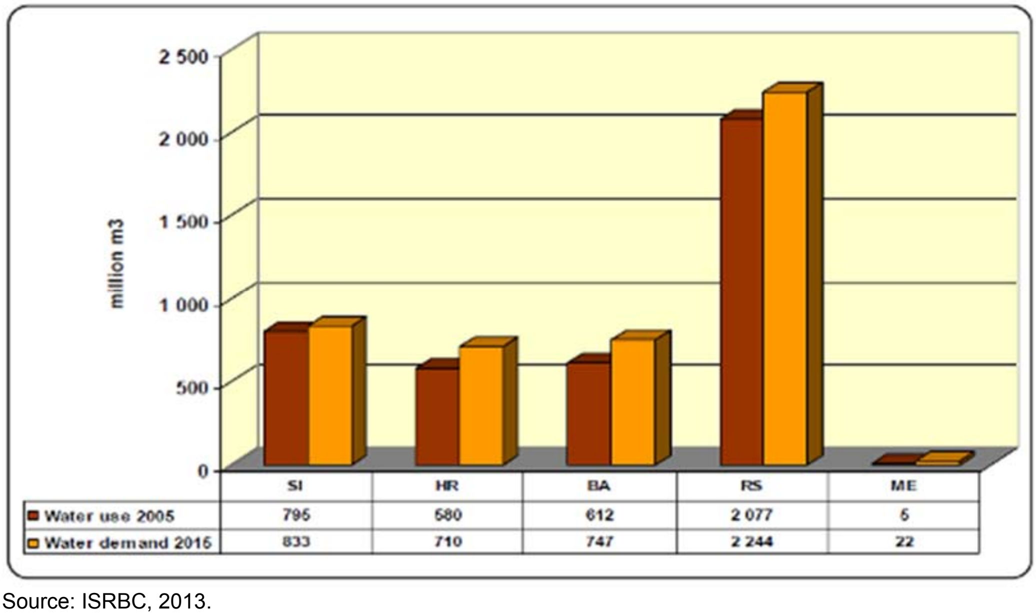
Based upon the Sava RBMP, the projection of water demand up to 2015 has the same structure as the analysis of existing water uses. The water demand projection is calculated based on different national methodologies. The trends are presented by economic sectors and by country. The overall volume of water use is not expected to change considerably by 2015 in the SRB (approximately 12% overall growth is planned). The total water demand is expected to reach 4.6 billion m^3. Higher demand is predicted in all sectors in 2015 than for 2005. The distribution of water use by economic sector in 2005 and the projected water demand in 2015 is presented in Figure 2-15.



Source: ISRBC, 2013.

Figure 2-15: Water demand by economic sector 2005-2015 (excluding hydropower)

The share of individual sectors in total water use is projected to change slightly: a growing proportion of use by the public water supply, industry and irrigation are expected. Irrigation is expected to increase the greatest due to more intensive agricultural systems being introduced in parts of the SRB, especially in Serbia. Total water use and water demand by country are presented in Figure 2-16. A minor increase of 5-8% in Serbia and Slovenia, moderate growth of 22% in BiH and Croatia, and a 4-fold increase in Montenegro are expected in water demand compared to the reference year.



Source: ISRBC, 2013.

Figure 2-16: Water demand by country 2005-2015 (excluding hydropower)

2.5.2 Hydropower

An increase in water use by hydropower plants is projected due to planned new capacity. The overall predicted increase of installed capacity in the SRB is 14%, from 2,449 MW to 2,800 MW, while the annual energy production is predicted to grow by 19%, from 6,445 GWh to 7,700 GWh per annum. A considerable number of hydropower plants less than 10 MW are predicted in Montenegro and BiH, which will increase the capacity and energy production data given above.

Furthermore new larger hydropower plants are planned in Slovenia on the Sava and in BiH on the Sava tributaries. Furthermore, a reconstruction of the existing hydropower plant (HPP Moste) is foreseen in Slovenia. No data for Serbia and Montenegro are available. The planned future increase of hydropower capacities in the SRB is nearly 500 MW, with planned annual production of more than 1,600 GWh/year. In Table 2-8 the new hydropower plants planned to become operational soon are specified.

Table 2-8: Planned new hydropower plants to be operational in the SRB in the near future

#	Country	Name	River	Installed Capacity (MW)	Installed Discharge (m³/sec)	Average annual Production GWH/Year
1	Bosnia	Ustikolina	Drina	59.0		255.0
2	Bosnia	Vranduk	Bosna	22.0		103.2
3	Bosnia	Unac	Unac	71.0		250.0
4	Bosnia	Ugar usce	Ugar	15.0		60.0
5	Bosnia	Vrletna Kosa	Ugar	25.0		63.0
6	Bosnia	Vrhpolje	Sana	68.0		157.4
7	Bosnia	Vlasenica	Jadar	0.9	0.7	6.9
8	Bosnia	Bogatić	Ţeljeznica	8.0	5.5	33.0
9	Bosnia	Mesići	Praĉa	3.1	8.0	16.0
10	Bosnia	Tišća	Tišća	2.1	0.7	10.0
11	Croatia	Lešće	Dobra	42.0		94.0
12	Serbia	NO DATA				
13	Slovenia	HE Blanca	Sava	42.5		160.0
14	Slovenia	HE Krško	Sava	41.5		145.0
15	Slovenia	HE Breţice	Sava	41.5		161.0
16	Slovenia	Addition to HE Moste	Sava	49.9		98.0
	TOTAL			**491.5**	**14.9**	**1,612.5**

Source: ISRBC, 2009.

Therefore In conclusion, water use in the SRB will not change significantly in the near future. The energy sector, i.e. thermal, nuclear and hydropower, is predicted to remain the most important water use in the SRB.

3 Trends Analysis for the Basin and per Country

Following on from the outline for the SRB presented in Chapter 2, this chapter presents the first step in the actual analysis of climate change by reviewing past climatic and hydrologic data.

3.1 Data Available for Trend Analysis

The SRB region has a long history of climate observation; the oldest station in Croatia being Zagreb-Grič, which has measured temperature, precipitation, and humidity records since December 1861. This station is known to be well correlated with other Croatian stations in recent years and it is therefore thought that Zagreb-Grič's long record characterizes a larger area reasonably well (Pandzic and Trninic, 2010).

In Slovenia, a weather station in Ljubljana and some hydrologic stations were established even earlier in 1850 and are still in operation on the SRB: Litija on the Sava River, Celje on the Savinja River, Vrhnika on the Ljubljanica River and Planina on the Unec River. In 1893, the "Central hydrographic office" was founded in Vienna which has through the provincial hydrographic sections of technical management consistently received, processed and published data in the central Year Book "Jahrbuch des hydrographischen Zentralbureaus "(Wien 1895-1918).

A few meteorological stations were opened after Zagreb-Grič in the later part of the 19th Century, but the data collected have never been digitized. In 1901 the Sarajevo station was opened; it is digitized and represents the second-longest available dataset. Subsequently numerous other stations have opened. During the period of conflict in the 1990s, observations were halted at many stations, especially in BiH, but by 2000, most had been brought back to operation.

In terms of hydrology data, the region has a shorter (when compared with other European Countries, e.g. UK), but still relatively good history of river discharge observations. Hydrological data from Zagreb, Bajina Bašta and Sremska Mitrovica are available from 1926 to the present day, while some other stations along the Sava River and the major tributaries have several breaks in the record due to conflicts.

Data used for the trend analysis included river discharge and meteorological variables, temperature (maximum, minimum, and mean), precipitation, and evaporation/evapotranspiration depending on the country. The climatic trends were analyzed at a total of 31 meteorological stations and 37 hydrologic stations in the SRB, with about 60% of stations having records longer than 50 years. Data was generally available up to 2008 or 2009, but some stations were closed in 1990's.

3.2 Sava River Basin Operational Definitions of Climate Variables

In the national meteorological agencies of the SRB, daily maximum and minimum air temperature are respectively defined from 9 pm (local time) of the previous day to 9 pm (local time) of the day for which the measure is recorded. Mean temperature is computed as a weighted average of measurements made at 7 am, 2 pm and 9 pm in local time. A second method for daily mean temperature as the mean value of minimum and maximum temperatures is also calculated for Serbia and Slovenia by the respective hydro-meteorological agencies.

All agencies report evaporation as a directly measured quantity. As for evapotranspiration (ET), Serbia, BiH and Croatia provided estimates of potential ET calculated according to a slightly modified Eagleman method (Pandzic et al. 2008).

The following Table 3-1 provides a summary of the defined climate variables that were considered in the trend analysis.

Table 3-1: Climate variables used for trend analysis, time intervals, and definitions

Category	Variables	Time Step
Temperature	*Maximum daily temperature* - Measured *Minimum daily temperature* - Measured *Mean daily temperature, definition 1:* $T_{mean} = (T_{7am} + T_{2pm} + 2*T_{9pm})/4$ *Mean daily temperature, definition 2:* $T_{av} = (T_{min}+T_{max})/2$	Daily, 10-day, monthly, and annually
Precipitation	*Accumulation* – Measured (always expressed as daily sum)	Daily, 10-day, monthly, and annually
Discharge	*Accumulation* – Measured (always expressed as daily mean)	Daily, 10-day, monthly, and annually
Evaporation and evapotranspiration	*Evaporation* – Measured (class A or similar open-pan measurements); *Evapotranspiration* calculated by Eagleman method.	Daily, 10-day, monthly, and annually

3.3 Climate Analysis

The study used the data and analysis of simple statistical measures and trends of the data from the national experts and analysis done within the World Bank to produce the results seen within. The trends of the data are typically linear or second order regression trends to observe the direction, if one exists or is significant, of the data provided. Spatial analysis is used to observe trends of certain variables throughout the basin to determine if there are significant differences within the trends from different parts of the basin.

The following sub-sections focus on the trends from the SRB overall and for country level for precipitation, temperature, evapotranspiration and river discharge.

3.3.1 Precipitation

Historical records of SRB precipitation show that it is highly variable. A net, regional, long-term trend is difficult to discern because the region sees slightly rising precipitation in some places and slightly declining precipitation in others.

At the Basin level, multi-decadal oscillations in long-term average annual precipitation are clearly important. As Figure 3-1 shows, long-term trends in precipitation are small or negligible, but a background oscillation in precipitation does exist. Therefore, a sequence of short-term trends resulting from this oscillation may provide useful support to planning. The multi-decadal oscillation in annual precipitation amounts to about 10-15% of total precipitation.

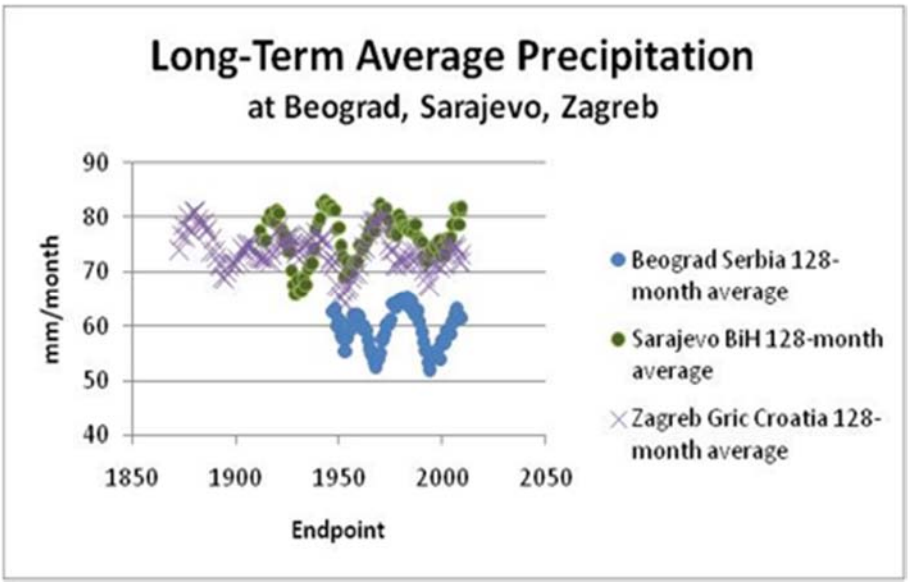


Figure 3-1: 128-month running average of monthly precipitation: Belgrade, Sarajevo and Zagreb

There is also an oscillation in the seasonal distribution of precipitation, with its tendency to concentrate in the rainy periods. The amplitude of the annual precipitation cycle ranges from 10-25% of total precipitation. Further details of these oscillations are contained in the trends report (World Bank 2011).

Generally, precipitation trends seem to be negligible and seem to follow the background oscillation. Although the seasonal precipitation trends show slight movements, typically within the basin the trends do not follow what is being modelled in the basin using the global models.

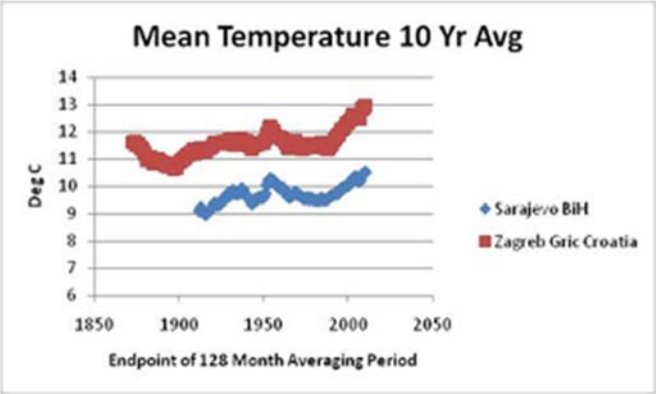
At the country level there are wide ranging differences:

- In Slovenia, it is not possible to discern trends by eye, although linear trends can of course be fit to the data (Brilly, 2010). Such fits yield positive trend lines at three stations (Novo Mesto, Kredarica, Postojna) and negative trend lines at four stations (Celje, Rateče, Ljubljana, Kočevje). The difference between the positive-trending and the negative-trending does not lend itself to any obvious explanation such as regional differences.
- Croatian data suggest a weakly negative trend in annual precipitation. Seasonal precipitation trends are negative for all seasons except for summer. An irregular multi-decadal oscillation of precipitation is observed seasonally and annually. It has been noted that highs and lows of annual precipitation are out of phase with high/low seasonal precipitation. The seasonal results are the reverse of the prognoses obtained from the downscaled global climate projections reported by IPCC in the Fourth Assessment Report (2007), which projected winter/summer precipitation trends of the opposite sign for South Eastern Europe including the SRB. Consequently, model projections must be used with care in strongly varying terrain of SRB. Certainly, the precipitation in Croatia is principally under the influence of air pressure patterns in Europe (Pandzic at al., 2008). But the influence of local terrain may determine the precise way in which long-term continental trends affect the SRB's local weather. For example, a change in the regional frequency of cyclones could alter the local distribution of wind directions, in turn influencing the distribution of precipitation in hilly regions like Croatia's share of the SRB. To take another example, higher temperatures may lead to more-frequent convective precipitation events.
- In BiH, the general synopsis is also inconclusive, as the data do not confirm a clear trend.
- In Serbia, a small but inconsistent drop in precipitation overall was observed. Precipitation trends are generally negative, except for Sjenica and Zlatibor, which are mountain stations, and Loznica, Ljubovija and Valjevo, which are often affected by severe storms that, in summer, bring large amounts of rain locally. Beograd and Sremska Mitrovica, both located on the Sava River, show significant precipitation decreases during the winter season.

3.3.2 Temperature

Temperature in the SRB seems to be rising, but in ways that were unexpected at first. Maximum temperatures are rising, but at a much different rate compared to minimum temperatures. For example, the maximum yearly temperatures do not seem to be increasing, but the occurrence of the highest temperatures is. Further, the coldest minimum temperatures do seem to be rising over time as does the minimum maximum temperatures in the summers. A further point is that the temperature trends seem to follow a large multi-decadal background oscillation.

Consequently, based on more than a century of historical records, it appears that mean temperatures are rising throughout the SRB, driven mainly by changes at the low end of the temperature spectrum. Cold extremes have become rarer, and higher temperatures are seen more often, but the highest "highs" have raised little if at all. Notwithstanding, in some high-altitude locations mean temperatures do not seem to be rising; but rising mean temperatures are the rule elsewhere.



However, it must be stated that the seasonal breakout of this trend changes from time to time. More recently the summers have been much hotter than normal and more than the general warming in winter months; in earlier epochs, it was the other way around. Large background oscillations in temperature (Figure 3-2) and seasonality of temperature may contribute to the difference between longer-term and more recent trends

Figure 3-2: 128-month running average of Mean Temperature at Zagreb-Grič and Sarajevo

At the country level the following observations are noted:

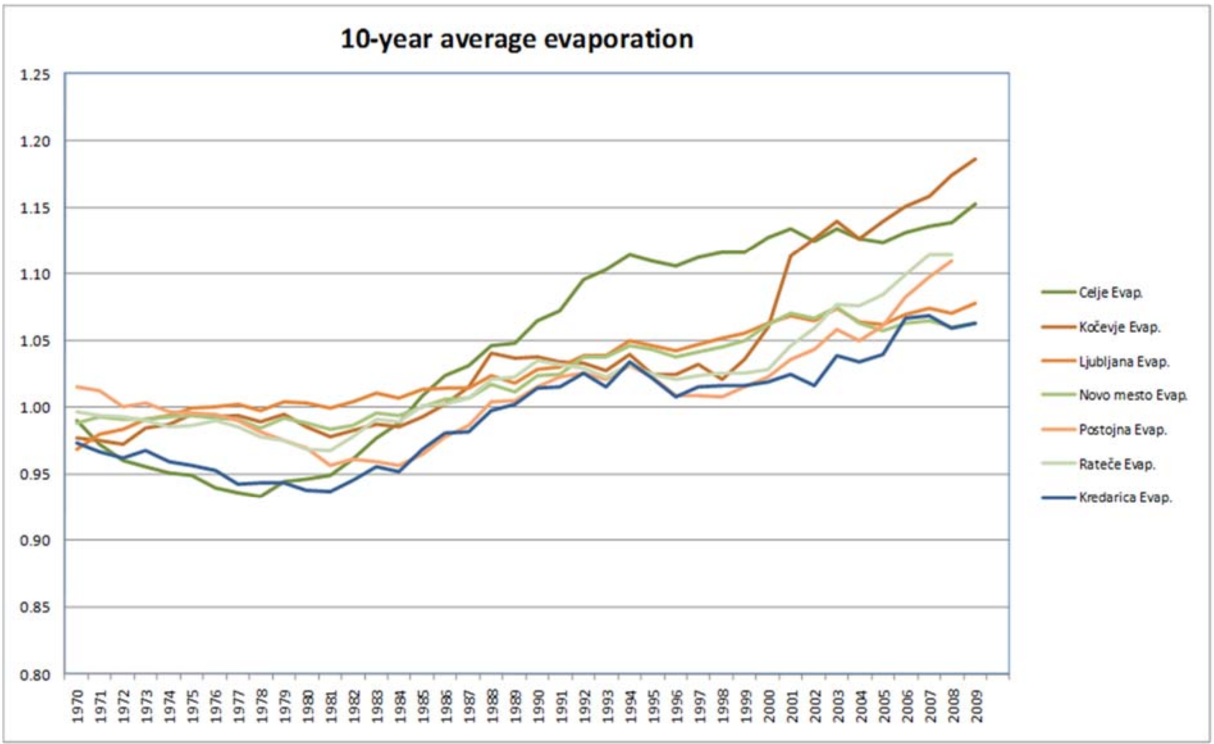
- In Slovenia, the data show a rising mean temperature with minima rising faster than maxima. For example data from Ljubljana provide an example where warm extremes are more common but are not rising; cold extremes are dropping out of the distribution. The temperature trend at most gauges in Slovenia are positive.
- In Croatia, data confirm a rising mean temperature, which is evident for example as a trend over the period of operation of Zagreb-Grič, 1862-2009, the SRB's longest temperature time series (Figure 3-2). In Croatia as in Slovenia, the rise in mean temperature comprises a consistent rise in minimum temperature and an inconsistent, smaller rise in maximum temperatures. However, the data from Croatia distinguish between summer and winter trends. Mean temperatures are rising in all seasons. Winter shows clear rising trends in both maxima and minima. While summer clearly shows rising minima, summertime maxima are rising more slowly and inconsistently. Systematic comparisons of data from Zagreb-Grič to other datasets in the Croatian part of the Basin were undertaken over the time periods where there is overlap and this showed a strong correlation.
- In BiH, temperature trends show similarity to the results from Slovenia and Croatia, the rising trend in maximum temperature is lower than the rising trend in minimum temperature. Data from the Republika Srpska distinguishes trends in mean temperature by season and shows that although mean temperature is rising in all seasons; it is increasing more rapidly during the months January to August than in September-December. The rising temperatures in December may be due to an effect of changing wind patterns that increasingly favor winds from the south and east instead of the north and west. But the interplay of factors is complex; the strongly marked terrain influences how cloud cover, humidity, and wind drive temperature. Further Banja Luka is also subject to these effects also known as "Foehn" [24] Discontinuities in climate over short distances may be attributable to these factors.
- In Serbia, data show rising trends in most locations, but two locations (Šid and Bogatić) show negative trends. These two time series ended in 1991 and 1993, earlier than the others. This raises the question of the extent to which positive trends seen elsewhere may also be sensitive to the endpoints of the segments analyzed. Other northern stations (Šabac, Beograd, Loznica, Ljubovija and Valjevo) show significant increases in all measures of temperature during the summer. The exception is Sremska Mitrovica, where only the trend in mean daily temperature is significant. The mountain stations, Sjenica and Zlatibor, show significant increases in maximum temperatures during the winter and mean temperatures during the summer. Sjenica also has a significant trend of minimum temperature during summer, while Zlatibor manifests an increase in maximum temperatures even during spring and summer.

[24] A Foehn wind is a type of dry down-slope wind that occurs in the lee (downwind side) of a mountain range. It is a rain shadow wind that results from the subsequent adiabatic warming of air that has dropped most of its moisture on windward slopes. As a consequence of the different adiabatic lapse rates of moist and dry air, the air on the leeward slopes becomes warmer than equivalent elevations on the windward slopes.

3.3.3 Evapotranspiration

Potential evaporation (evapotranspiration) trends show an increase within the SRB. The increase depends on the location within the basin. At the country level the following observations are noted:

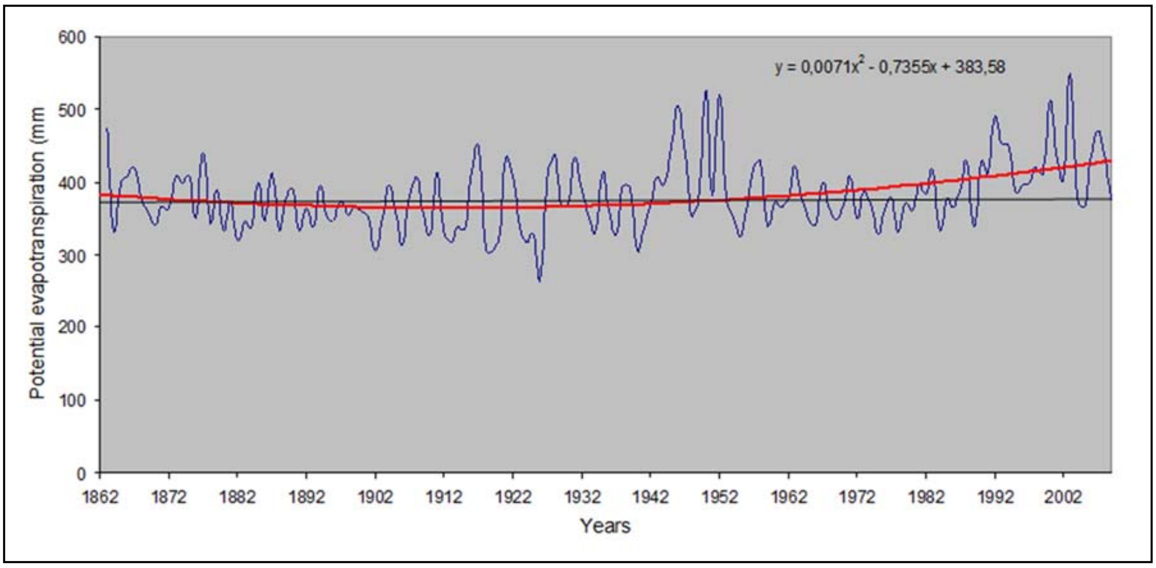
- Slovenian data indicate an increase in evaporation throughout the country. Figure 3-3 presents a 10-year moving average of evaporation at selected stations.



Source: Brilly, 2010.

Figure 3-3: The 10-year moving average of evaporation at selected stations

- In Croatia, water balance components for 10-day periods were calculated using a modified Palmer's procedure (Palmer, 1965). In addition to 10-day potential evapotranspiration, the following parameters were also calculated for the same periods: real evapotranspiration, recharge into the soil, loss from the soil, run-off and soil moisture content. For initial time steps it was presumed that the soil has maximum moisture within it, i.e., field capacity, which is 400 mm for Zagreb, Slavonski Brod and Donji Miholjac while for Ogulin it was taken as 250 mm.
- Evapotranspiration in Croatia is increasing and especially in summer months (Figure 3-4). Potential evapotranspiration has a rising trend in summer and annually, closely related to trends measured in temperature. An increase up to 30 percent could occur by mid-century. If so, even if precipitation does not decline, the high levels of potential evapotranspiration could reduce the other terms in the water balance significantly. Indeed, precipitation excess at Zagreb-Grič could in principle drop to zero, though the prognostic value of the trend line does not appear strong. Pandzic et al. (2008) have noted that the sensitivity of an area to global warming depends on the ratio of precipitation and potential evapotranspiration. Where the two are near in value, the water balance will be particularly sensitive to rising average temperatures. In turn, this balance varies seasonally; areas that have maximum precipitation in the cooler seasons are less vulnerable to evapotranspiration. The Pannonian Plain, however, receives its maximum seasonal precipitation during the warmest part of the year and is thus vulnerable to a changing water balance resulting from rising mean temperatures.



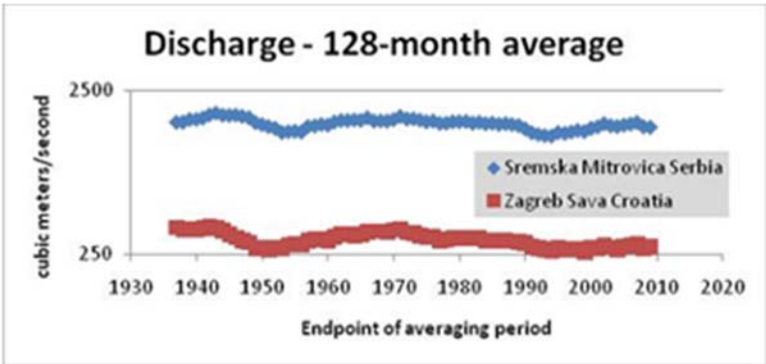
Source: Brilly, 2010.
Note: the black line is average over 1961-1990; the red line is quadratic trend fit to data. (Pandzic and Trninic, 2010)

Figure 3-4: JJA potential evaporation at Zagreb-Grič, 1862-2008

- Data from BiH show a strong decline in evapotranspiration in the 1970s, followed by an increase up to the present time.
- In Serbia, the trend in potential evapotranspiration has been mainly positive, following the temperature trend. An exception to the rule is Sremska Mitrovica where a significant evapotranspiration trend occurs during the winter, contrary to the temperature trend. The only negative value observed is that for Šid, one of the exceptional stations that also manifested a negative temperature trend, an anomaly attributed to an endpoint in the early 1990s.

3.3.4 Discharge

Discharge shows an overall decrease in the basin, but it must be noted that discharge within the basin is inherently impacted by anthropogenic forces that would naturally disturb the discharge within the basin.



It is also noted that other reasons including reforestation of agricultural lands and changes in agricultural practice impact the discharge locally throughout the basin.

Discharge is declining in the SRB. Figure 3-5 presents ten-year moving averages of discharge from two of the longest records in the SRB.

Figure 3-5: Running 128-month average discharge measured at Zagreb and Sremska Mitrovica

- Slovenia shows the normalized 10-year moving average of the discharge for the stations in Slovenia. There is a clear decreasing trend at all stations (Brilly, 2010).
- Discharge is declining although precipitation is not. Pandzic et al. (2008) suggest that the decline in discharge seems to be a consequence of increased evapotranspiration resulting from rising average temperature. Pandzic et al (2008) also remarks that the decline in discharge is more apparent in the Basin's larger flows, perhaps a consequence of longer flow concentration times that enhance the effects of evapotranspiration trends. There is an exception to the overall

decline: although the sub-basins to the right of the Sava (broadly, the southern basins) manifest a net declining trend, the tributaries to the left (broadly, the more-northern basins) do not manifest declining discharge. The very important gauge at Županja likewise does not manifest a decline in annual minimum flow.

- Trends at Zagreb and Županja if taken literally indicate a possible decline of up to 30 percent in discharge by the middle of the 21st century, but should not be taken literally as to magnitude, considering that the observed declines are due in part to a period of dam building upstream of Zagreb together with increased consumption of water.
- Most of the SRB regions in BiH show an increasing discharge trend (eastern part, Drina River) or with no change (middle part) in annual and seasonal level because of the increasing precipitation. The north-western region shows partially a negative trend or no change. It should be noted though that discharge in the most rivers in BiH are under control of power plants, except for the Bosna river, which displays a good example of increasing discharge due to an increasing precipitation influence. Table 3-2 shows the change in mean annual flow of the last decade (Q men) as compared to the mean annual discharge for the entire recording period (Q mean) as an example of how more recent flows differ from the entire recording period.

Table 3-2: Observed Discharge changes in last decade vs. total measured discharge

Station	River	Q max m³/s	Q mean m³/s	Q mn 2000-2009 m³/s
Banja Luka 1946 – 2009	Vrbas	1398	95	86
BL – Delib. Selo 1962-2009	Vrbas	1607	97	78
BL – Vrbanja 1961 – 2009	Vrbanja	704	17	16
Prijedor 1980 – 2009	Sana	1157	84	72
Novi Grad – downstream 1980-2009	Una	1385	204	214
Doboj 1987-2009	Bosna	2992	150	172
Foca- downstream 1980-2009	Drina	1061	180	210

Source: Rudan, 2010.

It has been noted that rising discharge values where cases of higher temperatures, higher evaporation rates, and increased precipitation could be attributed not only to higher precipitation but to geomorphologic change in the river bed that would devalue the discharge rating curves set for some gauging stations.[25] In these cases the stations need to be re-calibrated and validated data needs to be produced.

- In Serbia, river discharge trend is negative for all stations except Čedovo, which is located on the Vapa stream in the mountains and is strongly influenced by the increasing precipitation observed at the Sjenica meteorological station (as noted above). Significant negative trends of river discharge are noted on the Lim River (Brodarevo during winter and summer, Prijepolje during summer, and Priboj during all seasons) and the Sava River (Sremska Mitrovica over the whole year). Also, for one station on the Drina (Bajina Basta) and one on the Kolubara (Slovac), a negative river discharge trend is present during the spring.

3.3.5 Conclusions

Overall it can be concluded that historic hydro-meteorological data and trends can benefit the water management of the SRB in terms of planning for infrastructure and IWRM of the basin; however, the results of the analysis should be taken with care and careful treatment of the data.

Within the SRB, the main region where water resources are at greatest probability of highest risk based on the historical observations are those located on the Pannonian Plain, where precipitation occurs in the warmest part of the year. These areas are particularly exposed to rising evapotranspiration as an outcome of rising mean temperature. Runoff may decrease significantly under these circumstances, affecting rain-fed agriculture directly and altering the demand for irrigation water.
Overall, the precipitation data are showing a slight decline overall that does not validate the downscaled model outputs under IPCC scenarios, suggesting a need for caution in employing

[25] Noted from communication with Nada Rudan of the Hydro-Meteorological institute of the Republika Srpska

model outputs as the basis for large scale planning. Experts agree that local influences are at work affecting precipitation.

Agriculture is likely to be affected by rising mean temperatures. If crop species are selected for planting in light of climate change, care should be taken to ensure that species selected are adapted to the change that is actually occurring, namely a reduction in the occurrence of low temperatures and an increase in the occurrence of high temperatures, but not the setting of new record highs. Therefore, the statistics underlying the rising mean should not be interpolated in a too simplistic manner.

Although discharge is declining on an annual basis, it appears that the declining trend affects mean and maximum flows more than it affects minimum flows. This suggests that infrastructure does not necessarily need rehabilitation aimed particularly at managing minima, but rather an ability to store additional water.

3.3.6 Recommendations

Consequently, the principal recommendation for the water sector from the climate trend analysis is to ensure that infrastructure has adequate capacity to deal with the full range of precipitation levels that have been seen in the past seventy years, whilst not expecting that trends will carry precipitation far outside of these levels.

Furthermore, the water sector will need to manage rising mean temperature that occurs within large background oscillations.

The sector will also need to manage rising evapotranspiration, especially on the Pannonian Plain. The management of the rising evapotranspiration will have to come from institutions and stakeholders within the SRB that understand the specific details of the changing evapotranspiration and its effects and what specifically can be done in the basin in order to manage and adapt to such changes.

4 Future Climate Analysis for the Basin

The trends analysis undertaken in the previous chapter on past climate and discharge has helped to prepare the way for climate modeling. This chapter details the analysis of the characterization of the future climate in the SRB by assessing and comparing outputs of Global Circulation Models.

For the 21st century climate predictions, the A1B IPCC/SRES greenhouse gas (GHG) emission scenario was assumed. This scenario is considered as a mid-level intensity scenario and it is commonly used for future projection of GHG emission in many climate change studies. Two different approaches for developing climate scenarios were applied, both of which relied on an ensemble of Global Climate Models (GCMs) outputs. The first approach was based on developing probability distributions of future climate parameters in a Bayesian framework, while the second approach was based on downscaling of the GCM outputs by using the regional climate models (RCMs) in order to derive locally adjusted time series of future precipitation and temperature.

4.1 Probability Density Functions

Probability density functions (PDFs) of future climate variable statistics were produced from the change in climate variables within Global Circulation Models (GCMs). The intention was that these PDFs could then be used to build stochastic future time series, which could then be inserted into the hydrologic model as climate change scenarios to help determine events and possible future climatic situations that would affect the system.

The completed report (Jupp, 2012), presented cumulative distribution functions (CDFs) for future precipitation at 29 stations within the SRB for the early 21st century (2001-2031) and for the late 21st century (2068-2098). CDFs were derived for each season (December-January-February. March-April-May, June-July-August and September-October-November; DJF, MAM, JJA and SON) as well as for the entire calendar year (denoted by the abbreviation ALL). These CDFs were developed by weighting the predictions of 24 GCMs listed in Table 4-1, taken from the archive of the Coupled Model Inter-comparison Project phase 3 (CMIP3). The A1B SRES/IPCC emission scenario (IPCC 2007) is assumed for the 21st century predictions. This scenario is considered as a mid-level intensity and it is commonly used for future projection of GHG emission in many climate change studies.

Table 4-1: Climate models used

Model Identifier	Model Name	Model Identifier	Model Name
a	bccr_bcm2_0	m	ingv_echam4
b	cccma_cgcm3_1	n	inmcm3_0
c	cccma_cgcm3_1_t63	o	ipsl_cm4
d	cnrm_cm3	p	miroc3_2_hires
e	csiro_mk3_0	q	miroc3_2_medres
f	csiro_mk3_5	r	miub_echo_g
g	gfdl_cm2_0	s	mpi_echam5
h	gfdl_cm2_1	t	mri_cgcm2_3_2a
i	giss_aom	u	ncar_ccsm3_0
j	giss_model_e_h	v	ncar_pcm1
k	giss_model_e_r	w	ukmo_hadcm3
l	iap_fgoals1_0_g	x	ukmo_hadgem1

Source: Jupp, 2012.
Note: Models from the Coupled Model Inter-comparison Project phase 3 dataset in the “Climate of the 20th Century” experiment

The approach used to develop these CDFs was based on weighting the predictions of individual GCMs, using a Bayesian approach. The weight assigned to each GCM is referred to as the probability of the model and generates a probability density function (PDF) over the set of models. Models are weighted based on their ability to reproduce the mean, the variability (i.e. the statistical distribution) and linear trend of the observed precipitation in each season. The relative weighting of the climate models is updated sequentially according to the Bayes' theorem, based on the biases in the mean of the observed and simulated time series and the distributional fit of the bias-corrected time series as measured by the Kolmogorov-Smirnov statistic, *D*. Similarity of linear trends in observed and simulated series is measured by the difference in trend slopes.

Relative model weightings for each season as well as for the entire calendar year were derived for all stations by comparing the 20th century observed precipitation and simulated precipitation. For assessment of 20th century climate, data were considered at a monthly resolution for the period January 1901 - December 1999 (where available). Similarly, model predictions for the 21st century were considered at a monthly resolution for the period January 2001 - December 2099. Obtained model weightings were then used to produce predicted distributions of precipitation in the 21st century.

The analysis was performed by weighting the predictions of the 24 GCMs in two ways: 1) according to their relative abilities to reproduce the mean and variability of the observed precipitation in each season, and 2) according to their relative abilities to reproduce the observed trend in late 20th century precipitation.

The analysis suggested the following key findings:

- JJA precipitation may decrease by around 25% over the course of the 21st century.
- MAM and SON precipitation may also decrease slightly (less than 10%) by the end of the 21st century.
- DJF precipitation is less certain, since some “good” models suggest it will increase and some “good” models suggest that it will decrease. Furthermore, the results vary between meteorological stations.

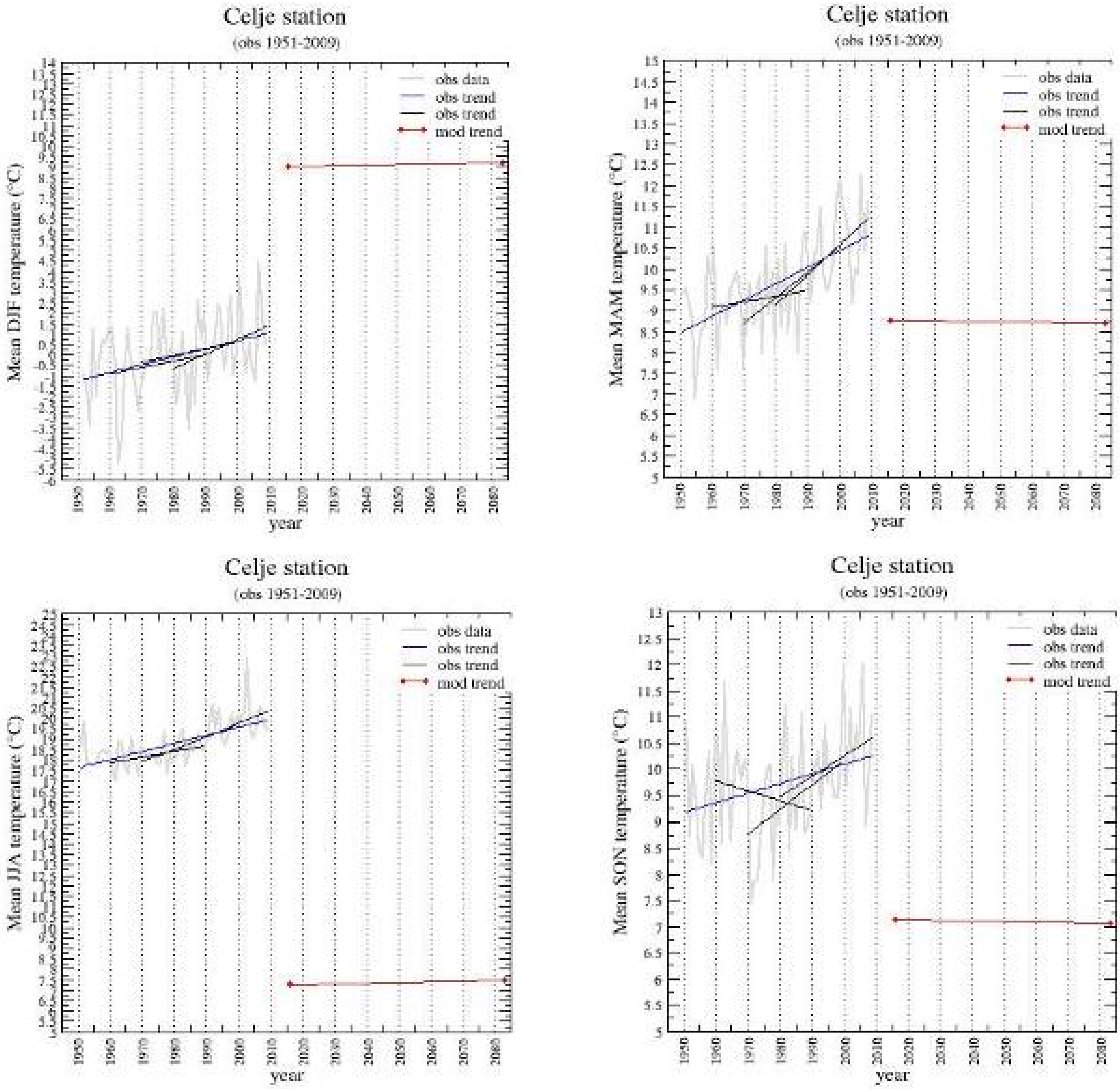
In addition to CDFs derived for precipitation, results for CDFs of temperature and evapotranspiration were also provided in digital form, but not analyzed in detail. The analysis provided assessments for seasonal averages and not for the finer time scale needed for hydrologic modeling (e.g. 10-day or monthly mean values).

4.2 Evaluation of PDF methodology

Review of the results was undertaken to compare characteristics of probability distributions and trends for climate variables for two future periods in the 21st century to observations in the 20th century (Vujadinovic 2013).

The evaluation found that future precipitation data show a change consistent with those found in other climate change studies, while changes in temperature and evapotranspiration are completely out of the climate variability range observed during the 20th century. An example for temperatures at the Celje meteorological station is shown in Figure 4-1. In the figure, mean temperature for both future periods (red dots) are out of the observed range (grey lines) for all seasons except MAM. Furthermore, seasonal variability is considerably disturbed and its amplitude flattened. Mean temperature for both future periods at the Celie range between 7 and 9 °C in all four seasons, while mean temperature in winter is higher than summer. This could be the consequence of the fact that in modeling CDFs weighting factors were created based on the fit of observed and modelled precipitation datasets, and the same weighting factors were applied to the temperature and evapotranspiration datasets.

The conclusion is that the two future precipitation scenarios are in agreement with findings of other climate change studies in the same region. The largest change is expected to occur at higher altitudes, especially during the winter, where snowfall could be reduced by up to 12% up until the end of the 21st century, in comparison with the period 1971-2000. In the summer season, the entire basin could suffer from a precipitation decrease by up to 40% by the end of the 21st century. Unfortunately, temperature and evapotranspiration predictions were found not useful.



Note: Observed seasonal mean temperature (grey), observed trends for the different periods (blue and black) and modelled trend for 2016-2083 for the Celje station (red), for different seasons.

Figure 4-1: Verification of climate scenarios

4.3 Regional Climate Model Analysis

Following on from the PDF evaluation work on the future climate scenarios assessed using the regional climate model (RCM) approach was undertaken. Future climate scenarios for the SRB have been developed for two 30-years periods, 2011-2040 and 2041-2070 (Vujadinović and Vuković, 2013). Daily meteorological observations of temperature and precipitation collected during the Project have been used for the statistical bias correction of the results of five RCMs. The obtained results were verified on a seasonal and monthly level for the reference period 1961-1990 and the same bias correction was applied for the two future periods. The results for the future climate are analyzed on a seasonal and annual level.

4.3.1 Observed Data

Meteorological datasets contain daily precipitation and temperature measurements during the 20th century and the first decade of the 21st century. The length of the time series depends on the availability of the measurement records at each station. Some of the chosen stations had a lot of missing values during the reference period 1961-1990. All the datasets were interpolated using a three-dimensional non-hydrostatic meso-scale model. For the purpose of developing climate scenarios, stations chosen are those that are used as an input to the hydrological model of the Sava River, which comprised 36 stations for temperature and 59 stations for precipitation. Figure 4-2 presents the station locations within the SRB for temperature and precipitation.

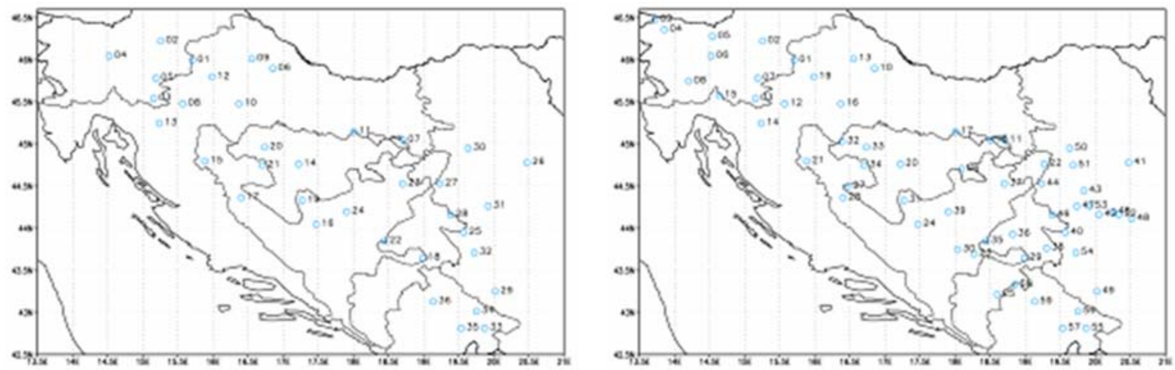


Figure 4-2: Temperature stations (left) and precipitation stations (right) in the Sava River Basin used for development of future climate scenarios as an input to the hydrologic model

4.3.2 Climate Predictions

A number of climate simulations over the European region are available as a result of the ENSEMBLES project.[26] All simulations were undertaken with RCMs as a dynamical downscaling tool from different GCM simulations, under the A1B SRES/IPCC scenario. Time frame of the integrations was 1950-2050 or 1950-2100. Horizontal resolution was about 50 km or 25 km, depending on the setup of a single RCM.

In total, there are 26 climate integrations among which five have coarser horizontal resolution (about 50 km), and six cover a shorter period (1950-2050). Additionally, six simulations represent a sensitivity test for two GCMs, and therefore were not appropriate for this application. From the remaining nine GCM/RCM combinations five were selected, in order to create a small multi-model ensemble and thus account for the uncertainties due to GCMs and RCMs.

Firstly, the intention was to choose simulations in a way that the ensemble consists of at least two simulations with the same GCM and different RCMs and two simulations with the same RCM and different GCMs. In this way the uncertainties coming from the choice of GCMs and those from the choice of RCMs could be assessed. Unfortunately, among the remaining nine simulations it was not possible to have one RCM driven by two different GCMs. Therefore, two of the most commonly used GCMs in climate change studies that are used over Europe, namely, ECHAM and HadCM were selected. The final choice of RCMs attached to the two selected GCMs was undertaken by the evaluation of their performance of ERA-40 re-analysis downscaling, which was also available within the ENSEMBLES project.

The final list of five chosen GCM/RCM combinations is given in Table 4-2. Daily fields of precipitation and mean temperature for the three chosen periods from each of five simulations have been downloaded. For each station, daily time series were assembled from the RCM grid point output closest to the station.

Table 4-2: The list of chosen GCM/RCM models from the ENSEMBLES project.

Climate model No.	Institution	GCM	RCM
CM1	KNMI	ECHAM5r3	RACMO
CM2	MPI	ECHAM5r3	REMO
CM3	ETHZ	HadCM3Q0	CLM

[26] ENSEMBLES was a five-year climate change research project involving 66 partners from across Europe. Led by the UK Met Office, and funded by the European Commission, it has been studying the likely effects of climate change across Europe as a whole

Climate model No.	Institution	GCM	RCM
CM4	METO	HadCM3Q0	HadRM3Q0
CM5	ICTP	ECHAM5r3	RegCM3

4.3.3 Bias Correction of Climate Model Output

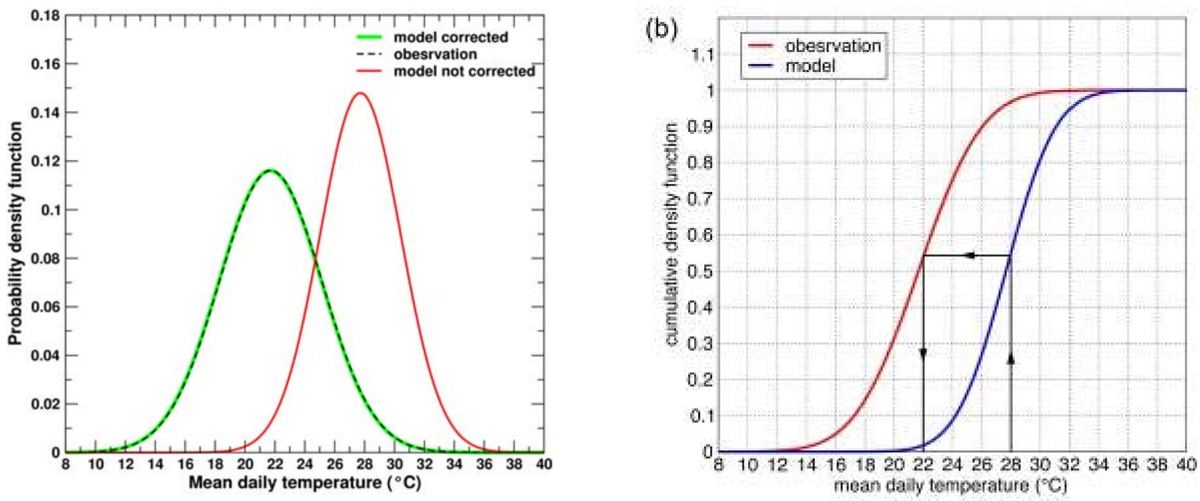
A commonly used measure for assessment of a model's ability to reproduce present climate is the bias, defined as the difference between the modelled and observed mean value of a variable for a reference period in the past. If a significant bias is found, the model results should be statistically corrected and the new dataset compared once more to the observations, in order to evaluate the success of the correction method.

A comparison of the mean seasonal and annual values at each station to the observed values for the reference period 1961-1990 showed a different behavior for each model. Models 1 and 2 mainly have a temperature bias of the same sign for all seasons at each station and it is in the range of -3 to +3 °C. Models 3 and 4 mainly have a large positive bias during summer and a negative bias during winter and autumn, which is greater than ±5 °C at some stations. Model 5 gives a colder climate than observations for all seasons, except for the winter when it is warmer than measurements on most of the stations.

Precipitation bias is mainly negative for all seasons for the models 1, 2 and 3. Models 1 and 3 have the largest bias during the summer, between -70 and -50 % for most stations. Model 2 has a similar value of bias for all seasons. Model 4 mainly gives smaller precipitation amounts during the summer and larger than observed during the winter and spring. Model 5 shows mainly a negative bias for all seasons at stations in the upper and middle part of the SRB, while downstream stations have smaller negative summer bias and positive spring and winter bias.

The comparison of the model results and observations showed a significant bias both in temperature and precipitation. Its size and sign vary across models, seasons and stations. Therefore, a further statistical correction was necessary before using these datasets in the climate impact study.

The statistical bias correction method used in this report is often referred to as "quantile mapping". It implies developing CDFs for daily observed and modelled variable for each station during the reference period. After this step, a corrective function is made which transfers modelled values to corrected (observed) ones for a given value of CDF (Figure 4-3). Once the correction function is determined, it is applied to the appropriate modelled daily datasets for the referent and future periods. The final product of this procedure is the daily time-series of corrected variables, for each station and all time periods (past and future). The corrected time-series for the reference period have probability distribution properties similar to the observed one. The bias correction function is calculated for each month, using daily data. This procedure is done for each variable and for each station.



(a)

Notes: (a) = Observed (black dashed line), modelled (red) and corrected (green) PDFs of daily temperature; (b) =observed (red) and model (blue) CDFs. Black arrows show the process of fitting the modelled CDF to the observed one.

Figure 4-3: Explanation of the bias correction procedure

4.3.4 Verification of the Bias Corrected Time Series for Past Climate

The verification of the bias-corrected values is done for the reference period 1961-1990, for each station and all models. Statistically corrected temperature datasets for all models showed an excellent match to the observations. For all seasons, models and stations, the temperature bias of corrected data is less than ±0.06 °C, i.e. smaller than a measurement error. The same conclusion is valid for the monthly verification of mean daily temperature and its standard deviation. For all models, stations and months, the differences and standard deviations are almost identical to the observed values. Therefore, the statistical correction of the temperature datasets can be considered very successful.

The issue of the precipitation bias is more complex, since its value varies remarkably across the models, stations and seasons, with values as high as 80 %. Due to the different dynamics of the models and local characteristics over the basin, finding a unique procedure for the statistical correction of the precipitation dataset was a demanding task. At the end, a procedure that gave the overall smallest bias across all stations, models and seasons was adopted.

The mean precipitation bias is mainly smaller than ±3 % for all seasons and models. For model 1, there are four stations with a summer bias between -5 and -6 %, model 3 has one station with spring bias about 5 %, while model 5 has two stations with a winter bias and one station with all biases except for summer of about 4 %. Overall, this is considered a very good result. Daily precipitation difference averaged over all stations is smaller than 0.1 mm, which is a measurement error. The absolutely highest precipitation differences of about 0.4 mm are found at stations with the highest seasonal bias for models 3 and 4. Standard deviation ratio averaged across all stations is between 0.98 and 1.1 except for two summer months in model 3, when it is 1.2. For all models, the highest individual value for this ratio is noted in the summer months and it is a consequence of a generally smaller number of dry days simulated by models during the summer.

4.4 Conclusions on Future Climate Tendencies

Upon evaluating the results of two methodologies applied to obtain future climate scenarios, the Regional Climate Model Analysis was adopted for further use. This section provides conclusions related to the outputs of this methodology.

For future periods, 2011-2040 and 2041-2070, all five climate models showed a temperature increase at all stations and for all seasons. In the period 2011-2040 the increase is from 0.7 to 2.5°C. Model 3 and 4 show the largest warming during the winter, except for the most southerly stations, where summer temperature increase was the highest. Models 2 and 5 show the highest increase during the autumn, while model 1 simulates the greatest change in summer months in the upstream part of the basin.

In the period 2041-2070, the projected temperature increase is more pronounced and it is between 1.8 and 5°C. Models 1, 2 and 5 simulate the highest increase during the winter season, while the other two models have the largest warming during the summer months, especially in the most southern stations.

Unlike temperature, projected precipitation change differs from model to model. For the period 2011-2040, models 1, 2 and 3 show a similar tendency of precipitation change, with an increase during the winter and a decrease during the spring and summer. However, the size of the change and its spatial distribution differs among the models. Model 4 simulates an increase of winter precipitation in the upstream part of the basin, while in the middle and downstream part this increase is shifted to the autumn months. During the summer, this model also predicts a precipitation decrease for all stations. Model 5 differs most from the other models. It generally predicts the smallest change, but is generally positive (a precipitation increase) in all seasons, with an exception for the upstream stations, where it shows a decrease during the spring and winter, and a few stations across the basin that show a negative summer change.

For the period 2041-2070, the first four models generally show the same tendency – precipitation increase during winter and, at some stations, during autumn, and the decrease during the summer months. Model 5 has slightly different results showing a general summer precipitation deficit at many stations, whilst some stations in the upstream part of the basin show a precipitation increase during the summer months. In these areas, a winter decrease is more pronounced than at the rest of the stations, while for the majority of the stations, a spring or autumn increase on precipitation is more dominant than the winter.

So to conclude, the climate simulations using several models provide an insight into a range of possible future changes of precipitation and temperature. Figure 4-4 and Figure 4-5 present median annual values of the temperature and precipitation changes from the ensemble of five models. Figure 4-6 and Figure 4-7 provide some examples of the mean annual temperature and annual precipitation time series as predicted by the five climate models at selected locations in the basin that could serve to indicate general tendencies and uncertainty in the expected climate. A general conclusion is that all models simulate a temperature increase across the SRB, with larger values for the period 2041-2070. Precipitation change is more complex, but in general shows an increase during the winter and a decrease for the summer months. Summer precipitation deficit is more pronounced in 2041-2070 period.

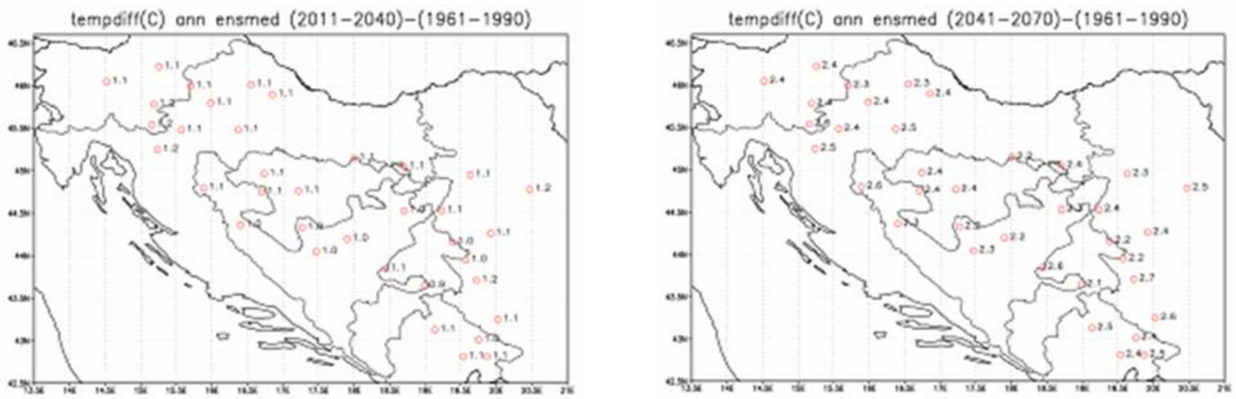


Figure 4-4: Median annual temperature change (in º C) for 2011-2040 (left) and for 2041-2070 (right) relative to the reference period 1961-1990

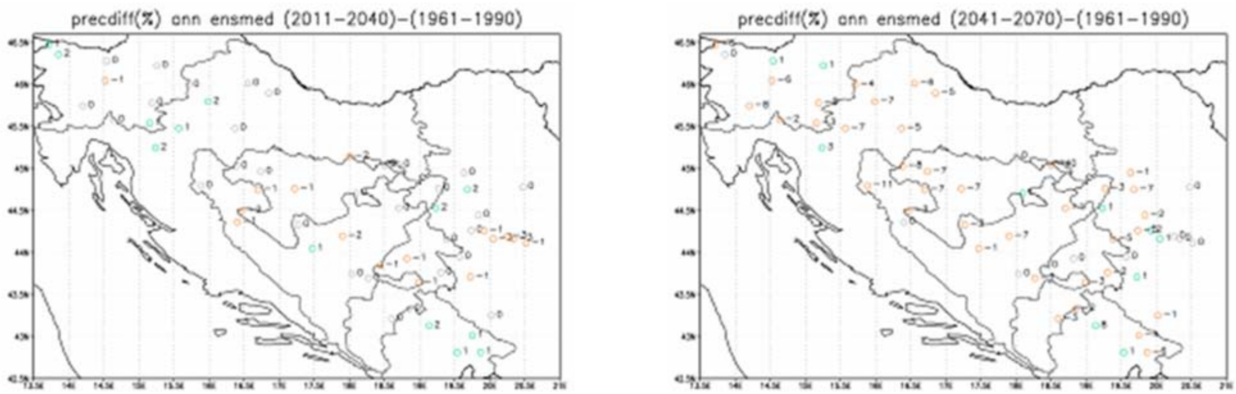


Figure 4-5: Median annual precipitation change (in %) for 2011-2040 (left) and for 2041-2070 (right) relative to the reference period 1961-1990

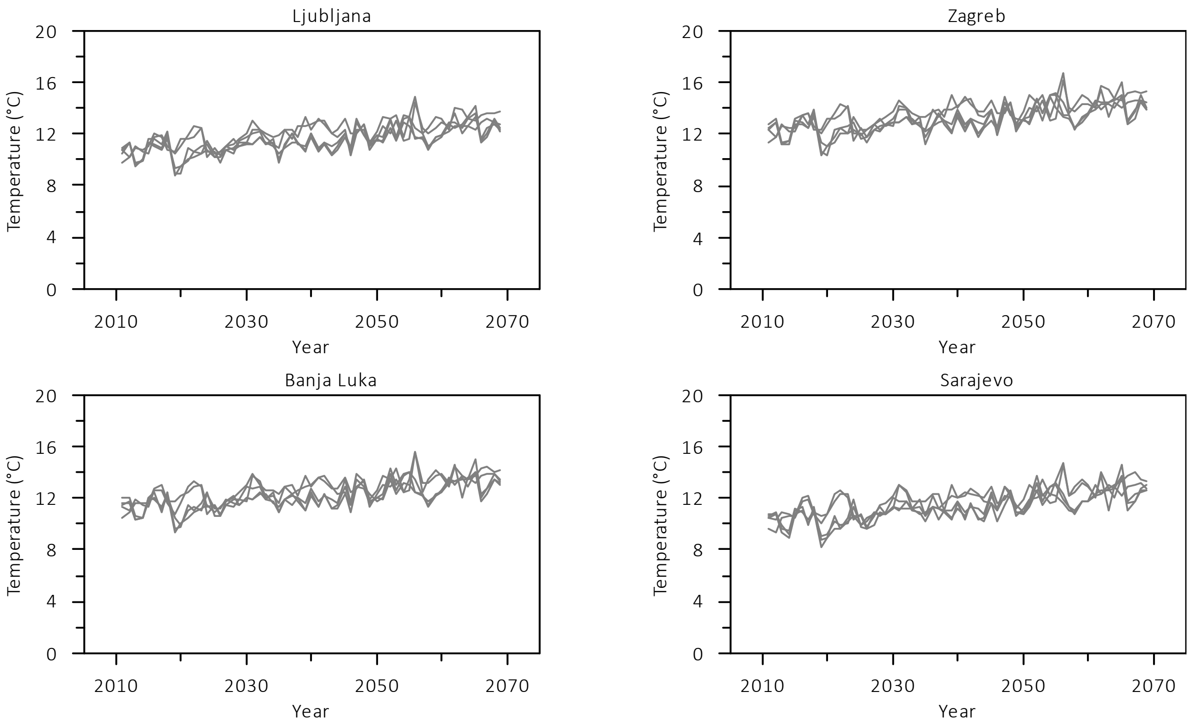


Figure 4-6: Mean annual temperature as predicted by the ensemble of five climate models for selected locations in the Sava River basin.

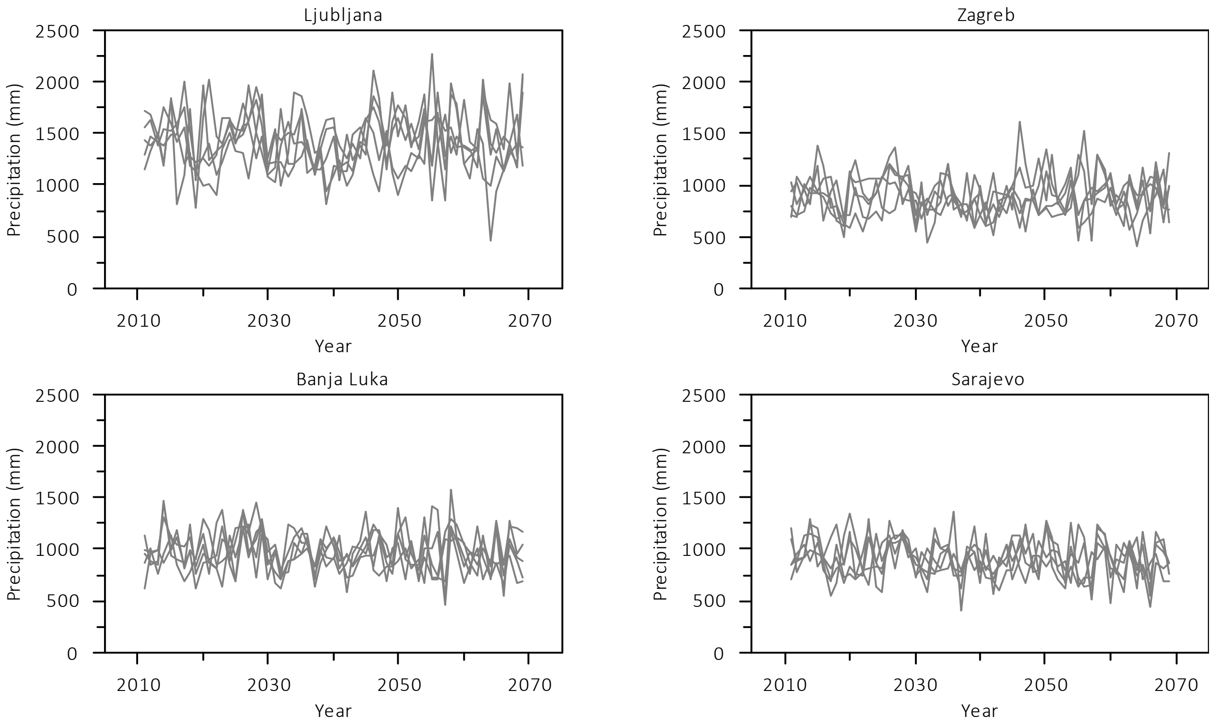


Figure 4-7: Annual precipitation as predicted by the ensemble of five climate models for selected locations in the Sava River basin.

The historical trends in temperatures described in Chapter 3 agree with the future temperatures as predicted by GCM outputs only in trend direction (rising temperatures), but the two approaches quantify this increase differently. Precipitation tendencies as given by trends and by GCM outputs do not correlate highly, but the spatial patterns of these tendencies across the basin are so variable both from trends and from GCMs so that this indicates that a very high uncertainty in future precipitation exists.

5 Hydrologic Modeling of the Sava River Basin

Development of a hydrologic model that should be used to assess the hydrologic response of the SRB to future precipitation and temperatures is one of the key steps in establishing the WATCAP for this basin. A hydrologic model of the whole SRB has never been developed before. The most noteworthy modeling efforts have been made for Slovenian part of the Sava Basin (e.g. Kobold and Brilly, 2006; Primožič et al, 2008), but the primary purpose of these models was flood forecasting. Recently, a rainfall-runoff model for the Vrbas basin was developed (COWI, 2012). In Serbia, a model of the Kolubara River basin has been developed by the Republic Hydro-meteorological Service of Serbia (Haddeland et al, 2013).

This chapter briefly presents development of the hydrologic model for the SRB for the purpose of estimating climate change impacts. Model calibration for proper simulation of the basin and verification against independent historic data set are described. The results of the simulations with future climate scenarios and the characterization of future hydrologic regime in the SRB are the subject of Chapter 6. A more detailed description of the model development and the simulation results is presented in the separate report which is provided as an Annex 1 to this report.

5.1 Model Used

The decision to use the Hydrologic Engineering Centre - Hydrologic Modeling System (HEC-HMS) (USACE, 2010) for development of the hydrologic model of the Sava basin has been made in agreement with ISRBC for two reasons. First, a preliminary HEC-HMS model for the Sava basin had been developed and initially calibrated by US Army Corps of Engineers (USACE) in course of development of the unsteady hydraulic model of the Sava River. Second, a HEC-HMS model can easily be disseminated to the relevant users in the riparian countries since the HMS software is obtainable free of charge. HEC-HMS has low data requirements, which is an advantage in the case of general poor data availability in the SRB.

HEC-HMS models runoff in five steps: it calculates interception, surface detention, infiltration, direct runoff, and baseflow. For a basin divided into sub-basins, routing the outflow hydrograph from a sub-basin toward downstream nodes of the river network is also necessary. Different methods can be applied in each step, but not all the methods are applicable for continuous simulation.

In the case of the SRB, daily computational time step was initially chosen for modeling since this is the longest possible time step in HEC-HMS. However, a 12-hour time step was later adopted to resolve the issues related to daily precipitation data representation (measured from 7 am one day to 7 am next day, in contrast to flow and temperature measurements that are averaged over a 0-24 hour period) and to enable more realistic hydrologic routing on smaller sub-basins.

Basin subdivision was made with respect to daily time step of input data (sub-basin sizes approximately from 2000 to 5000 km^2) and to data availability and quality (i.e. reliable measurements, no gaps). Priority was generally given to stations recommended by riparian experts, but the final subdivision was made in accordance with available hydrologic and meteorological data.[27]

5.2 Data Collection

The principal input data for the model are: daily precipitation, daily air temperatures, and monthly potential evapotranspiration. In addition to the meteorological input, hydrologic data (daily flows) are needed for calibration and verification purposes.

[27] During the WATCAP project five experts were hired by the World Bank on separate contracts to provide their expertise and also to provide much needed data that would be required for the model development. Experts were from Slovenia, Croatia, Bosnia and Herzegovina (both RS and FBiH) and Serbia.

Data for the Sava hydrologic model were collected from several sources. Part of the required hydro-meteorological data was available from previous work on trend analysis (see Chapter 3) at 33 meteorological and 38 hydrologic stations over the SRB. Additional data were provided by five experts from riparian countries. Data from Montenegro needed for modeling of the Drina River Basin were obtained by courtesy of the Hydro-meteorological service of Montenegro via ISRBC. A small amount of data for the Vrbas River basin was also used from the Vrbas Study project (COWI, 2012). The detailed specification of collected data is presented in the separate report provided as an Annex 1 to this report.

5.3 Selection of the Calibration and Verification Periods

Poor data availability in the Sava Basin after 1990 suggested that the calibration and verification periods should be selected prior to this year, i.e. from the standard climatological period 1961-1990. A preliminary analysis of the hydrologic regimes at 63 hydrologic stations has indicated two 5-year periods in which the hydrologic regime could be considered representative for the whole 1961-1990 period. Hence the final choice of the calibration and verification periods was as follows:

- Calibration: 5 hydrologic years from October 1979 to September 1984;
- Verification: 5 hydrologic years from October 1969 to September 1974.

5.4 Record Extension

Some of the stations selected for model development (29 precipitation stations and 13 temperature stations) had gaps and therefore the records needed extension in order to facilitate simulations for the complete 1961-1990 timeframe. Filling in the missing observations and extension of short records was based on application of a regional climate model, calibrated and validated using observed data from 59 precipitation stations and 36 temperature stations. The verification has shown that the record reconstruction produced satisfactory results, except for some underestimation of precipitation at stations in the Montenegrin part of the Drina River basin. This is because the applied model could not perform well in the mountainous region such as the upper Drina basin without proper boundary conditions. However, subsequent hydrologic simulations proved that this uncertainty did not affect the modeling process significantly.

5.5 Model Structure

For modeling purposes, the complete Sava River basin was divided into sub-basins. Two levels of division are made. On the first level, 14 major sub-basins shown in Figure 5-1 are defined. The odd-numbered sub-basins represent the upper Sava in Slovenia and major tributaries (Kupa, Una, Vrbas, Bosna, Drina, Kolubara rivers), and even-numbered are the sub-basins along the Sava valley between the major tributaries. In further subdivision of major sub-basins, the total number of sub-basins amounted to 44, whilst 35 hydrologic stations were used for calibration and verification.

Figure 5-1: Major sub-basins for the Sava hydrologic model; the second-level division is shown with grey lines)

A HEC-HMS project consists of basin models, meteorological models and control specifications. A basin model serves to define elements of the basin (such as sub-basins, reaches and junctions), and runoff computation method for each element. A meteorological model is used to define methods for calculation of basin precipitation, snow melt and potential evapotranspiration. Control specifications are used to define the time window for computation. To perform a simulation run, these three components need to be specified.

The Sava Basin hydrologic model is built with 14 separate basin models in HEC-HMS representing major sub-basins. The model is implemented in this manner to allow application of different meteorological models to each basin. This is particularly important for the snowmelt and evapotranspiration representation. If the whole Sava Basin had been described with one basin model in HEC-HMS, only one set of snowmelt parameters and one set of potential evapotranspiration data could have been used. The major basins are modelled separately and linked sequentially for joint simulations using the source elements in the even-numbered basins. A source element is used to represent boundary conditions to the basin model.

The model uses a total of 48 precipitation stations and 26 temperature stations. The modeling methods for describing hydrologic and meteorological processes in HEC-HMS are discussed in Annex 1 in detail.

5.6 Model Performance

Evaluation of model performance was made for the calibration and verification periods 1979-1984 and 1969-1974, and an additional verification was conducted for model simulations with the extended input data records in the 1961-1990 period. The evaluation was based on comparing the observed and simulated daily and monthly flows at 30 hydrologic stations. A complete historical stream flow record for 1961-1990 was available for 19 stations, but the remaining 11 stations were not excluded since their records are longer than 20 years.

Extensive overview of the model performance is given in Annex 1. Examples of the results at three selected stations along the Sava River (Zagreb, Slavonski Brod and Sremska Mitrovica) are shown in Figure 5-2. The graphs show simulated vs. observed mean monthly flows for fiver water years during the calibration period. Simulated vs. observed seasonal distribution of flows at selected stations is shown in Figure 5-3.

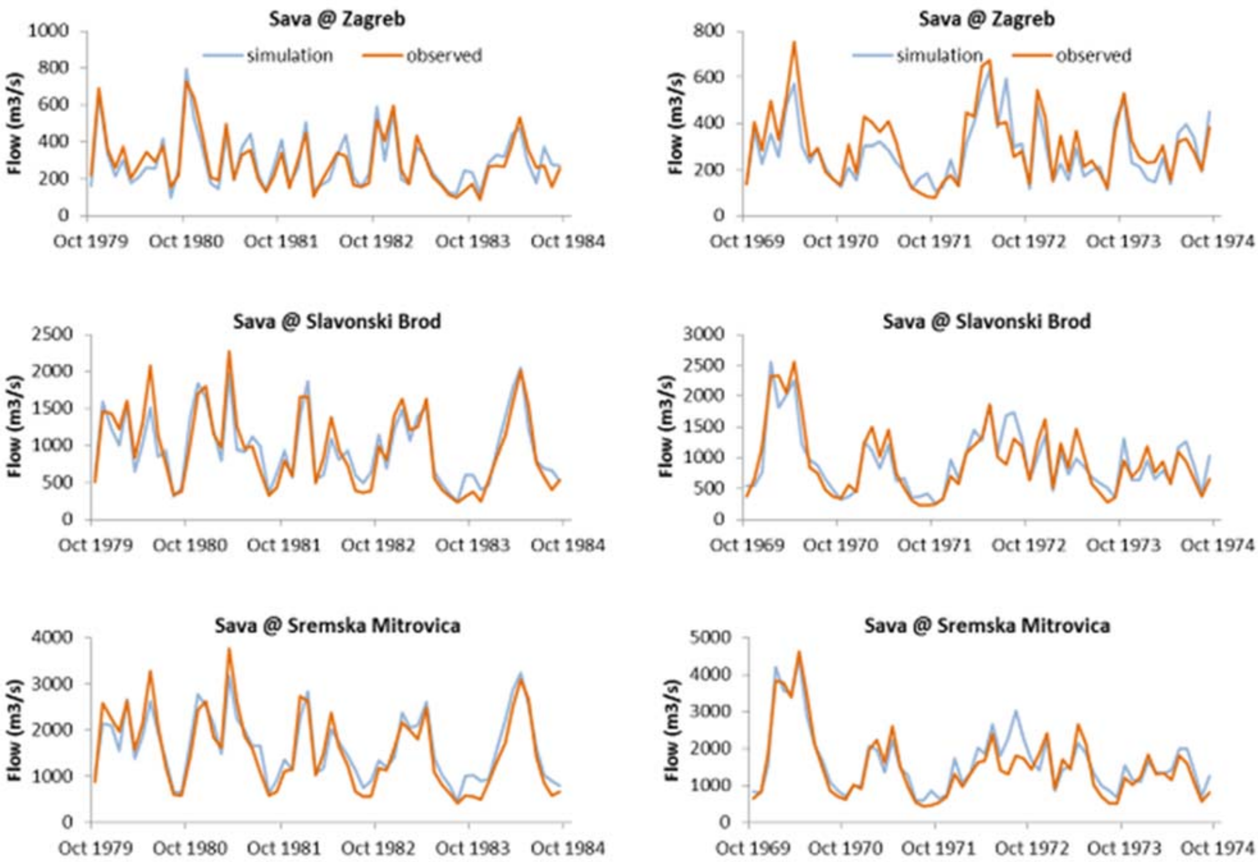


Figure 5-2: Results for the Sava hydrologic model at selected stations: calibration (left) and verification (right) periods.

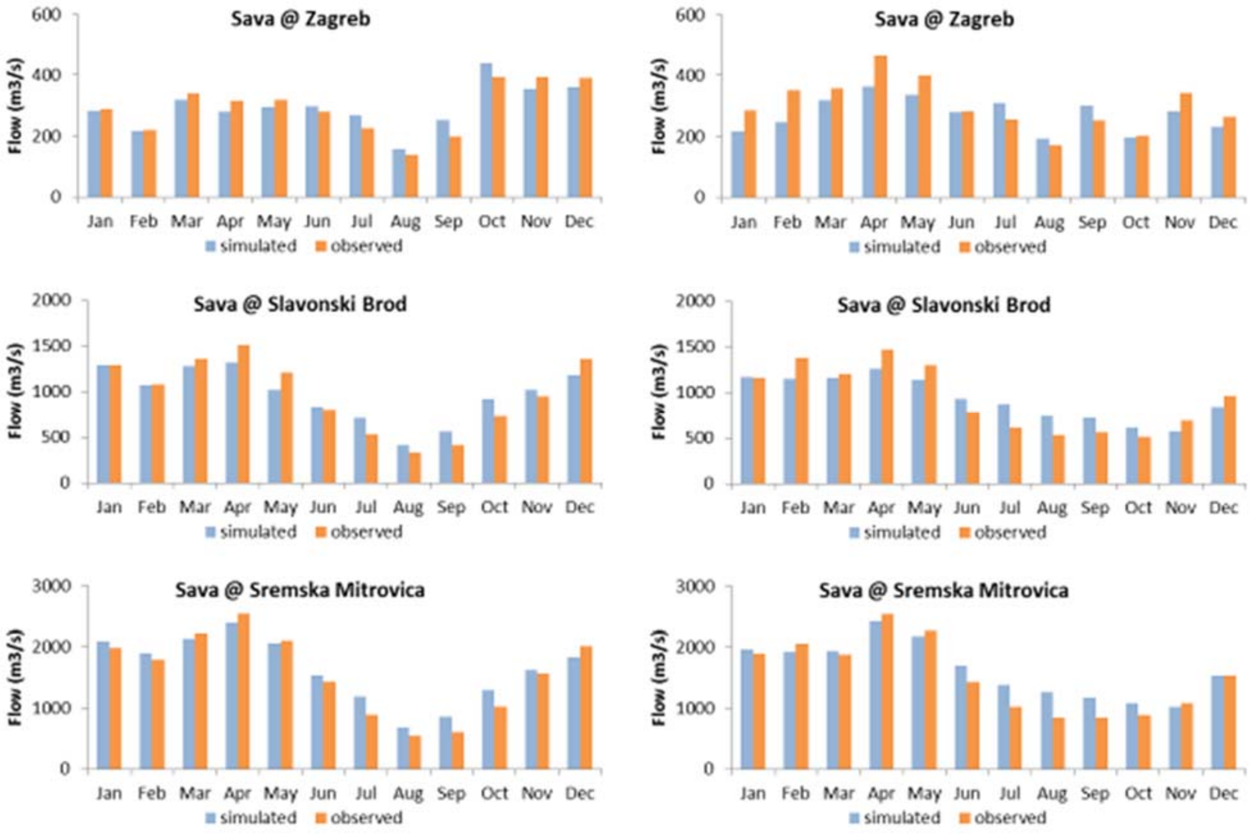


Figure 5-3: Simulated vs. observed seasonal runoff distribution at selected hydrologic stations for calibration (left) and verification (right) periods

Criteria for evaluating model performance were selected having in mind the project goals. For a model intended to perform long-term simulations of present and future hydrologic regime, the goal is to predict the long-term mean flows on a monthly and annual scale with reasonable accuracy. Therefore, the following measures were used to assess performance of the Sava Basin model:

- Percentage error or bias in long-term mean annual flow (PBIAS),
- Nash-Sutcliffe efficiency coefficient (NSE) for monthly flows, and
- Mean absolute percentage error in long-term mean monthly flows (MAPE).

Although there are no generally accepted criteria for model evaluation in terms of the accuracy of simulated flow compared to measured data, the performance ratings for PBIAS and NSE given by Moriasi et al. (2007) are used here. In general, a model simulation can be judged as satisfactory if NSE > 0.50 and if PBIAS < ±25%; performance is very good if NSE > 0.75 and PBIAS < ±10%; for intermediate values of NSE and PBIAS, the performance is rated as good.

The percentage error in mean flows (PBIAS) is shown in Figure 5-4. This error is quite small in the calibration period; in the verification period it can be larger, but only 5 stations are rated as “satisfactory” while the majority is rated as “very good” and “good”. The underestimation at the Slovenian stations is due to the use of the constant monthly baseflow method, i.e. the constant values of baseflow for each of January, February, etc. that can be unrepresentative in some years. This method proved to be superior to the recession method for Slovenian stations, and was kept for further simulations. Stations on the Bosna River and Delibašino Selo on the Vrbas River exhibit significant overestimation in the verification period, but this overestimation is not conveyed downstream in any significant amount. One of the reasons for this overestimation in the Bosna River basin could be that available precipitation data is either not representative for the basin in question or is subject to errors. For Delibašino Selo on the Vrbas River it could be assumed that there is either a strong influence of the Bočac reservoir or a problem with hydrologic measurements.

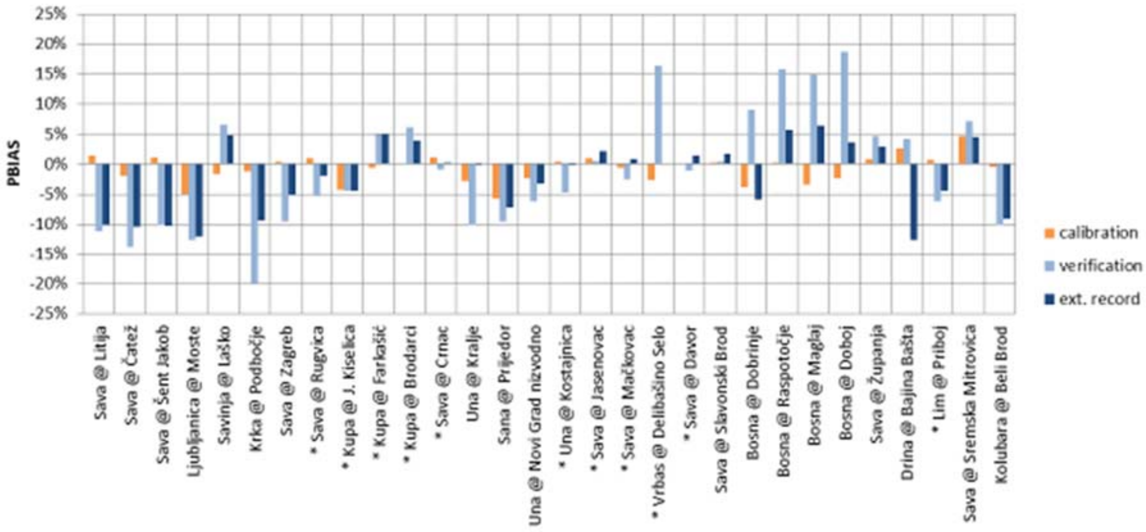


Figure 5-4: Percentage error in mean flows (PBIAS) for calibration, verification and simulation with the extended record 1961-1990 (denotes stations with incomplete stream flow record during 1961-1990)*

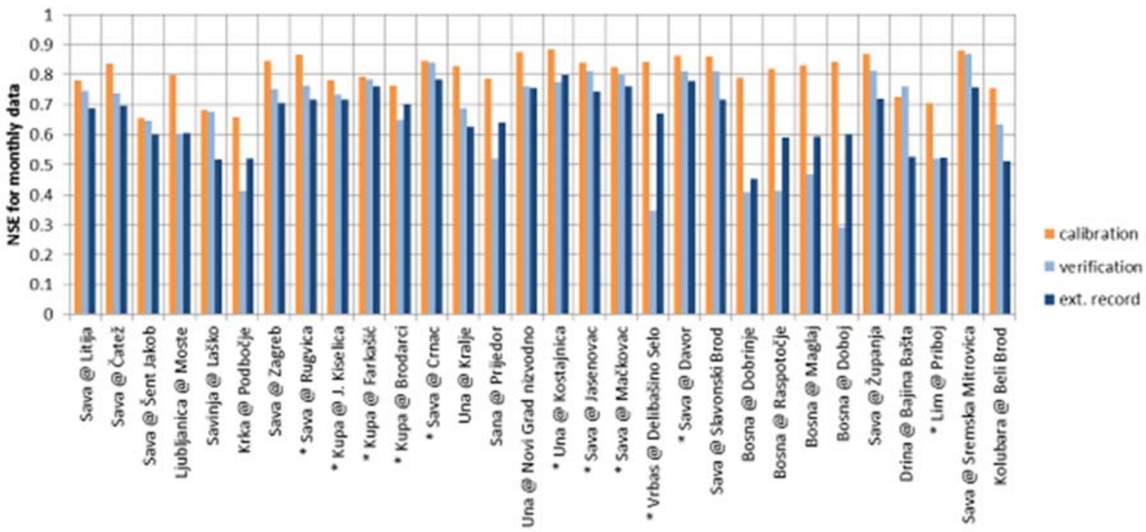


Figure 5-5: Nash-Sutcliffe model efficiency (NSE) coefficient for monthly flows for calibration, verification and simulation with the extended record 1961-1990 (denotes stations with incomplete stream flow record during 1961-1990)*

The Nash-Sutcliffe efficiency (NSE) coefficients for monthly flow series are shown in Figure 5-5. Values of about 0.8 that are achieved here in calibration for monthly values at majority of stations are considered “very good” according to the previously mentioned criteria. Results for the verification period generally give slightly lower NSE than for calibration, except again at stations on the Bosna River, the Delibašino Selo on the Vrbas River and the Podbočje station on the Krka River. It should be noted that the hydrologic regime of the latter station is under heavy influence of karst in the catchment.

The mean absolute percentage error (MAPE) in long-term mean monthly flows, used to evaluate differences in the simulated long-term mean seasonal flow distribution compared to the observed one, is shown in Figure 5-6. In the calibration period this measure ranges from 8% to 16%, with two exceptions for the Podbočje station on the Krka River and the Beli Brod station on the Kolubara River. The possible reasons for unsatisfactory model performance for the Krka at Podbočje have already been mentioned. On the other hand, the Kolubara basin is very heterogeneous in terms of relief and geological structure. There is also karst present in some of its sub-basins, but the major obstacle to better modeling results seems to be unreliable precipitation data, especially during winter. The values of MAPE are somewhat higher in the verification period, where again the worst results are attributed to the Bosna River basin and the Delibašino Selo station on the Vrbas River. Since there are no recommended limits to assign ratings to the values of MAPE, based on the results from the calibration period and visual inspection of seasonal distributions, it could be assumed that the MAPEs below 10% or 15% could be characterized as an acceptable model performance.

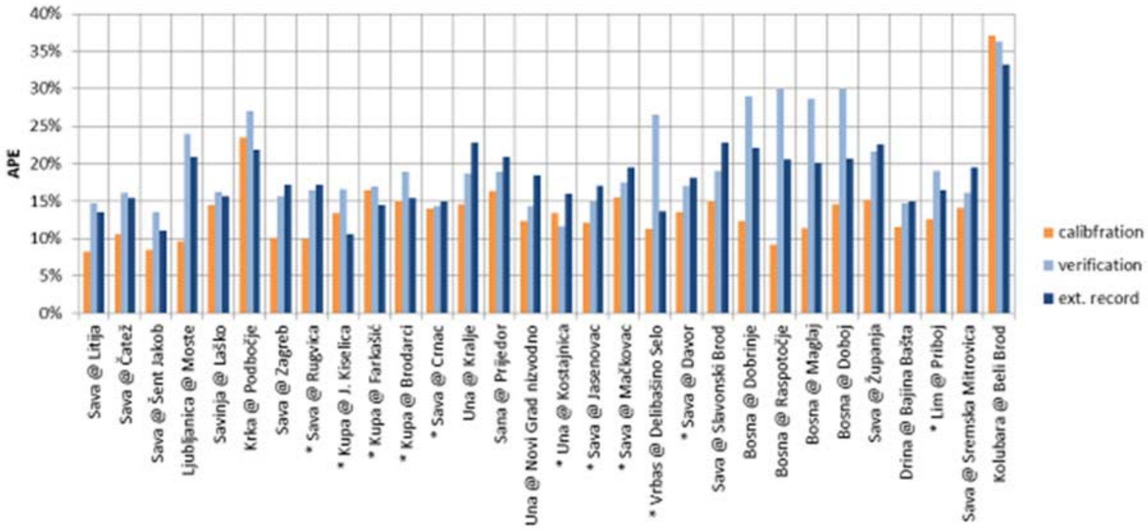


Figure 5-6: Mean absolute percentage error (MAPE) in long-term monthly flows for calibration, verification and simulation with the extended record 1961-1990 (denotes stations with incomplete stream flow record during 1961-1990)*

The three measures of model performance with the extended record 1961-1990 are given in Figure 5-4, Figure 5-5, and Figure 5-6 along with the corresponding values for the calibration and verification periods. The error in the long-term water balance as reflected by PBIAS is generally smaller for the whole 1961-1990 period than in the verification period 1969-1974. The bias remains relatively large at Slovenian stations, which exhibit underestimation of about 10%. It is interesting to note that the large bias from the verification period at stations Krka at Podbočje, Vrbas at Delibašino Selo and the stations on the Bosna River has decreased to more acceptable values with the extended simulation period. The only exception is the Bajina Bašta station on the Drina River which exhibits greater underestimation in this overall period than in the calibration and verification periods. This is a consequence of underestimated precipitation in the Montenegrin part of the Drina River basin after the record extension.

The results obtained from the modeling of the SRB have led to the conclusion that the model can reproduce month-to-month or year-to-year runoff variations reasonably well at most hydrologic stations. Poorer results are related to locations where a doubt exists about validity of measurements and/or good representation of precipitation over the sub-basin, or where complex geological structure that includes karst would require more complex runoff estimation methods.

6 Implications of Modeling Results

6.1 Characterization of Future Hydrologic Regime on the Basin

Runoff simulations using the hydrologic models with the baseline and future climate scenarios provide the means to estimate the impact of climate change on the hydrologic regime. The results therefore offer an insight into the range of potential consequences of climate change on water resources at the basin scale. This chapter describes the results of hydrologic modeling with an aim to characterize the regimes of mean flows, low flows and flood flows of the Sava River and its tributaries.

The results of hydrologic modeling using the model described in Chapter 5 were used to characterize changes in mean flows and low flows (sections 6.1.1 and 6.1.2). A separate assessment of flood flows was made with another hydrologic model of the SRB which was is specifically calibrated for flood flows (section 6.1.3).

6.1.1 Mean Seasonal and Annual Flows

Hydrologic simulations with the baseline and future climate scenarios are used to estimate the relative change rather than the absolute runoff values.

The following indicators of the hydrologic regime are considered to assess the change in mean flows:

- mean annual runoff, defined as the long-term average flow across years in a given 30-year period,
- mean seasonal runoff, defined as the long-term average flow in four seasons across years in a given 30-year period,
- high annual flow, defined as the annual flow with 10% probability of exceedance in a given 30-year period, and
- low annual flow, defined as the annual flow with 90% probability of exceedance in a given 30-year period.

Simulations of the future hydrologic regime of the Sava River and its tributaries were performed using the hydrologic model described in Chapter 5 and future climate scenarios developed as described in section4.3. The climate scenarios consist of daily precipitation and temperature data series and of a typical seasonal distribution of monthly potential evapotranspiration (PET) as an input for each sub-basin in the model. The precipitation and temperature scenarios were developed from five global/regional climate model (GCM/RCM) simulations listed in Table 4-2. These five GCM/RCM combinations are denoted as climate models 1 through 5 (CM1 through CM5) for easier communication.

The future scenarios for PET were not available from the GCMs, and therefore they had to be defined in another way in order to enable hydrologic simulations. To achieve this with very limited data availability, an approach was adopted to assume that the change in future PET can be assessed from the change in temperature. This approach is described in detail in the separate report which is provided as Annex 1 to this report.

Although it would be reasonable to expect that changes in land use would also affect the hydrologic processes in the basin, the simulations of the future hydrologic regime were made without an assumption on these changes. Several difficulties are related to including this aspect into the analysis: (1) unavailability of land use data at various time horizons; (2) lack of information that would support establishing valid correlation of land use with the hydrologic model parameters; and (3) unavailability of any projections on land use changes in the future. However, by not introducing the land use changes, the marginal effect of the climate change can be analyzed with the model outputs.

Climate scenarios were defined for three 30-year periods:

- 1961-1990 (past or baseline climate scenario),
- 2011-2040 (near future climate scenario), and
- 2041-2070 (distant future climate scenario).

The results of the hydrologic simulations with baseline scenarios (i.e. with input from five climate models for past climate 1961-1990) were compared to the observed runoff data and the simulations with the extended precipitation and temperature record for 1961-1990 (see section 5.4) in order to perform verification of the baseline climate scenarios from climate models. Having in mind that the climate model outputs were corrected for bias with different transfer functions for each month (see section 4.3.3), mean monthly precipitation and temperatures over 1961-1990 from the climate models are in good agreement with the corresponding observed values. Consequently, a reasonable agreement is achieved between simulated and observed mean monthly flows. Since the bias correction of the output from climate models was performed using the extended precipitation and temperature record, results of the hydrologic simulations with baseline scenarios are grouped around the mean values of simulations with the extended record data rather than around the observed means (examples are shown in Figure 6-1). This indicates that the uncertainty inherent in the extended record propagates through the hydrologic model and that, in combination with the GCM/RCM uncertainties, produces variable results in the seasonal distribution of stream flows. Due to the overall uncertainty that comprises all possible sources (observed data uncertainty, uncertainty of the record extension procedure, climate modeling uncertainty and finally the hydrologic model uncertainty), it was found preferable to make the assessment of the impacts on stream flow through a comparative hydrologic simulation using baseline and scenario conditions which are both generated from a climate model.

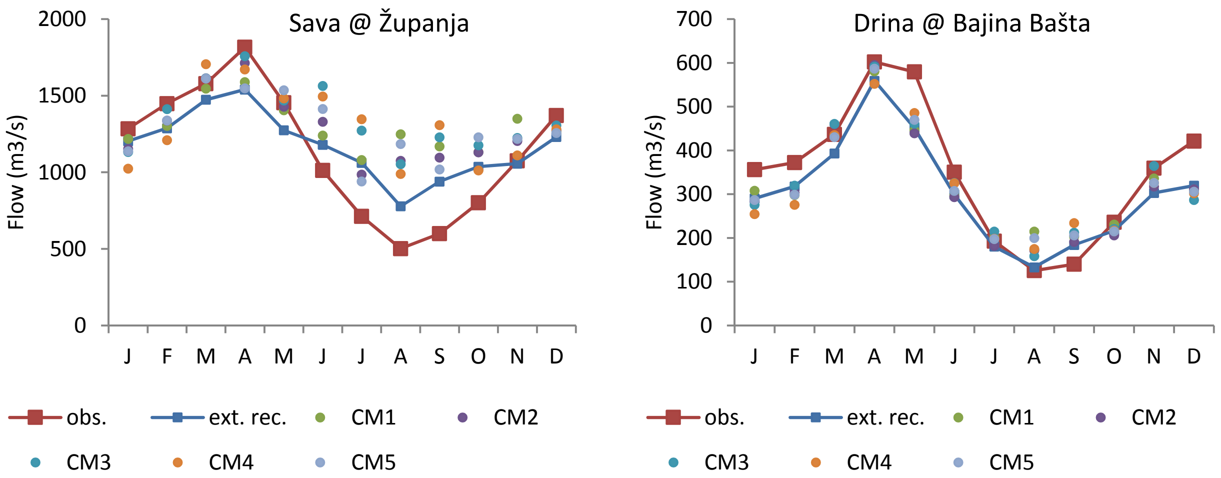


Figure 6-1: Examples of mean monthly stream flows for 1961-1990 from climate models compared to the observed flows and the flows simulated with the extended record of input data

After performing hydrologic simulations with future climate scenarios using the input (precipitation, temperature and PET) from five different climate scenarios and for two future periods, 2011-2040 and 2041-2070, the change in the mean seasonal and mean annual stream flow at all relevant locations in the Sava basin was assessed for each future time frame as the percentage change of future stream flow relative to that in the baseline period. The output from the hydrologic model for all runs has been processed into mean annual flows (ANN) and mean flows for four seasons:

- Winter: December, January and February (DJF);
- Spring: March, April and May (MAM);
- Summer: June, July and August (JJA); and
- Autumn: September, October and November (SON).

Complete results are shown in the separate report that forms Annex 1 to this report, while Table 6-1 and Figure 6-2 present a synthesis of all results showing the ensemble median change in mean seasonal and annual flows averaged over 50 locations across the Sava basin. The error bars in the graph in Figure 6-2 indicate the range of changes at the 50 locations.

Table 6-1: Change in ensemble median values of mean seasonal (DJF, MAM, JJA, SON) and annual (ANN) runoff, averaged over 50 locations in the Sava River Basin, and number of locations exhibiting increased or decreased runoff

Time frame	2011-2040					2041-2070				
Season	**DJF**	**MAM**	**JJA**	**SON**	**ANN**	**DJF**	**MAM**	**JJA**	**SON**	**ANN**
Average change	11.0%	-9.0%	-5.1%	0.4%	-1.4%	13.0%	-11.4%	-15.1%	-3.3%	-4.7%
Minimum change	0.7%	-23.1%	-17.3%	-6.7%	-5.0%	3.3%	-26.7%	-24.3%	-18.8%	-16.2%
Maximum change	22.2%	-0.6%	4.4%	13.8%	2.9%	41.9%	3.5%	-6.0%	9.9%	7.3%
No. of sites with an increase	50	0	8	26	12	50	1	0	18	10
No of sites with a decrease	0	50	42	24	38	0	49	50	32	40

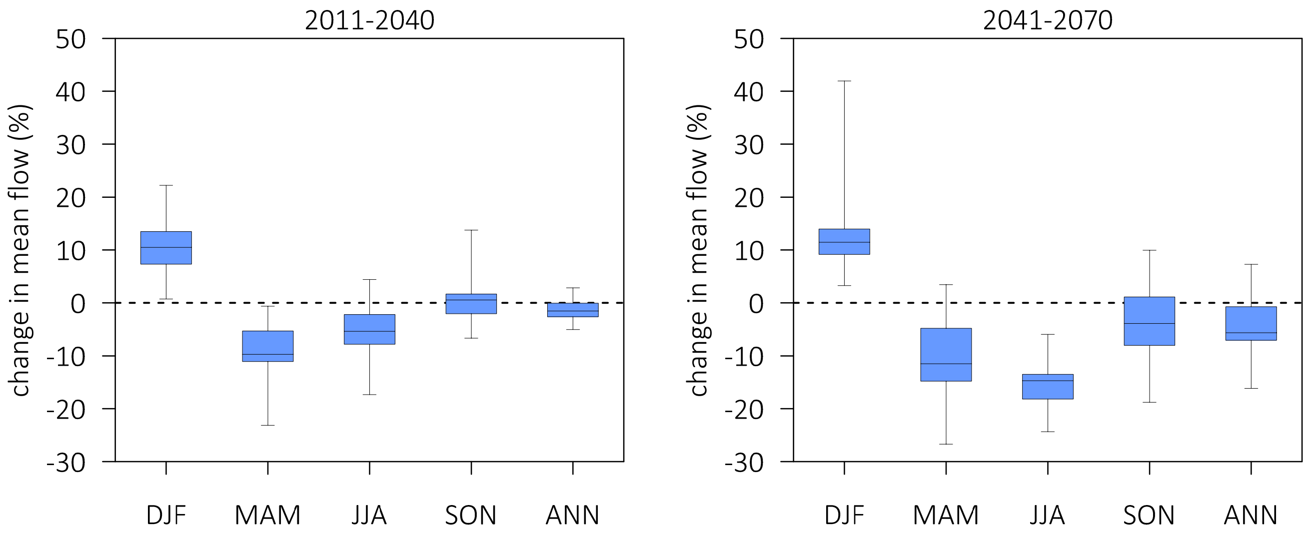


Figure 6-2: Change in ensemble median values of mean seasonal (DJF, MAM, JJA, SON) and annual (ANN) runoff; box plots indicate variation across the basin

A general conclusion that can be made from the results is that change in the hydrologic regime corresponds to the projected change in precipitation and temperature. The most notable change in both the near and distant future is the increase of stream flow in the winter season for 11% and 13% respectively on average, as the result of the increased precipitation and a significant increase in temperatures. The higher temperatures and increased precipitation in the winter season suggest that there would be either a smaller share of snow compared to rainfall or more snowmelt, but both alternatives lead to greater winter stream flow. This increase is evident in the results from all five climate scenarios in both time frames and over the whole basin (Figure 6-3).

A substantial decrease of stream flow is expected in the spring and summer seasons, but somewhat differently in the near and distant future. The spring decrease is clear in both near and distant future over the whole basin, being greater in the distant future with greater variation over the basin. Summer runoff decreases in the near future according to four scenarios, and increases according to scenario CM5. Because of the positive changes for CM5, the ensemble median decrease is moderate (on average around 5.1%), with 8 locations exhibiting an increase. In the distant future, summer runoff decreases substantially by about 15% on average and clearly over the basin. This behavior mostly follows the pattern of decreased precipitation and higher temperatures projected by the climate models, except that the near future summer runoff reduction is less pronounced despite greater reduction of precipitation.

The autumn season exhibits a very small change in average for both the near and distant future. The five scenarios produce changes in basin response with opposite signs, so that the change in ensemble median runoff is almost negligible in the near future (on average +0.4%) with almost equal number of locations exhibiting increase and decrease. For the distant future the stations are exhibiting a prevailing decrease over those with an increase, so that the average change in ensemble median runoff across the basin is small, but negative (-3.3%).

The overall change in runoff on an annual level is small as a result of opposite winter and spring/summer trends. Similarly to the autumn runoff, the five scenarios produce annual runoff changes of opposite signs, which results in a small decrease in ensemble median runoff for the near future (an average of 1.4%). In the distant future, this decrease becomes more pronounced (an average of 4.7%) despite a very similar proportion of the number of locations with decreased runoff to that in the near future (40 compared to 38).

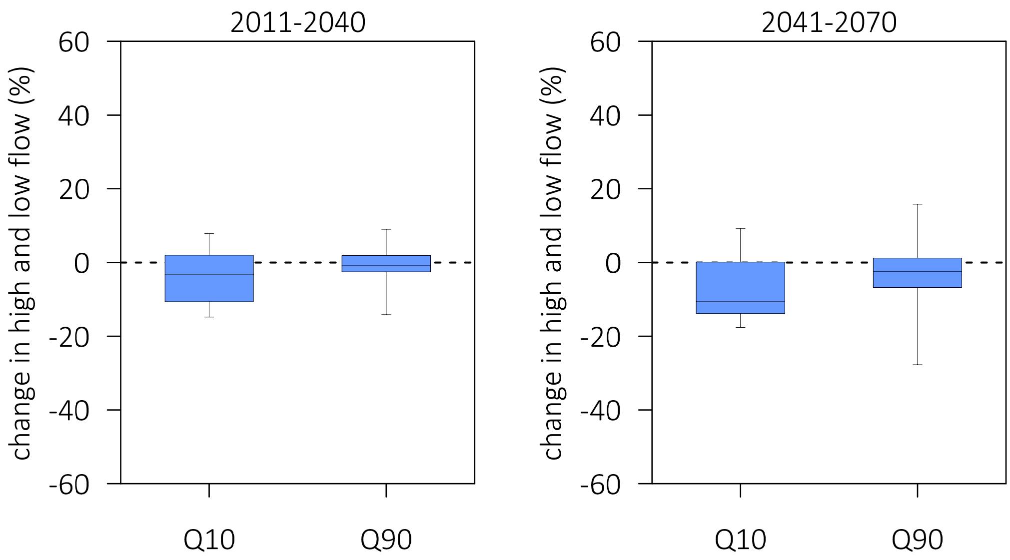


Figure 6-3: Change in high (Q10) and low (Q90) annual flows; box plots indicate variation across the basin

Changes in high and low annual flows, defined as the flow with 10% and 90% respective probability of exceedance in the 30-year series of mean annual flows, are shown in Figure 6-3. The results indicate that low annual flows are subject to a small reduction, meaning that the proportion of very dry years would slightly increase. On the other hand, high annual flows show greater reduction, indicating that the proportion of very wet years would decrease. Altogether, these results are in accordance with the fairly small overall reduction in runoff on an annual level, as shown in Table 6-1.

6.1.2 Low Flows

The low flows are usually characterized by the annual minimum values of mean flows in a given number of days (e.g. minimum 7-day flow is the lowest average flow in any 7-day window during a year), or by the number of days in a year with flows below a certain threshold. The first measure gives an indication of the intensity of low flows and volume deficit, which are important for water use and water quality considerations. The second measure indicates the low flow frequency and is therefore more relevant for navigation and waterway management (Nilson et al., 2012).

Annual minimum flows are usually described with flow-duration-frequency curves, which relate flows of different durations and probability of occurrence. Water supply and other systems for water use are typically designed taking into account values of annual minimum 30-day flows of 80% and 95% probability of exceedance. Closely related to annual minimum 30-day flows are the minimum mean monthly flows, which are used here as a surrogate for the former because of less calculations involved in their determination.

Low-flow thresholds for the Sava River are associated with target water depths that facilitate navigation with maximum draft and with a reduced draft. In this respect the ISRBC applies two standards as given in section 2.4.1: navigation must be possible for 65% of time with maximum draft and for 95% of time with a reduced draft. These requirements are related to discharges which are exceeded for 65% and 95% of time during a year (denoted as Q65 and Q95 respectively), and are determined from the long-term flow duration curves for a given river cross section.

The characterization of future low flows in the Sava River is based on the results of hydrologic simulations on the Sava River basin with future climate scenarios as described in section 6.1.10. The following indicators are used:

- minimum mean monthly flows with 80% and 95% probability of exceedance (denoted Qmm80 and Qmm95); and
- flows exceeded 65% and 95% of time during a year (denoted Q65 and Q95), from long-term flow duration curves.

The results are presented for locations of ten hydrologic stations along the Sava River, including seven stations downstream from Sisak where navigation is currently possible and three additional hydrologic stations upstream of Sisak (Rugvica, Zagreb and Čatež).

It should be noted that the following interpretation of the simulation results for low flows assumes that there is no influence of any water management controls on low flows, such as storage or withdrawal.

The results of hydrologic modeling with baseline and future climate scenarios from five climate model chains listed in Table 4-2 were used to extract series of annual minimum mean monthly flows for the selected ten stations. Frequency analysis of these series was performed and the log-Pearson type III probability distribution, a commonly used model for low flows, was fitted to the observed data. The quantiles for probabilities of 80% and 95% (Qmm80 and Qmm95) for the baseline scenario were compared to those from simulations with future climate scenarios. Changes in Qmm80 and Qmm95 for future time frames relative to the baseline period are shown in Figure 6-4 and Figure 6-5 respectively. The mean changes from the climate model ensemble in the graphs indicate that Qmm80 is not likely to change in the near future, while a significant decrease could be expected in the distant future downstream of Sisak (from 6% at Crnac to 18% at Županja). The conclusions for Qmm95 are similar, but even some increase could be expected in the near future along the Sava River (not more than 7%), and in the distant future upstream of Jasenovac (up to 5%). Downstream of Jasenovac a decrease for less than14% could be expected in the distant future.

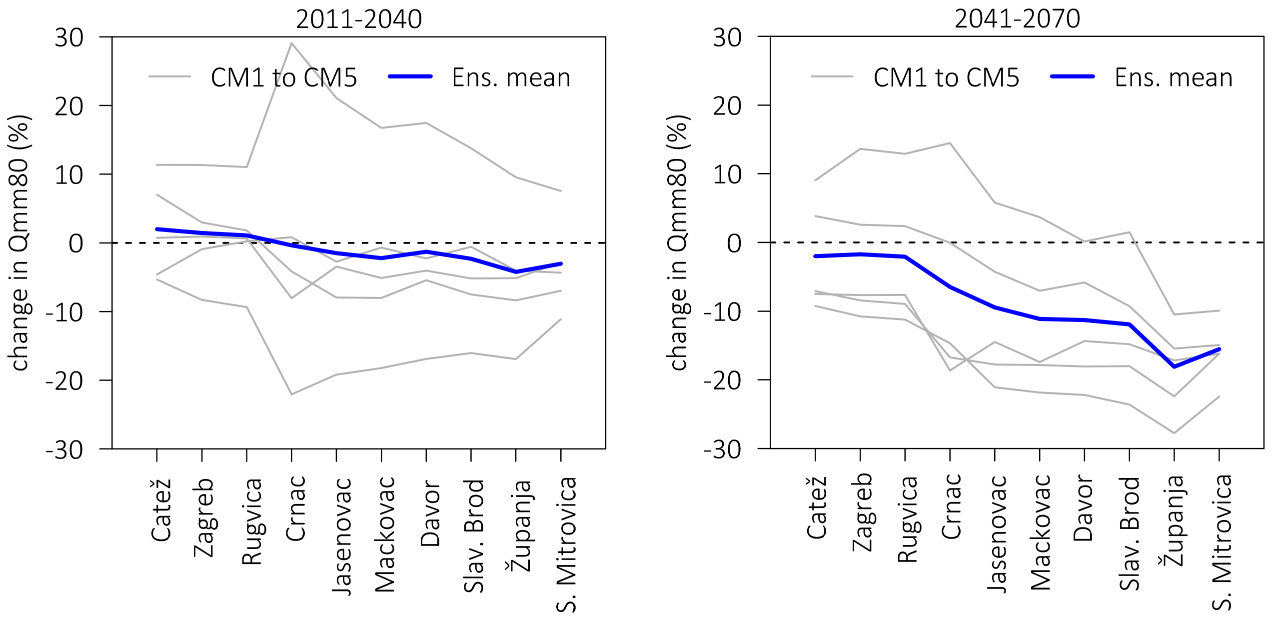


Figure 6-4: Change in minimum mean monthly flow of 80% probability of exceedance (Qmm80) in near future (left) and distant future (right along the Sava River)

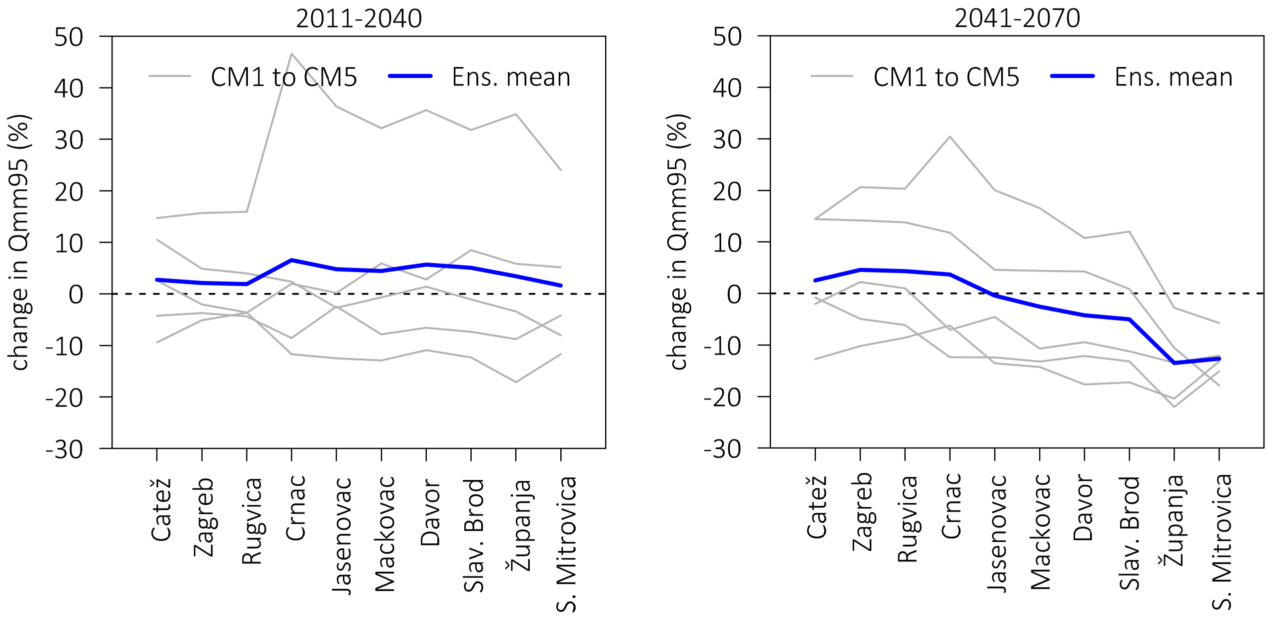


Figure 6-5: Change in minimum mean monthly flow of 95% probability of exceedance (Qmm80) in near future (left) and distant future (right) along the Sava River

Changes in flows exceeded 65% and 95% of the time during a year (Q65 and Q95), taken as the corresponding percentiles from the long-term flow duration curves constructed from the hydrologic simulations with the baseline and the future climate scenarios, are shown in Figure 6-6 and Figure 6-7. Similar conclusions about low flows can be drawn from these graphs, as from the statistically derived characteristic low flows. The modeling results in terms of the ensemble mean values indicate that virtually no change of Q65 and Q95 would occur in the near future, while a modest decrease could be expected in the distant future. Again, this change in the distant future is more significant downstream of Sisak (i.e. the Crnac station), with the largest decrease of 6% for Q65 and 11% for Q95 at the most downstream part at Županja and Sremska Mitrovica.

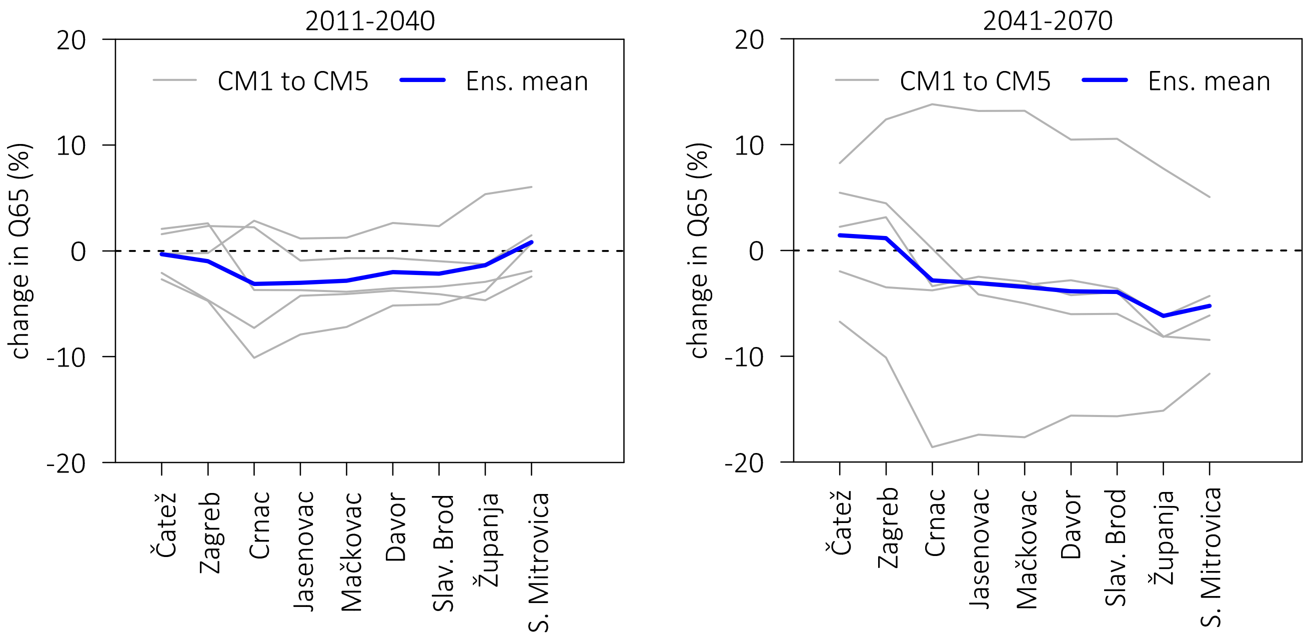


Figure 6-6: Change in flows of the 65% duration (Q65) in near future (left) and distant future (right along the Sava River

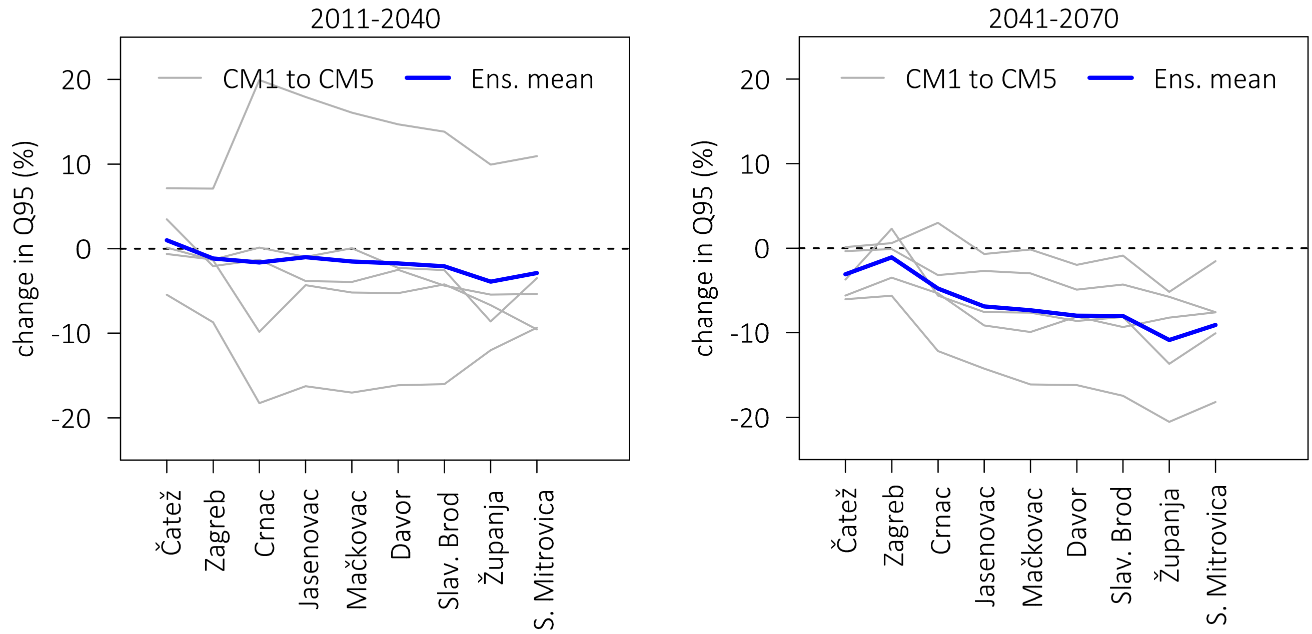


Figure 6-7: Change in flows of the 95% duration (Q95) in near future (left) and distant future (right) along the Sava River

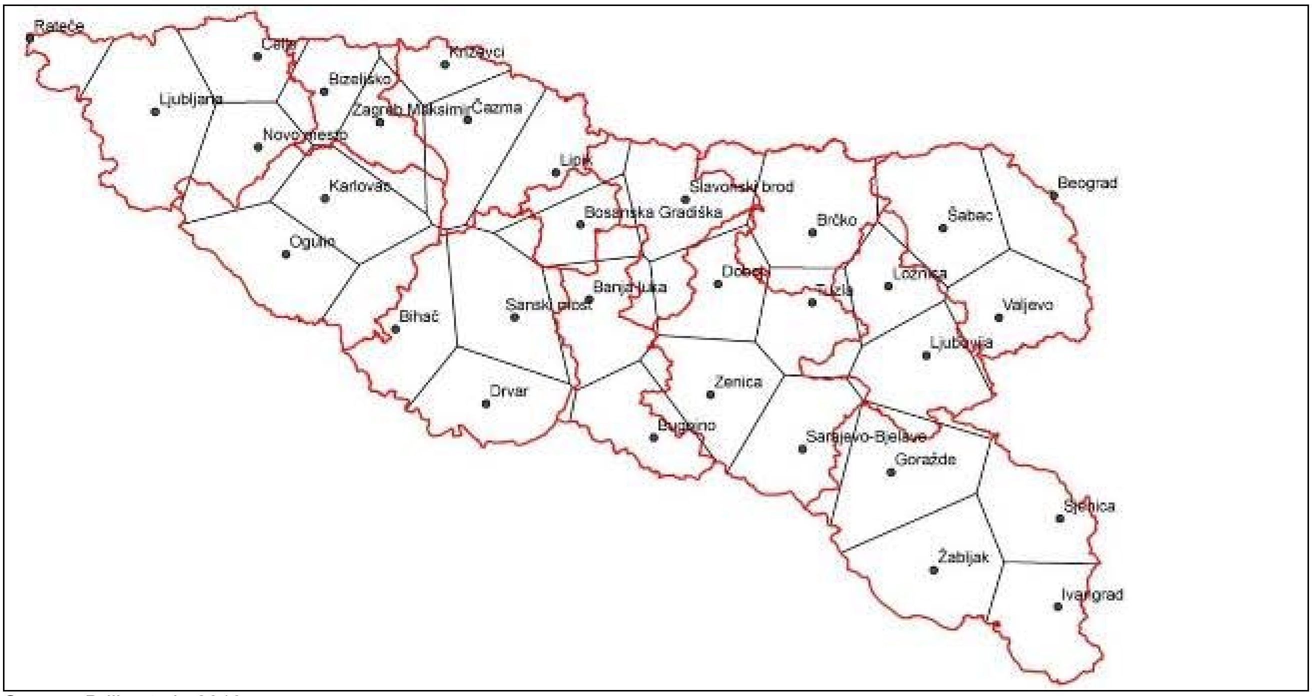
In regard to somewhat higher uncertainty in some of the results, it should be noted that these results related to low flows should be taken with caution, since the applied climate and hydrologic models were not calibrated in this study to reproduce extreme flows, but rather mean flows and runoff volumes. However, the results obtained are in accordance with the general conclusions from the Strategy on Adaptation to Climate Change for the Danube River Basin (ICPDR, 2013), where the alpine areas of the Danube River Basin have either no clear trend or a slight improvement of the mean annual low flow and drought situations. The future low flow regime also depends on changes in water use, which could impair or improve the general trend.

6.1.3 Flood Flows

Changes in flood flows were determined based on the results of climatological models and hydrological model specifically calibrated for flood flows (Brilly et al., 2013). Full details on this modeling study are contained in the separate report which is provided as Annex 2 – Flood Guidance Note to this WATCAP main report.

The climatological model provided projections of average temperature and maximum precipitation with 20 and 100 years return periods for different time periods. Calculations were made for the baseline period 1960-2010 and for future time frames 2011-2040, 2041-2070 and 2071-2100.[28] Generally the largest increases for the Basin have been projected for the autumn season, whilst the highest projection for the summer was observed only in lowland areas. Hence, for further analysis, the autumn period was used, which is the period when major floods on the Sava River are likely to occur. The results of the prediction of the autumn daily maximum precipitation, for the distant future (from 2071 to 2100) and for stations used in the model (Figure 6-8), are shown in Table 6-2.

[28] The future period 2071-2100 was not considered in other WATCAP analysis except for floods.



Source: Brilly et al., 2013.

Figure 6-8: Sava River watershed with precipitation stations and Thiessen polygons

The climate modeling results have shown that maximum daily precipitation in autumn will increase on average by 23% for the 20-year return period and by 32% for the 100-year return period (Table 6-2). However, the percentage increases span widely and seem to be randomly distributed over the Basin. Higher maximum daily precipitation values are observed on the edge of the Basin and in the area of the Dinaric Mountains, while the lowest values are in the central part of the Basin. Maximum daily precipitation shows great variability between individual stations: ratio between the maximum and minimum values for 20-year return period is 1:4.3, and for 100-year return period is 1:5. In the future, standard deviation of the values across the basin is also increasing: by 6% for the 20-year return period and by 14% for the 100-year return period.

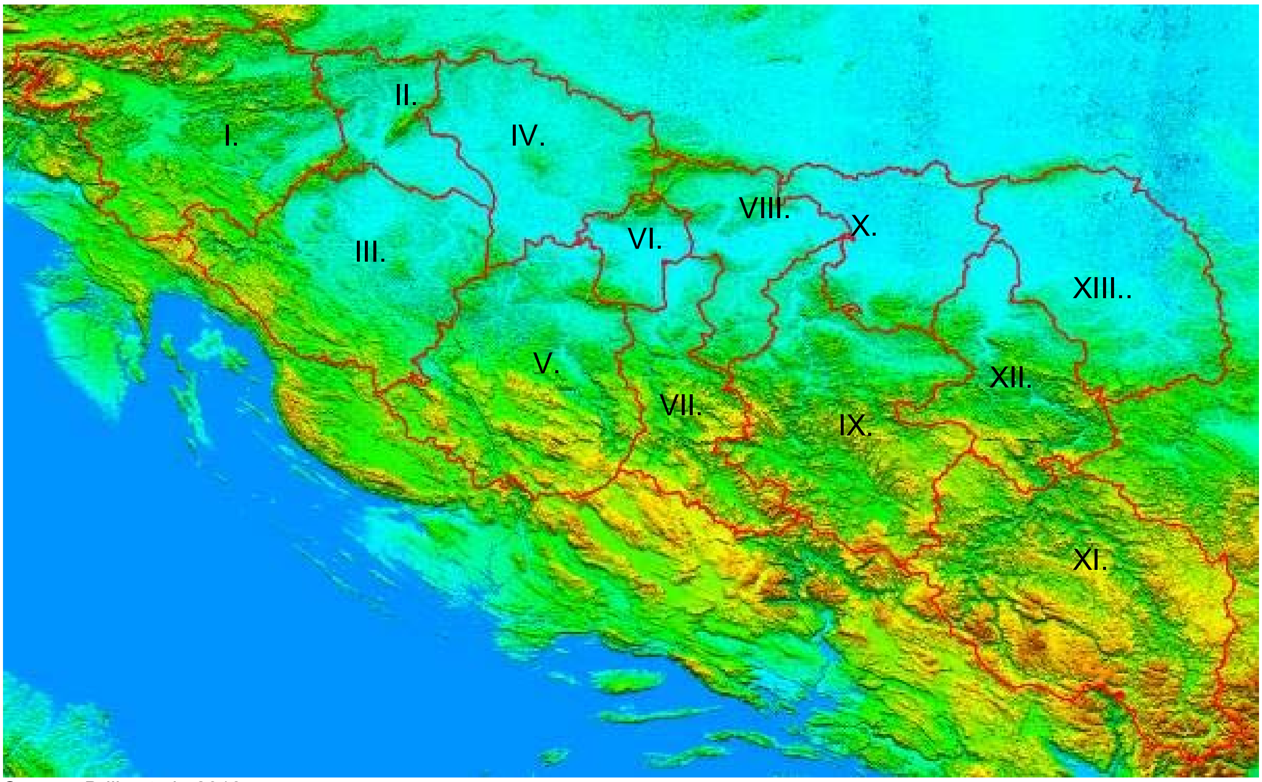
Table 6-2: Change in the maximum daily precipitation in autumn at the end of 21st century

Station	EOBS 20 yr.	EOBS 100 yr.	2071-2100 20 yr.	2071-2100 100 yr.	2071-2100 20 yr.	2071-2100 100 yr.
	(mm)				increase (%)	
Rateče	131.9	171.1	155.7	201.9	18	18
Ljubljana	88.5	110	113.3	153.2	28	39
Celje	85.4	105.3	111.1	149.8	30	42
Bizeljsko	64.3	77.1	86.8	126.9	35	65
Novo Mesto	79.7	101.5	108.4	164.3	36	62
Križevci	47.1	55.9	59.7	80.4	27	44
Ogulin	86.6	103.8	110.8	148.7	28	43
Karlovac	62	71.9	82	111.7	32	55
Zagreb - Maksimir	43.6	50.3	56.3	80.4	29	60
Čazma	40.1	45.5	50.1	62.4	25	37
Lipik	32.3	34.3	37.3	38.9	15	13
Slavonski Brod	31.1	38.6	36.8	45	18	17
Bos. Gradiška	31.7	39.2	37.1	46.2	17	18
Bihač	69.7	83.4	88.4	114.2	27	37
Drvar	54.9	69.3	64.7	86.6	18	25
Sanski Most	47.9	68.6	56.5	82.1	18	20
Banja Luka	34	44	39.1	50.7	15	15
Bugojno	38	50.4	43.9	62.2	16	23
Zenica	34.7	42.4	40.3	51.2	16	21
Doboj	30.7	34.9	35.8	41.6	17	19
Tuzla	31.7	35.2	39.3	48.6	24	38
Brčko	33.3	39.4	40.6	49	22	24
Sarajevo - Bjelave	37.6	42.6	44.5	52.8	18	24
Goražde	42.2	52.6	50.3	66.5	19	26
Ložnica	34.6	37.5	41.6	46	20	23
Ljubovija	35.5	39.5	42.5	50.6	20	28
Šabac	36	43.4	43.3	53	20	22
Valjevo	39.3	47.2	47.2	59.4	20	26
Beograd	36	46.1	44.8	61	24	32
Sjenica	42.9	51.3	52.6	66.1	23	29
Žabljak	37.1	45.7	44.1	61.6	19	35
Ivangrad	44	53.1	58.5	76.6	33	44
Average	49.5	60.3	61.4	80.9	23	32
Standard deviation	23.2	30.1	29.9	42.5	6	14
Maximum	131.9	171.1	155.7	201.9	36	65
Minimum	30.7	34.3	35.8	38.9	15	13

The mean autumn temperatures vary across the SRB between 6°C and 12°C. Modeling has shown that there is an increase in average temperatures throughout the entire basin. Temperatures are predicted to increase by 0.8°C for the period 2011-2040, by 1.8°C for the period 2041-2070 and by 2.9°C for the period 2071-2100. The standard deviation is 0.1°C for the first two periods and 0.2°C for the third period. In a further simulation of climate change impact, the average value of temperature increase for the entire basin was considered.

The hydrological model has been developed using the HBV modeling software with a similar structure as the model presented in Chapter 5 (Brilly et al., 2013).[29]

[29] The Hydrologiska Byrans Vattenbalansavdelning (HBV) model is a conceptual model developed in the by the Swedish Meteorological and Hydrological Institute for continuous calculation of runoff used to simulate hydrological forecasting



Source: Brilly et al., 2013

Figure 6-9: Sava river basin topography with sub-basins

Table 6-3: List of sub-basins used in hydrologic modeling for flood flows

Sub-basin number	Sub-basin name	River	Sub-basin Area [km^2]
I.	Sava I	Sava	10,073
II.	Sava II	Sava	3,481
III.	Kolpa/Kupa	Kolpa/Kupa	9,501
IV.	Sava III	Sava	6,702
V.	Una	Una	9,907
VI.	Sava IV	Sava	1,880
VII.	Vrbas	Vrbas	5,295
VIII.	Sava V	Sava	4,403
IX.	Bosna	Bosna	10,261
X.	Sava VI	Sava	5,021
XI.	Drina I	Drina	13,781
XII.	Drina II	Drina	5,979
XIII.	Sava VII	Sava	8,425
		All sub-basins	**94,708**

Source: Brilly et al., 2013

For the hydrologic modeling, the basin was subdivided into sub-basins as shown in Figure 6-9 and Table 6-3, with the main right tributaries presented as separate units (namely the Kupa River, the Una River, the Vrbas River and the Drina River). The Drina River, due to its size was further divided into two parts as shown in Figure 6-9. To simulate climate change impacts on flood flows, the hydrologic model was used to simulate the remarkable 1974 flood event with input data to which changes in temperature and maximum daily rainfall were introduced.

This enabled hydrologic simulations for the 20-year and for the 100-year precipitation from the European observation high-resolution gridded data (E-OBS) as the baseline scenario and for predictions of climate change, for different periods in the future.

Using the results of the hydrologic simulations, a specific analysis was undertaken to derive the probability distributions of flood discharges at selected gauging stations along the Sava River for different future time frames (Brilly et al., 2013). The results of this analysis are shown in Table 6-4.

Table 6-4: Probability of flood discharges for selected water stations along the Sava River in m³/sec

Hydrologic station	Baseline Flood			2071-2100 Flood			Increase (%)		
	Probability			Probability			Probability		
	10%	1%	0.1%	10%	1%	0.1%	10%	1%	0.1%
Čatež	2524	3027	3400	3560	4687	5060	41	55	49
Crnac	2240	2456	2613	2460	2780	3030	10	13	16
Slavonski Brod	2966	3535	4041	3332	4050	4605	12	15	14
Županja	3585	4215	4759	4343	5268	5802	21	25	22
Sremska Mitrovica	5140	6000	6760	5666	6526	7556	10	9	12

The Čatež hydrologic station, which controls the headwater part of the SRB, shows relatively high flood discharges with a great impact of climate change. From the confluence with the Sotla River and downstream of Zagreb, representing a large inundated area, a substantial decline the Sava River flood discharges is noticed up to the Crnac hydrologic station for 23%.

Due to the large inflow of flood flows from tributaries, the flood discharges are increasing along the river. Downstream of the confluence with the Drina River flood flow rates significantly increase up to 43 %, due to the large flow of the Drina River. Flooding in the lower part of the Sava River has a marked impact due to the Drina River, the largest tributary of the Sava River. Unlike the headwaters, the increased flow in the middle and downstream part are much smaller, from 10% to 25%. Such a regime of flooding reflects the large influence of the extensive floodplains in the middle and lower parts along the Sava River.

Impacts of climate change on the entire basin were analyzed based on the results of the model in which each sub-basin was considered as a whole (see Table 6-5). Individual river basins are relatively large and heterogeneous in their hydrological composition and morphology and so require more detailed modeling and processing in future. However, the data suggest certain characteristics of the hydrological regime of the river basin.

Table 6-5: Percentage of increase in flood flows by sub-watershed at the end of 21st century

Watershed	20yearsreturn period	100 years return period
Headwater of the SRB	33	49
Kupa/Kolpa	8	17
Una	24	58
Vrbas	11	33
Bosna	36	49
Drina upstream	5	16
Drina downstream	7	18
Lower part of the SRB	-2	3

Headwaters of the Sava River in Slovenia contain two important tributaries; the Ljubljanica River and the Savinja River. The Ljubljanica River has large areas of karst fields, which successfully retain water and reduce flood flows and also reduce the impact of climate change, so much that smaller impacts from climate change in the catchment area are likely, as it is presented in Table 6-5. The Savinja River has a torrential character without major floodplains and in this tributary an increase from the impact of climate change can be expected.

The Kupa River has substantial karst in the headwater part of watershed, which holds flood flows, and downstream there are extensive floodplains that also dissipate flood flows. In the upper part of watershed, therefore, similar values as observed for the neighboring watershed in Slovenia can be assumed. In the downstream part of the watershed, it can be assumed that discharge values will have a much smaller impact from climate change, with flow rates increasingly slightly in the lower part by 8% for the 20-year return period and by 17% for the 100-year return period.

The Una River collects water from a relatively large area of the Dinaric Mountains without large floodplains or inundated areas that could dissipate flood discharges. Calculations indicate a relatively high impact from climate change with percentages of flood discharges being the largest in the entire SRB (24% for 20-year return period and 58% for 100-year return period).

The Vrbas River collects water from the central part of the mountainous areas of BiH. Impact from climate change is relatively large, with predicted discharges increasing by a third, but still less than in the basins of the Una River and the Bosnia River. The Vrbas also has no major floodplains in the basin, except near the confluence with the Sava River.

The Bosna River is the second largest tributary for the Sava River. In the upper reaches water accumulates from karst areas with extensive floodplains. The impact from climate change shows similar values to the headwaters of the Sava River with predicted increase of up to 50 % for the 100-year return period.

The headwater part of watershed for the Drina River is situated in karst areas of Montenegro and drains a very large area without major floodplains. The lower part of the Drina watershed has a drier climate. As mentioned previously, the modeling divided the Drina River into two parts, which display similar, relatively small effects from climate change. Flows are expected to increase by up to 16-18 % for the 100-year return period.

Tributaries in the lower northern part of the SRB collect water from a relatively flat surface without significant rainfall and with extensive floodplains. Due to predicted higher temperatures in the future there will be increased evaporation and flooding is predicted to be less despite increased precipitation due to climate change. In fact there will be a reduction in flow rates by -2% for the 20-year return period and a very small increase of 3% in flows for the 100-year return period.

6.2 Impact of Climate Change on Selected Sectors within the Basin

6.2.1 Floods

Impact from climate change on flood risk in the SRB is significant and should not be neglected. This impact differs significantly within the Basin; it decreases from the mountainous regions to the plain but also from the west to the east. The main impacts are associated with future social and economic development, essentially through urbanization.

There is general migration of people from rural areas that were at one time working in agriculture to other economic sectors causing them to settle more in urban areas. This trend in urbanization of the SRB can be expected to continue in the future. This increases the flood risk to the main capitals built by the Sava River e.g. Ljubljana, Zagreb and Belgrade but also to towns such as Sisak, Slavonski Brod, Brčko etc. which all are prone to flooding on the Sava River and its tributaries. The May 2014 floods proved that the urban areas are at the greatest risk, since the most heavily affected areas were towns like Doboj and Obrenovac; some other towns were at serious threat as well.

It follows therefore that flood protection of urban areas and critical infrastructure (e.g. roads, railway, pipelines etc.) should be prioritized. This implies that costs for flood protection will increase in future and this should be at the expense of protection of agriculture areas, which should decrease if it is considered necessary. Consequently, carefully designed adaptation measures for long-term flood planning should be developed. To some extent this has already been started with some reconstruction of Middle Posavina flood protection system in Croatia completed, but more needs to be done. The May 2014 floods also proved that the existing natural retentions in Croatia have a limited capacity to prevent major floods; this emphasized the need to increase this means of flood protection to complement the aging and insufficient system of embankments.

In Slovenia, the greatest risk from flooding is the Ljubljana Barje (marshes), an area which houses a large suburb of Ljubljana City. This represents a large floodplain with a very shallow gradient which is underlain by consolidated clay with poor percolation rates. Flooding, in this area is also exacerbated by poor maintenance with overgrown vegetation along the banks of the watercourses.

Work on the drainage of the Ljubljana marshes was carried out even in ancient times, but much more intensively from the 18th Century to the present. At the end of the 18th Century the large Grubar Channel was built as an alternative and in the 20th Century the Ljubljanica River was deepened in the city area and sluice gates built. However, over the last 50 years some settlement and subsidence have occurred implying that these flood preventative measures are inferior and Ljubljana faces the same flood risk as before.

The most important floodplain in Croatia is covered by Zagreb Municipality. Due to a large flood in 1963, an extensive system of dikes and alternative channels was built, which protected the city from floods with an expected 1000-year return period. Due to the deepening of the riverbed of the Sava River (through dredging by erosion), this security has even been increased. However, the problem is a larger area downstream from the Slovenian - Croatian border, which is not protected. In addition, future protection will be provided by integration with hydropower development along the Sava River.

Belgrade, the capital of Serbia, has the most vulnerable status along the Sava River. The new part of the city in the past had protection from floods with an expected 1000-year return period. However substantial urban growth (metalling of roads and concreting) especially in the new suburb of Belgrade (New Belgrade), the impact of the Iron Gate hydro power plant and more modern and accurate hydrologic analysis imply that flood defences for Belgrade are no longer satisfactory. Reconstruction of existing levees and a rearrangement of green areas along the River will be necessary.

6.2.2 Hydropower

Climate change (CC) impact on the hydropower sector is mainly seen in the effects on power generation potential. Hydropower (HP) production would either be positively or adversely affected, depending on the CC effects and how are they managed. The change of three climate parameters as a consequence of CC was analyzed, namely: precipitation, temperatures and evaporation/ evapotranspiration (ET). These three parameters are all important components of the hydrological cycle that affects river discharge, which in turn is a major input to power generation calculation. Consequently, major projected climate change impacts on the HP sector are:

- Decreased or increased HP generation potential due to more or less precipitation and consequently more or less river runoff;
- Reduced or increased energy demand for heating or cooling, with regard to CC by means of higher or lower air temperatures;
- A decrease or increase of installed flow for facilities changing HPP effectiveness;
- Flooding and landslides damage or complete destruction of HP structures (e.g. dams, transmission and distribution networks), which may create conflict with downstream communities, increase social vulnerability e.g. through involuntary resettlement; and
- Energy security and economic development activities will be compromised and production costs will increase.

Major vulnerability of hydropower plants and systems to CC lies in change of key parameters for power production, because they are directly linked to climate parameters. Key parameters whose change would largely affect hydropower production are:

- River discharge or mean flow and on specific dam profiles: a significant change would affect production in the same direction;
- Duration curves or a fluctuation of discharge in one time period (i.e. year, season,…) for the dam profile: a change would affect the change in total volume used for production and in the same manner production by itself; and
- Evaporation/ET would affect volume of available water for production.

Some characteristics of hydropower facilities affect their vulnerability to climate change. For instance, energy generation capacity would be decreased or increased in a bigger or a smaller scale depending on the type of facility, size of the reservoir, etc. The vulnerability of different hydropower characteristics to CC is given in Table 6-6 below.

Table 6-6: Hydropower climate change vulnerability according to HPP characteristic

Climate parameter	Climate parameter change	HPP type			Reservoir storage area: volume ratio		Reservoir size	
		Reservoir type	Run-of-river	Pumped storage	High	Low	Large	Small
Evaporation/ET	Increase							
	Decrease							
River runoff	Increase							
	Decrease							
Temporal variability	Flood				N/A			
	Drought							
	Seasonal offset							

Legend: bigger decrease; smaller decrease; bigger increase; smaller increase

Using this pattern shown in Table 6-6, it is possible to define adaptation strategies depending on a specific situation. The issue of adaptation strategies is further discussed in Chapter 8.

As has been discussed earlier in Chapters 4 and 5, climate change analysis in the SRB has used a hydrological model for the SRB developed in HEC-HMS. The future climate scenarios are taken from five GCM/RCM simulations under the A1B scenario (IPCC) denoted as climate models CM1 through CM5; with each climate model daily flows are simulated for three 30-year periods:

- 1961-1990 (past or baseline climate scenario),
- 2011-2040 (near future climate scenario), and
- 2041-2070 (distant future climate scenario).

According to work undertaken under this WATCAP study (refer to the separate Hydrologic Modeling Report), change in the SRB implies:

- Temperature increases about 1°C in the near future and 2.3°C in the distant future.
- Change of mean annual precipitation ranges between -6% to +4% across the Basin, but seasonal change takes values between -12% to +14% in the near future and as much as -32% to +19% in the distant future, as a mean value for all stations on the Basin. For some parts of the SRB difference is as high as ±30% in near and ±40% in the distant future.
- Seasonal variability as described by CM1 to CM5 is not the same for all. Predictions of two climate model for the near future and three for the distant future indicate an increasing precipitation trend will occur in the winter and a decreasing trend in the summer season.

Taking the information from Table 6-6 and the overall climate scenario results for the SRB area overall, the following conclusions can be drawn:

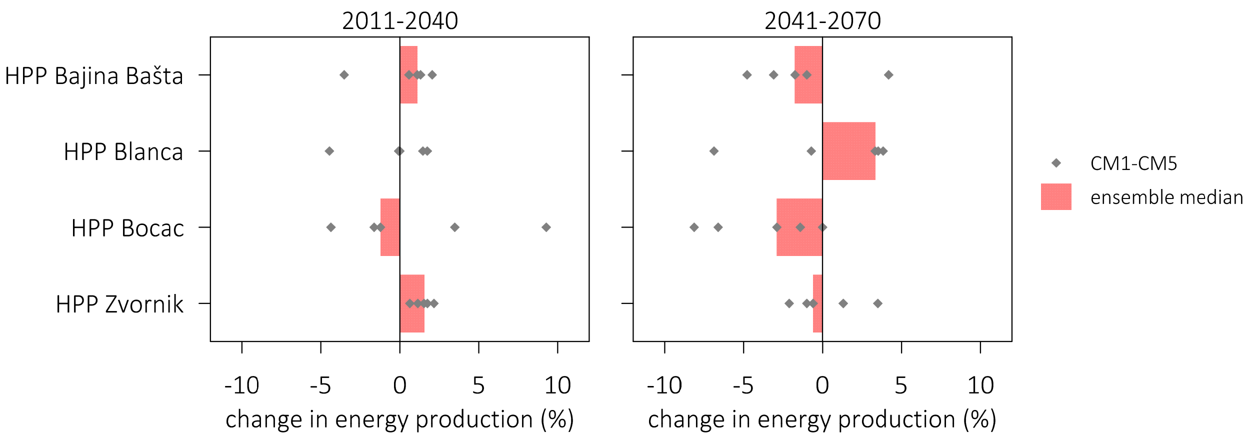
- With increasing evaporation/ET, due to temperature increase in the future, a larger decrease of hydropower production is expected to occur on reservoir type and pumped storage type dams with a high storage area/volume ratio and small reservoirs. Other types of HPP would show smaller effects, but still experience a decrease of hydropower generation;
- A decrease in river runoff would affect power generation with a reduction on all facilities but in particular with run-of-river schemes in the SRB because they are highly and solely dependent on river runoff; and
- Floods in the fall/winter and droughts in the spring/summer would mostly affect run-of-river HPPs and HPPs with small reservoirs. With this climate change parameter, an overall power generation decrease is expected.

From all of the above, it can be concluded that it would be customary in the future to have lower energy generation in the SRB from larger or smaller schemes, depending on the region and the HPP facility. The magnitude of the change has been reviewed by conducting further analysis through case studies on the following HPPs:

- Blanca HPP on the Sava River in Slovenia
- Bočac HPP on the Vrbas River in BiH
- Zvornik HPP on the Drina River in Serbia and
- Bajina Bašta HPP on the Drina River in Serbia

The HPP case studies were chosen based upon their significance in the hydropower sector in the SRB and the fact that there was sufficient data for analysis through the HEC-HMS Model due to their close proximity to existing hydrological stations with reliable data.

Simulated daily flows for the above mentioned three 30-year periods and five CM outputs were used to calculate the daily production for the selected HPPs. The resulting energy production for each 30-year period in both near and distant future were compared in relation to the baseline scenario (period 1961-1990). The results are given in Figure 6-10.



Source: Figure produced by COWI

Figure 6-10: Relative change in energy production five climate scenarios CM1-CM5 and near and far future

The results for all HPPs in the near future show a small expected change in the average annual energy production, with rather small variation between the climate models (CMs) except for HPP Bočac. Based on the ensemble median values (as a more robust estimate than the ensemble mean, which might be under influence of extreme values in short samples like this one), an increase in the range of 1-1.5% is expected at two HPPs on the Drina River (Bajina Bašta and Zvornik), and a small decrese is expected at HPP Bočac.HPP Blanca in Slovenia results in 0% change. Greater variation for HPP Bočac gives a power production decrease of 4% (with CM4) and an increase of 9% (with CM5), thus indicating a higher uncertainty related to the Vrbas basin hydrologic simulations and consequently to the derived energy production.

For the distant future the variation between the scenarios is greater, which is expected with the simulation period being further away from the observation period. The energy production is expected to change more markedly in this period, between -8% (HPP Bočac) and +4% (HPP Bajina Bašta), although the order of the magnitude of these changes is still in the range of the modelling and measurement uncertainties. The trend at two HPPs on the Drina River (Bajina Bašta and Zvornik) is reversed and their annual energy production is expected to decrease slightly by 1-2%. The decreasing trend at HPP Bočac continues in this period as well, while the energy production at HPP Blanca is expected to increase.

In addition to above, seasonal energy production variability was also analyzed for HPP Bajina Bašta and the results are given in

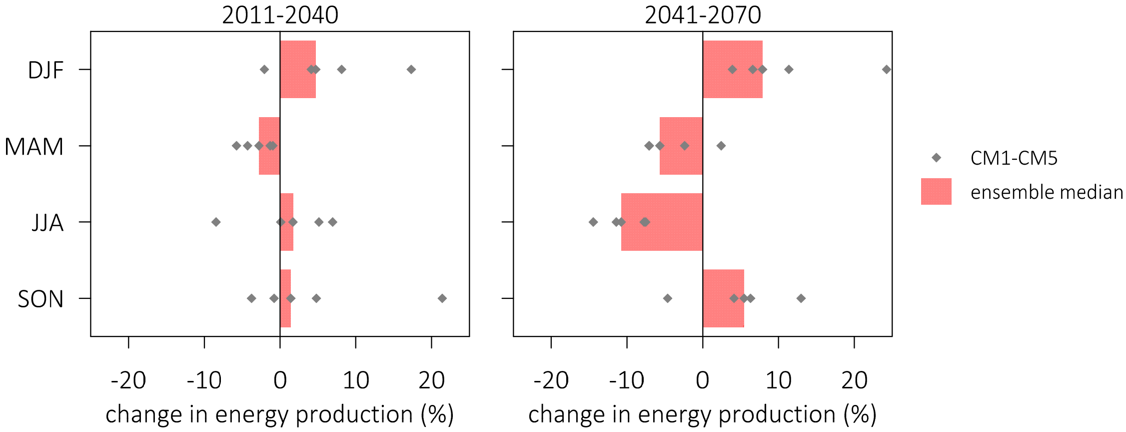


Figure 6-11. The near future results show greater energy production in winter and fall seasons, whilst in the spring months a decrease in energy production is expected. Interestingly, the energy production in the summer season is not expected to change significantly. The distant future results show greater energy production decrease in the spring and summer seasons – by 4% and 10% on average, respectively, whilst in the winter and fall energy production is expected to increase by 11% and 5% on average, respectively.

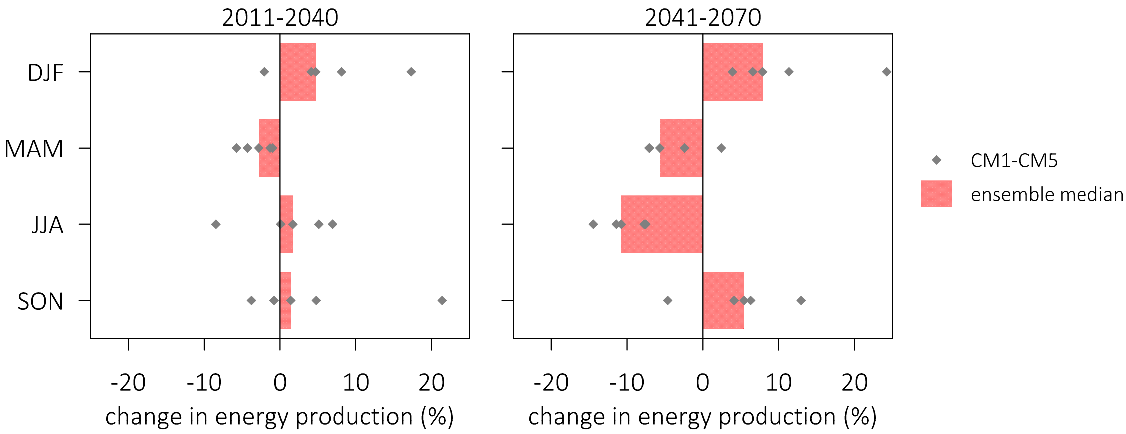


Figure 6-11: Change of energy production for HPP Bajina Bašta by seasons

DJF=December-January-February,
MAM=March-April-May,
JJA=June-July-August,
SON=September-October-November

6.2.3 Navigation

Climate change impacts on navigation are described in detail in the Guidance Note which is provided as a separate Annex 4 to this report. Following on from Section 2.4.1, the potential impacts that climate change may have on river navigation can be subdivided as follows:

- Low flows,
- High flows,
- River ice, and
- Visibility (fog).

The first two phenomena are the result of the hydrologic regime, which is driven mainly by precipitation, temperature and evapotranspiration. Ice formation is under the influence of air and water temperatures, whilst the fog results from higher humidity during lower air temperatures. All these factors can directly or indirectly change the navigability of waterways. Such changes in water level in rivers, ice formation and fog may affect the number of days per year that waterways can be used without restriction. Clearly therefore, the consequences of climate change are important for inland navigation and need to be assessed.

Earlier studies (PIANC, 2008 and Nilson et al., 2012) have shown that the hydrologic regime, sediment transport and riverbed morphology are closely related. Changes in water level and velocity can also lead to changes in sedimentation processes such as bank failure, local scour, and locations of aggradation and degradation. Changes in sediment processes, in turn, require changes in channel maintenance activities, such as increased or decreased dredging. However, this chain is not easy to model and even more difficult to predict for the future. Consequently, as has been done with these earlier mentioned studies, climate change impacts on navigation for this report are analyzed by neglecting the impacts of changes in river morphology.

The focus has been on the main Sava River waterway, since the navigation on the tributaries is possible only to limited lengths of between 3 and15 km. Although navigation is currently possible downstream from Sisak (including hydrologic stations: Crnac, Jasenovac, Mačkovac, Davor, Slavonski Brod, Županja and Sremska Mitrovica), two additional hydrologic stations upstream of Sisak were included in the analysis (Zagreb and Čatež) to support potential extension of the waterway. With the available data, it was possible to investigate the climate change impacts on navigation related to low flows, high flows and ice cover. However, there was no data to support an analysis of changes in visibility and their influence on navigation.

As mentioned previously, climate change impacts on relevant indicators are assessed using the future climate scenarios developed from five GCM/RCM simulations under the A1B scenario (IPCC), denoted as climate models CM1 through CM5, with each climate model simulated for three 30-year periods:

- 1961-1990 (past or baseline climate scenario),
- 2011-2040 (near future climate scenario), and
- 2041-2070 (distant future climate scenario).

<u>Low Flows</u>

Low flows result in reduced water depths and reduced widths of the fairway, and consequently in reduced draft of vessels and increased risk from grounding and collision of ships. Contrary to floods, which are usually considered as short-term events, low flows can be long-lasting and therefore can impose significant restrictions to navigation.

The water management practices can have a significant effect on the low-flow statistics. This effect is difficult to quantify since some practices can work in direction of enhancing the flows (e.g. by releasing more water from reservoirs in the summer on account of storing water in the winter), while the others can contribute to further depletion of the basin reserves (e.g. greater withdrawal to meet increased user needs during summer).

Low-flow thresholds for the Sava River are associated with target water depths that facilitate navigation with maximum draft and with a reduced draft. In this respect, ISRBC applies two standards as previously mentioned in Section 2.4.1: navigation with maximum draft must be possible for 65% of time, and with a reduced draft for 95% of time. These requirements are related to discharges which are exceeded 65% and 95% of time during a year (denoted as Q65 and Q95 respectively), and are determined from the long-term flow duration curves for a given river cross section.

The results of hydrologic modeling with baseline and future climate scenarios were processed to assess the flow duration curves at all selected locations for the three 30-year time frames. The modeling results are presented in Section 6.1.2 and indicate that virtually no change of Q65 and Q95 would occur in the near future, while a modest decrease could be expected in the distant future. This change in the distant future is more significant downstream of Sisak (i.e. the Crnac station), with the largest decrease of 6% for Q65 and 11% for Q95 at the most downstream part at Županja and Sremska Mitrovica.

The number of days with flows below the Q65 and Q95 for the baseline period 1961-1990 (denoted as Q65_base and Q95_base) at selected stations is equal to 128 and 18 days per year, respectively (on average over 30 years). To verify this in the results from climate models, the simulated and the observed distributions of the annual number of days below Q65_base and Q95_base (denoted by n65 and n95) were compared and a satisfactory agreement was found.

The near and distant future hydrologic simulations for 2011-2040 and 2041-2070 show (Figure 6-12) that the number of days n65 and n95 is likely to increase very little in the near future (on average 3 days for n65 and 2 days for n95), but a significant increase could be expected in the distant future downstream of Sisak (on average 13 days for n65 and 8 days for n95).

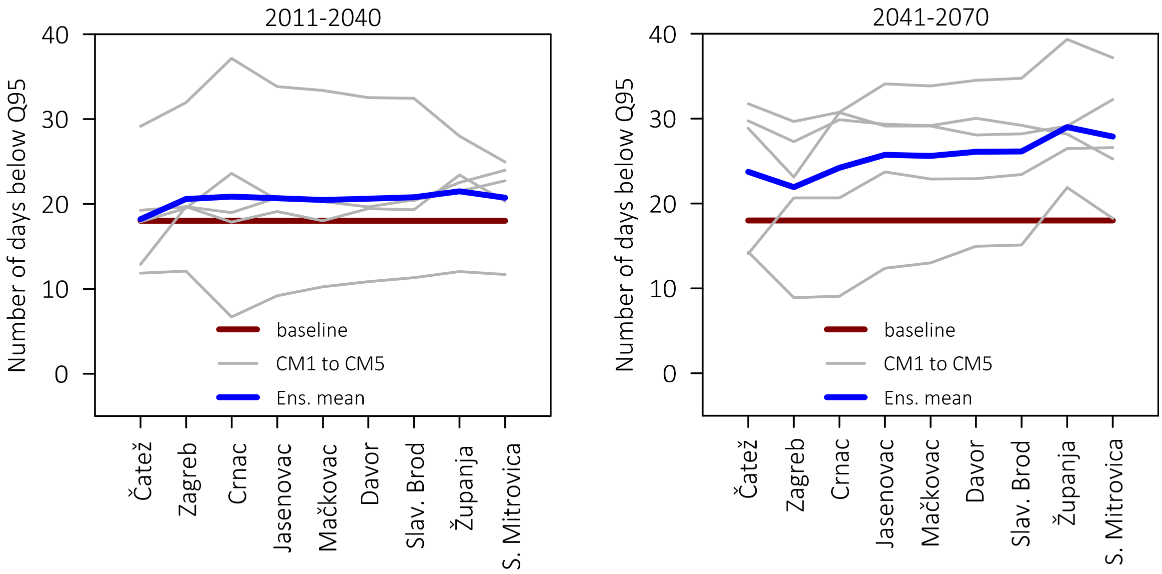


Figure 6-12: Change in the number of days per year with flows below Q95_base in near future (left) and distant future (right)

<u>High Flows</u>
High flows can lead to restriction or suspension of navigation. Similar to low flows, high flows are influenced not only by meteorological conditions but also by the water management activities such as river training or introduction of storage facilities. For the analysis, it is assumed that the effect of water management practice is the same as in the reference period, so that only the climate change effects are evaluated.

To analyze the effect of climate change of the number of days per year with restrictions related to high flows, two thresholds were considered. These are the flows assessed from the long-term flow duration curves for duration of 1% and 3%, i.e. the flows exceeded in 1% and 3% of time during a year, denoted as Q1 and Q3 respectively.

The results of hydrologic modeling with baseline and future climate scenarios were processed to assess the flow duration curves at all selected locations for the three 30-year time frames. The results reveal a lack of significant tendencies in these indicators. The near future period exhibits an interesting sequence of changes in both Q1 and Q3 along the Sava River where a weak increase in the upper parts gradually turns into a weak decrease at the downstream end. However, the magnitude of change (up to 3.4% in near future and up to 6.3% in distant future) is probably smaller than the magnitude of the overall uncertainties in the modeling chain and a firm conclusion on this is not possible. These results are generally in accordance with the conclusions of ICPDR that there is no clear tendency in the development of future flood events for the Danube River Basin.

The number of days with flows exceeding the Q1 and Q3 for the period 1961-1990 at selected stations is equal to 3.65 and 11 days per year, respectively (on average over 30 years). To verify this in the results from climate models, the simulated and the observed distributions of the annual number of days above Q1_base and Q3_base (denoted n1 and n3) in the baseline period were compared and a satisfactory agreement was found.

The near and distant future hydrologic simulations for 2011-2040 and 2041-2070 show (

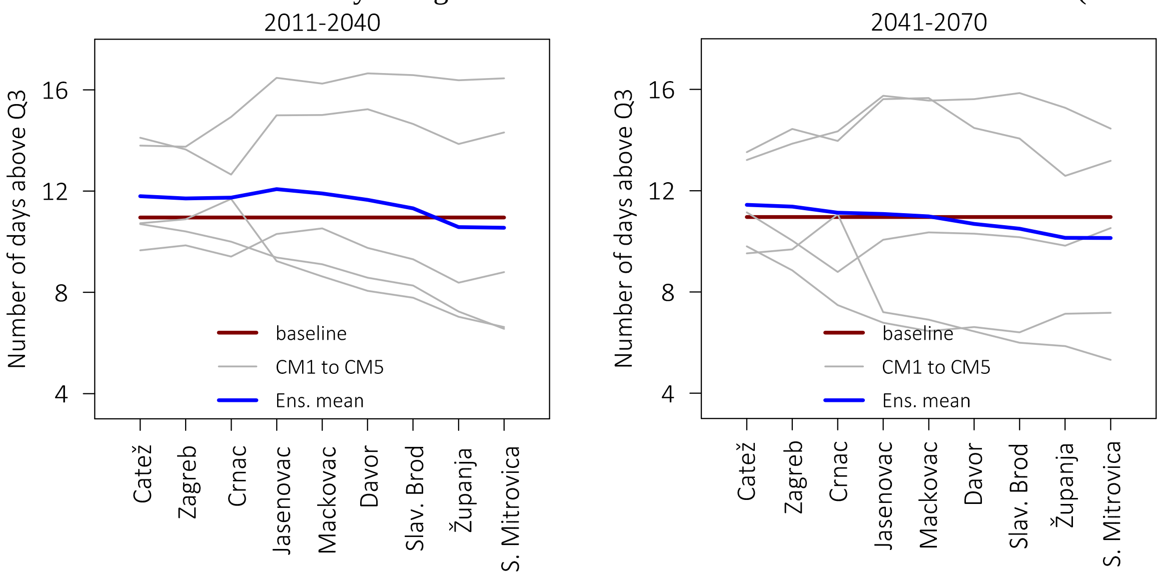


Figure 6-13) that the number of days n1 and n3 are not likely to change significantly in both near and distant future (on average for less than 1 day). There is a slight increase of the number of days in the upper part of the Sava River and a slight decrease in the lower part. This change in the number of days with high flows is gradual in a downstream direction. However, this conclusion might not be valid since this change is very small and is most probably within the uncertainty limits of the hydro-climatic modeling outputs.

It can therefore be concluded that the climate change impact on high flows would not have additional implications on the navigation sector in terms of the number of days in which navigation would be restricted or suspended compared to the current conditions.

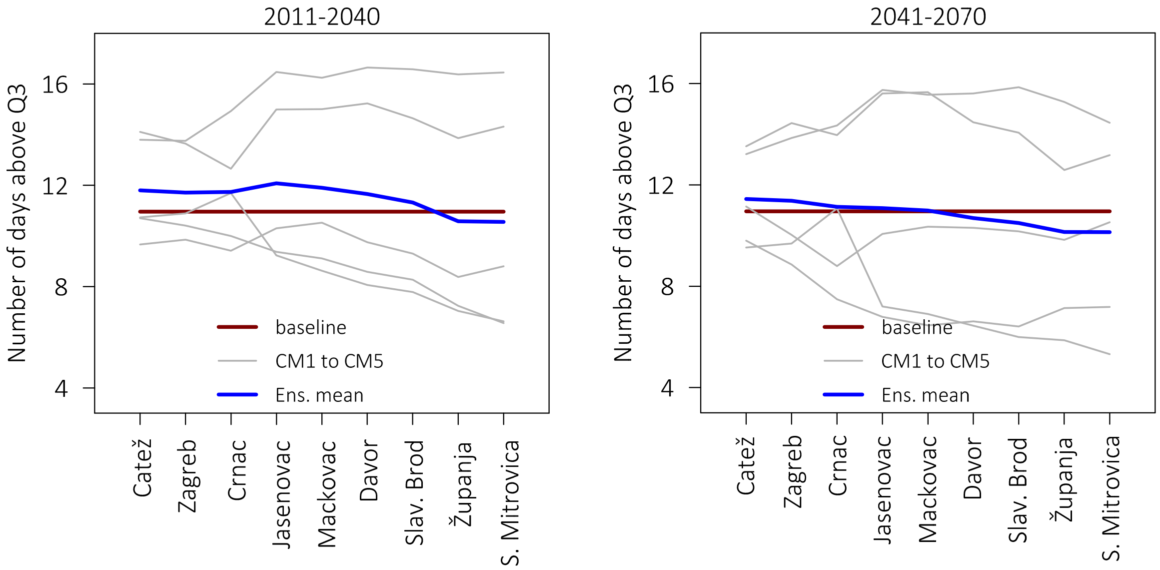


Figure 6-13: Change in the number of days per year with flows above Q3_base in near future (left) and distant future (right)

<u>Ice</u>

River ice has the potential to damage the ships and thus is a major cause for suspended navigation during the days with ice cover on the rivers. Ice development is conditioned by continuous low air temperatures over several days in combination with low flow velocities. In addition, discharges from power plants and industry have an impact on water temperature and chemical composition and can, therefore, play a significant role in ice formation.

The water temperature in navigable river sections depends on the air temperature. Since an increase in the annual mean air temperature of approximately 0.25 °C per decade is expected on average within the SRB, it can be assumed that the water temperature in rivers will rise by a similar amount. With the rise of water temperature, especially in winter, freezing of rivers would occur less often. To investigate changes in the possibility for ice formation in the future, the sum of temperatures below 0°C between November and March was used as an indicator (following Nilson et al., 2012). This variable is usually applied as an indicator of the severity of a winter season and of a potential for ice formation on standing water bodies (e.g. lakes).

Air temperature data from meteorological stations located near the Sava River (Zagreb, Sisak, Slavonski Brod, Gradište/Županja, Sremska Mitrovica and Beograd) were used from the five climate model outputs (CM1-CM5) for the baseline period (1961-1990) and two future time frames (2011-2040 and 2041-2070).

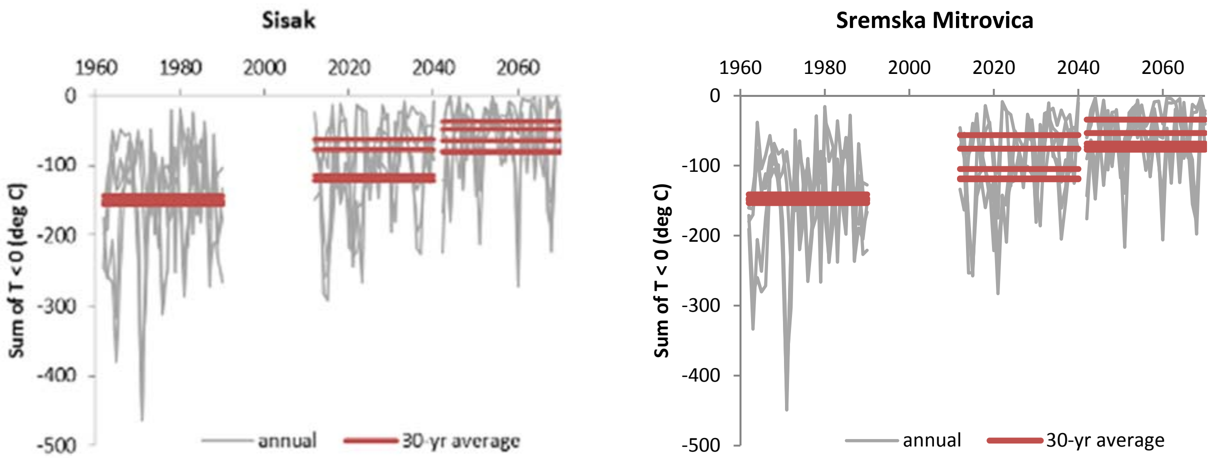


Figure 6-14: Change in the sums of negative daily temperature in the November-March season at two meteorological stations along the Sava River waterway as an indicator of the potential for ice formation (horizontal bars indicate average values for 30 years from different climate models)

It is not surprising given the general trend in rising temperatures that all climate models predict a reduced potential for ice formation along the whole navigable part of the Sava River (Figure 6-14). This, of course, would have a beneficial impact for inland navigation since the number of days per year with navigation suspended due to ice is expected to decrease.

However, earlier studies (PIANC, 2008) warn that although shorter periods of ice cover are indicated, a high degree of variability in local climatic conditions is still expected to cause ice impacts to inland navigation.

6.2.4 Agriculture

Following on from Section 2.4.3 which raised the water management issues affecting agriculture, the predicted impacts from climate change will only exacerbate this situation, so early action is needed to address these concerns. Agriculture is considered an important sector for the SRB and a detailed assessment of climate change impacts are described in detail in the Guidance Note, which is provided as a separate Annex 5 to this report. The following text provides a synopsis to this note.

Whilst the SRB riparian states are actively trying to improve their agricultural production, the agricultural food sector lags behind the rest of the economy in growth terms, due to being undercapitalized, fragmented, and dominated by small producers.

The current status of irrigation coverage is very low in the SRB and accounts for less than 1% of total water withdrawals; in some countries, it is less than 0.6%. A vulnerability analysis was considered important to assess the impact of changing climate on the crop water status and crop yield using the crop water balance to determine the water stress and subsequent crop yield changes.

The analysis was undertaken for precipitation (P) and evapotranspiration (ET) at 4 selected locations (one for each riparian state) using the five regional climate models (CM1 – CM5) mentioned in previous chapters. It is important to point out, however, that the analysis does not take into consideration the effects on changing crop yields from temperature, sunshine and air (CO_2) content on crop photosynthesis.

The analytical process involves water balance and yield response on four representative crops on a representative soil at each of the four locations using the CROPWAT model from the Food and Agriculture Organization (FAO) under the United Nations. The CROPWAT model provides the actual ET (ETa) and the potential ET (ETp) which the crop would use in optimal water availability, both expressed in mm of water layer. The ratio of ETa/ETp therefore is a good indicator for the water stress of a crop, and through CROPWAT, this value can determine reductions in crop yield.

Data availability and records are limited throughout the SRB. Slovenia has better records but in other states it remains unreliable and it is particularly complex in BiH due to two entities having completely different database systems.

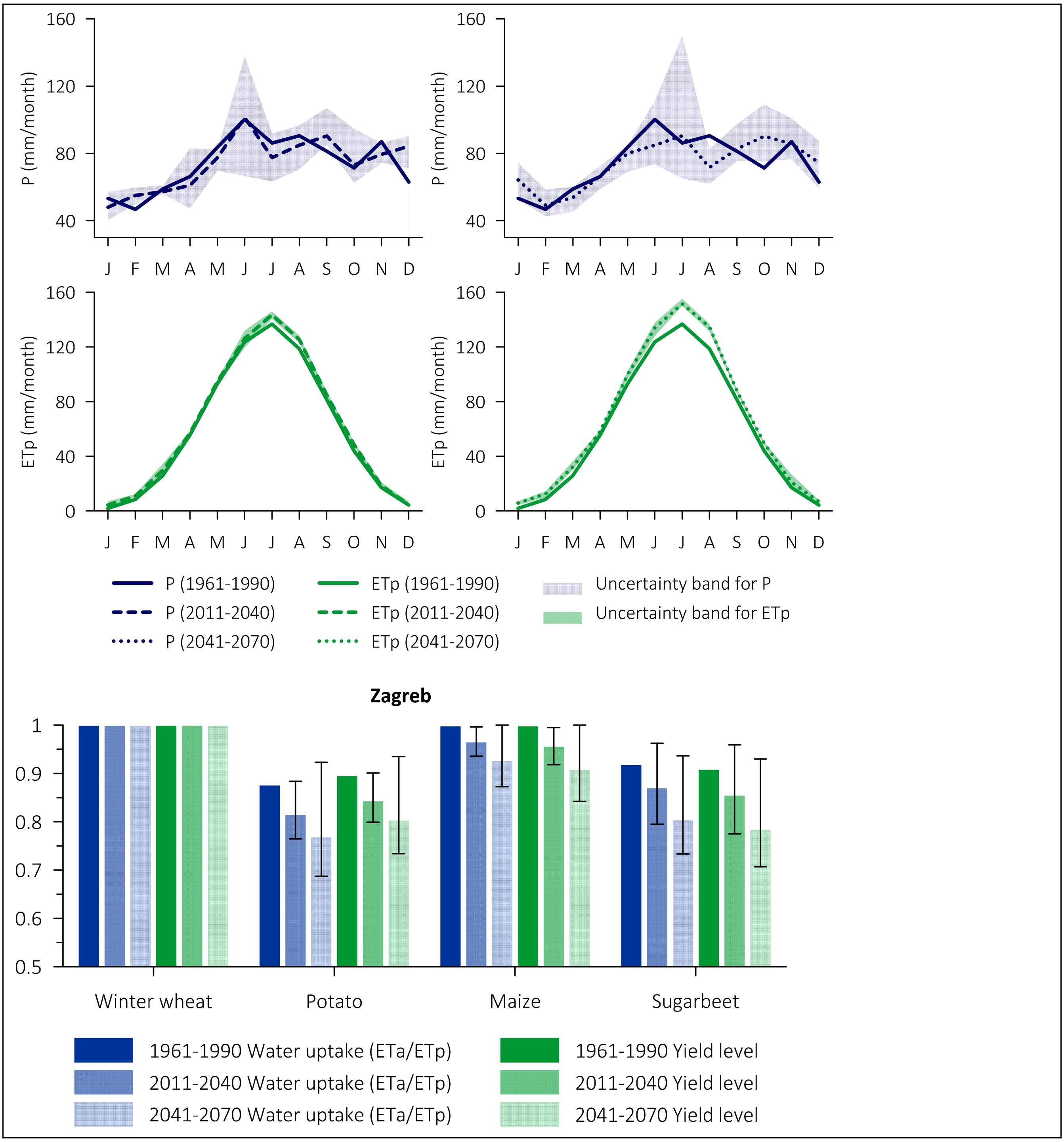
From the information gathered across the Basin, there is wide difference in the amount of land used for agriculture. In Croatia it is only 21%, whilst in Serbia it is 65%. The majority of the agricultural land is privately owned, whereas with forests most is under state control, with the exception of Slovenia where 72% of forest land is under private ownership. The overall trend is that agricultural land use is falling as more people migrate to urban areas. Nonetheless, agriculture still accounts for around 6-10% of GDP in the riparian states. The four representative crops used in the analysis for each of the riparian states were as follows:

- Slovenia – winter wheat, maize, potato and grapes;
- Croatia – winter wheat, maize, potato and sugar beet;
- Bosnia – winter wheat, maize, potato and tomato; and
- Serbia – winter wheat, maize, potato and sugar beet.

The impacts on the selected crops at the four selected locations were as follows:

- For Slovenia – Ljubljana was chosen that receives high - very high rainfall, with an average of 1405 mm/year (1961-1990). Precipitation is lowest in the winter and highest in the summer months. Climate scenario modeling shows rainfall slightly increases to 1415 mm/year (2011-2040) and 1425 mm/year (2041-2070), with an increase in winter precipitation and a slight decrease in summer precipitation. Precipitation greatly exceeds potential ET for most of the year, except for July. Model projections indicate that overall precipitation decreases slightly for the period April-August, and increases slightly in the winter from September to March. There is more uncertainty for future precipitation as opposed to uncertainty in evapotranspiration, which is primarily constant throughout the year. Predicted impact of changes in the crop water balance to the changes in precipitation and ET are minimal. The surplus rainfall in winter gets stored in the root zone, so most deep rooting crops have a significant water storage buffer. Therefore, the expected impact of climate change on the water balance of crops is minimal. The representative crops (winter wheat, maize and grapes) are not affected by water stress due to changing P and ET in part due to deep roots for maize and grapes. A slight yield decrease for potatoes is predicted in the longer time frame from 1.5% to 3.7% for the 2011-2040 and for the 2041-2070 periods respectively. There is a small uncertainty for potato and almost zero uncertainty for the other three crops stemming from the climate modelling results,

- For Croatia – Zagreb was chosen that has medium rainfall, with an average of 888 mm/year (1961-1990). Precipitation is lower in the winter months and higher in the summer months. Climate scenario modeling shows that precipitation increases very slightly to 890 mm/year (2011-2040) and 894 mm/year (2041-2070), with a slight increase in winter precipitation and a slight decrease in summer precipitation. Overall ET is projected to change more significantly than rainfall, increasing from 710 mm/year (1961-1990) to 748 mm/year and 794 mm/year respectively for the 2011-2040 and 2041-2070 timeframes. Almost all this increase would occur in summer months. However, there is a high uncertainty in future precipitation that is especially pronounced in the summer months. The uncertainty for evapotranspiration is much smaller and similar to Ljubljana, with a possibility for the summer evapotranspiration in the distant future to significantly increase compared to the near future. Model projections indicate impacts are pronounced in the crop water balance due to changes in P and ET. Surplus rainfall in winter gets stored in the root zone, so there is some storage buffer that suits winter wheat, but towards the end of the growing season, the summer crops (potato, maize and sugar beet) are experiencing water stress. Some water stress is already being experienced by potato and sugar beet, as a result of their relatively shallow root zone compared to maize, and water stress is projected to become more pronounced as the ET increases in summer, with significant yield reductions as a result. Due to high uncertainty in future precipitation, uncertainty in the crop modelling results is also considerable, especially for the distant future. Examples of the climate projections and the effects of water uptake and yield levels for selected crops for Zagreb together with uncertainties are shown in Figure 6-15 below.

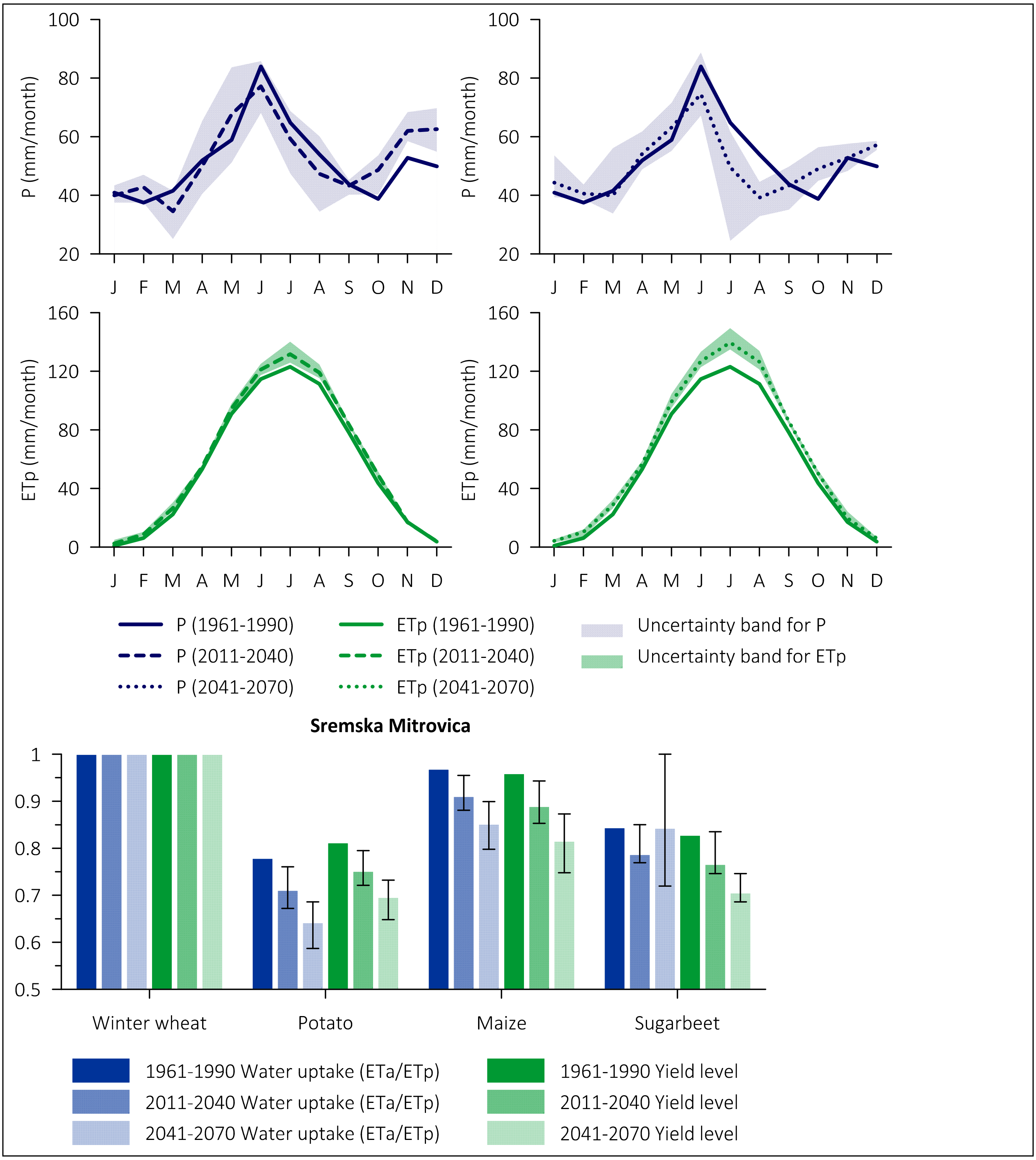


Source: Figure produced by COWI 2015 Error bars indicate uncertainties

Figure 6-15: Climate projections and water uptake (ETa/ETp) and yield levels for Zagreb with uncertainties

- For BiH – Banja Luka was chosen that has high rainfall, with an average of 1002 mm/year for (1961-1990). Precipitation is higher in early summer and late autumn and lowest in the early spring. Climate scenario modeling shows that precipitation decreases very slightly to 991 mm/year (2011-2040) and 950 mm/year (2041-2070), with a slight increase in winter precipitation and a decrease in summer precipitation. Overall ET is projected to change more significantly than rainfall, increasing from 651 mm /year (1961-1990), to 695 mm /year and 737 mm /year respectively for the 2011-2040 and 2041-2070 timeframes. Almost all this increase would occur in summer months, which is combined with a reduced summer precipitation in the distant future. There is a small uncertainty about the future evapotranspiration; uncertainty in future summer precipitation is somewhat greater, but the reduction is clearly visible. Model projections indicate impacts are pronounced in the crop water balance due to changes in P and ET. Surplus rainfall in winter gets stored in the root zone, so there is some storage buffer enabling winter wheat to be unaffected, but towards the end of the growing season, the summer crops are experiencing water stress. Some water stress is already being experienced by potato and tomatoes under the current climate conditions, as a result of their relatively shallow root zone compared to maize, and water stress is projected to become more pronounced as the ET increases in summer, with significant yield reductions up to 20% on average as a result. Although the uncertainty is propagated from the climate parameters, the yield reductions are clear for potato and tomato.

- For Serbia - Sremska Mitrovica was chosen that has medium-low rainfall, with an average of 619 mm/year (1961-1990). Precipitation is higher in summer and lowest in the autumn and early spring. Climate scenario modeling shows that precipitation increase slightly to 636 mm/year (2011-2040) and then decreases to 608 mm/year (2041-2070), with a slight increase in winter precipitation and a decrease in summer precipitation. Overall ET is projected to change more significantly than rainfall, increasing from 665 mm/year (1961-1990), to 712 mm/year and 753 mm/year respectively for 2011-2040 and 2041-2070 timeframes. Almost all this increase would occur in the summer months. However, precipitation at Sremska Mitrovica would significantly increase during winters in the near future and significantly decrease during summers in the distant future, although a degree of the summer reduction is fairly uncertain (for example, average reduction in July is 15 mm/month, but one climate modelling chain results in a reduction of 40 mm/month). Model projections indicate impacts are pronounced in the crop water balance due to changes in P and ET. Surplus rainfall in winter gets stored in the root zone, so there is some storage buffer enabling winter wheat to be unaffected, but towards the end of the growing season, the summer crops are experiencing water stress. Significant water stress and yield reduction is already experienced by potato, maize and sugar beet under the current climate conditions, as a result of a combination of root zone depth and low overall rainfall, and water stress is projected to become more pronounced as the ET increases in summer, with significant yield reductions up to 30% on average as a result. The uncertainty is propagated from the climate parameters, but the yield reductions are clear not only for potato and sugar beet, but also for maize and provide potential justification for farmers to consider a move to more drought tolerant crops in the future. Examples of the climate projections and the effects of water uptake and yield levels for selected crops for Sremska Mitrovica together with uncertainties are shown in Figure 6-16 below.



Source: Figure produced by COWI 2015 Error bars indicate uncertainties

Figure 6-16: Climate projections and water uptake (ETa/ETp) and yield levels for Sremska Mitrovice with uncertainties

In general, the riparian states have made no specific analysis on the impacts on agriculture as a result of climate change. The only exception is Slovenia that has a recent sector strategy for adaptation in agriculture and forestry. Consequently, the main impacts to agriculture have been abstracted from the riparian states' National Communications for Climate Change, a requirement of the United Nations Framework Convention for Climate Change (UNFCCC). Slovenia and Croatia are currently on their 5th National Communication, whilst BiH and Serbia are on their Initial Communications.

The general consensus for all of the four riparian states is that overall impacts of extreme events (heavy rainfall, storms, hail, floods and droughts, heat-waves and frost) will occur more often or with more intensity that will test the current systems and impact the economy of SRB countries. The resulting evaporation from temperature rise will create more aridity and increase probability of forest fires occurring. Higher temperatures will affect crop development and cause heat stress in livestock and increase likelihood of pests and diseases in crops and animals. There may also be phenological changes leading to altitude and latitudinal shifts of plant ranges.

Lower river flow will impact agriculture (i.e. more stress on irrigation). This is because the overall reductions in availability of water in the river will be in the summer months when irrigation demand and withdrawals are at their highest. There will be greater probability of droughts and frosts occurring. Climate models have indicated that the impact of vulnerability in the SRB will increase the further south and east within the basin.

In the future, there may also be possible spatial conflicts where decisions will need to be made whether to use areas as agricultural land or for flood protection. Also, producer and consumer prices for agricultural products might increase.

On a positive note, climate change may provide an increase to the growing season with longer summers, and warmer winters, which may provide more potential for an increase in agricultural production for selected crops that require less watering.

7 Partial and Preliminary Economic Evaluation of Climate Change Impacts in the SRB

With the dissolution of the Federal Republic of Yugoslavia in the early 1990's, the Sava River became by default one of the biggest and most important international waterways in the South East Europe (SEE) region and hence of significant economic importance.

As mentioned in Chapter 2, the SRB (Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia and Slovenia) connects three South-European capitals: Ljubljana (Slovenia), Zagreb (Croatia) and Belgrade (Serbia) and is the largest right hand tributary of the Danube River Basin, with a total length of 945 km draining a surface area of 95,719 km². The SRB is home to about 8 million people; around 46% of whom reside in the four main riparian countries (Slovenia, Croatia, BiH and Serbia).

7.1 Objectives of the Economic Evaluation

The principal objective of the economic evaluation is to measure the expected economic costs of climate change impacts on selected crops and adaptation options under alternative water regime scenarios in the SRB. This analysis aims to capture climate change impact at the sector and economy-wide level.

7.2 Scope and Approach to the Economic Evaluation

The economic evaluation covered a slightly different area compared to the other analysis, taking in Albania and Macedonia, as well as the four main countries that make up the SRB, namely Slovenia, Croatia, BiH and Serbia.

The study adopted an integrated approach combining crop modeling with an economy-wide analysis in three steps:

- First, a methodology to estimate the change in crop production based on the changes in several climate variables was developed.
- Second, an economy-wide model for the SRB countries was developed to describe the most likely economic growth path for the regions without taking into account the potential impact of climate change.
- Third, the economy-wide model and the crop model were combined to obtain a better understanding of the impacts of climate change and adaptation options.

7.3 Sources of Data

The economic evaluation used data from various sources. However the principle ones were:

- GCM/RCM analysis,
- Global Trade Analysis Project (GTAP) country specific data for Slovenia, Croatia and Albania
- World Bank projections (2009-2015),
- IMF-World Economic Outlook data (2007-2015),
- OECD data (2007-2009): Slovenia,
- United States Department of Agriculture (USDA),
- FAO data on crops (2007-2009): Slovenia, BiH, Croatia, Albania, Montenegro & Serbia,
- Experts from riparian states, and
- National statistics.

7.4 Models Used

For this economic assessment, multiple analytical tools were used to provide a better understanding of the climate change impact in the SRB and the related adaptation policies, including:

- At the systems level (using GCM),
- At the economy-wide level (GTAP - Computable General Equilibrium (CGE), and
- At the sectoral level (using GTAP-CGE, CROPWAT-FAO).

7.4.1 GTAP-CGE Model

The static comparative GTAP - CGE model (version 8) was used in recursively in this analysis for 30 consecutive years. [30] The standard GTAP-CGE model/data covers 113 countries and 57 sectors which were aggregated into 5 regions as Albania, Croatia, Slovenia and the rest of SRB (e.g. Montenegro, BiH and Serbia). The 57 sector disaggregation was maintained to allow multi-country/multi-sector analysis measure Climate Change implications at the Sectoral/National/Regional (SRB) levels.

The GTAP database for SRB was complemented with statistics from WB/IMF sources, from national statistics and from previous modeling studies.
GTAP database was disaggregated further to comprise the crop categories used in CROPWAT[31].

The GCE model covers 16 sectors and eight of these are in Agriculture as shown below:

Agriculture Sectors
- Paddy rice;
- Wheat;
- Other cereal grains;
- Vegetables, fruit, nuts;
- Oil seeds;
- Sugar cane, sugar beet;
- Plant-based fibers; and
- Other crops.

Other Sectors
- Forestry,
- Electricity,
- Water services (utilities),
- Trade,
- Air transport,
- Sea transport,
- Other transport, and
- Rest of the economy.

7.4.2 CROPWAT Model

CROPWAT (version 8.0) is a simulation model to determine the crop water use and irrigation requirement of crops given mean climate variables over a growing period. [32] CROPWAT includes a standard method, which is a revised estimation from the crop evapotranspiration reference, adopted from the original Penman-Monteith approach, as recommended by a FAO Expert Consultation held in May 1990 in Rome.

Standard FAO crops used the climate data provided from the experts from the different riparian states that were working on the WB project.

A standard calculation uses:

1) The climate data to simulate evapotranspiration for the region,

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[30] CGE models specify all their economic relationships in mathematical terms and put them together in a form that allows the model to predict the change in variables such as prices, output and economic welfare resulting from a change in economic policies, given information about technology (the inputs required to produce a unit of output), policies and consumer preferences. They do this by seeking prices at which supply equals demand in every market goods, factors, foreign exchange. One of the great strengths of the CGE models is that they impose consistency of one's view of the world, e.g., that all exports are imported by another country, that the sum of sectors' employment does not exceed the labor force, or that all consumption be covered by production or imports. This consistency can often generate empirical insights that might otherwise be overlooked in complex policy analysis - such as the fact that import protection gives rise to an implicit tax on exports.

[31] The mapping between GTAP database and CROPWAT was developed by the GTAP team based in Purdue and the World Bank experts.

[32] CROPWAT is a practical tool to help agro-meteorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain fed conditions or deficit irrigation

2) Water demand for the crop of interest, and
3) The irrigation needed for the given climate to predict the crop yield (vice versa).

The CROPWAT model can forecast yield changes and crop water status for different crop types

As can be seen the CROPWAT model is developed using FAO data which differs from GTAP databases' classification. Hence a mapping at the crop level was developed between GTAP and FAO classification.

7.4.3 Baselines

For both the GCE and CROPWAT models, the baseline refers to the most likely economic growth path that the SRB countries are expected to follow and does not take into account any potential climate change impact. The baseline is used as the reference scenario against which the climate scenarios will be compared.

The model baseline simulations consist of using the CGE model to replicate the SRB countries' growth performances predicted by the IMF for 2009-2015, these projections are then extended to 2070 using information from different sources (e.g. USDA). This exercise comprises three steps:

- First, population growth forecast are used as an input; shocks corresponding to the annual population growth are applied to the base year population data for each country represented in the GTAP database
- Second, the Total Factor Productivity (TFP) growth estimates (from the literature) are applied as a shock to the initial model parameters
- Finally, the capital accumulation parameter is adjusted in order to reach the GDP growth estimates developed by the IMF and USDA.

7.4.4 Simulations

The simulation exercise adopted a multidisciplinary approach. Different modeling techniques are combined to provide a robust effort in understanding the impact of climate change on Water Resources in the SRB. Based on historic trends, future projections and various scenarios have been developed with regard to temperature and precipitation. On the basis of technical analyses of historic meteorological and hydrological data trends, the General Circulation Model (GCM) projections was used (e.g. CLM, HadRM3Q0, RACMO, REMO and RegCM3). Then using the WATCAP model, climate change impact is then translated into yield changes for each crop produced in different SRB countries for the 2040 and 2070 horizon.

These yield changes are introduced as productivity (TFP) shocks into the CGE model. These generate a ripple effect through price changes that will be reflected to the market prices of analyzed crops which down the line will have an impact on consumer welfare, external trade and growth.

7.5 Results of Simulations on Climate Change Impact

Countries facing a severe impact of climate change on the agricultural sector will witness rising agricultural prices which will be reflected to higher consumer prices. Rising prices will negatively affect consumer's disposable income and incentivize them to substitute the consumption of agricultural goods with less expensive commodities or imported agricultural products.

Simulation have been undertaken to assess yields and prices. According to the model simulations for yield there is a marked variation depending on the GCM used. Results indicate yields may vary from the baseline from -6% to +3.5% for each crop and producing country through time. Regarding crop prices, with the exception of Winter Wheat, crop prices will rise with respect to the Baseline scenario (i.e. climate change impact not taken into account). Serbia and BiH are the most vulnerable regions where the price hikes are predicted to be the highest. The CGE model signals different price changes according to the choice of the GCM climate model: the lowest and highest values are predicted as 8%-18% for Winter Wheat; 15%-80% for Potato, Grape, Tomato; Maize and Sun Flower; and 5%-100% for Sugar Beet. Thus, the predicted price variation between regions is the highest for Winter Wheat and the lowest for Sugar Beet. For a majority of the crops the price variation varies between 15% and 80% compared to their 2010 prices, according to the CGE model simulations.

8 Adaptation strategies for the Sava River Basin

This chapter assesses the different adaptation strategies for the SRB which are principally taken from guidance notes (contained in separate Annexes 2 through to 5 inclusive) from several case studies covering the following sectors:

- Navigation,
- Flood control,
- Hydropower, and
- Agriculture and Irrigation,

However, before dealings with the specific adaptation measures associated with the case studies it is important to assess the main framework policies relevant for climate change adaptation and also the levels of uncertainty involved with such adaptation strategies.

8.1 Main Framework Policies

The main framework policies that are relevant for climate change adaptation in the SRB are:

- the EU Water Framework Directive 2000/60/EC (WFD) together with many associated “daughter directives” and
- the EU Floods Directive 2007/60/EC (EFD)

In addition, the European Commission’s policy on Water Scarcity and Droughts and the EC’s White Paper on Adaptation are also very important. The riparian states within the SRB have all adopted EU WFD and the EFD in their respective legislation in the process to join the EU.[33]

8.1.1 EU Water Framework Directive

Although climate change is not specifically mentioned in the WFD, it establishes a legal framework for protecting and restoring the water environment and ensuring long-term sustainable use of water. Part of the WFD requirement is the production of the RBMP and the associated program of measures. The step-wise and cyclical approach to the WFD and the RBMP in particular (requiring renewal every 6 years) makes it well suited for introducing, coping with and responding to medium- and long-term implications of climate change. It is therefore important that the program of adaptation measures has the necessary flexibility to enable adjustment to changing climate, or if of a fixed nature, that climate change considerations are incorporated into the measures’ design.

8.1.2 EU Floods Directive

The EFD enables the establishment of a legal framework for management and assessment of flood risk with the intention to reduce the adverse consequences of flooding to the environment, cultural heritage, economic activity and human health in particular. In a similar cyclical manner to the WFD, the EFD requires the preparation of flood risk management plans (FRMP) together with flood hazard and flood risks maps that are updated every 6 years and, hence, are suited for introducing, coping with and responding to medium and long-term implications of climate change. The EFD explicitly includes climate change in its wording, requiring an assessment of the impacts of climate change on flood occurrence.

8.1.3 National Adaptation Strategies

National Adaptation Strategies (NAS) provide a focus on assessment of the present situation and on the requirements for climate change. The current status of NAS within SRB is that NAS is in

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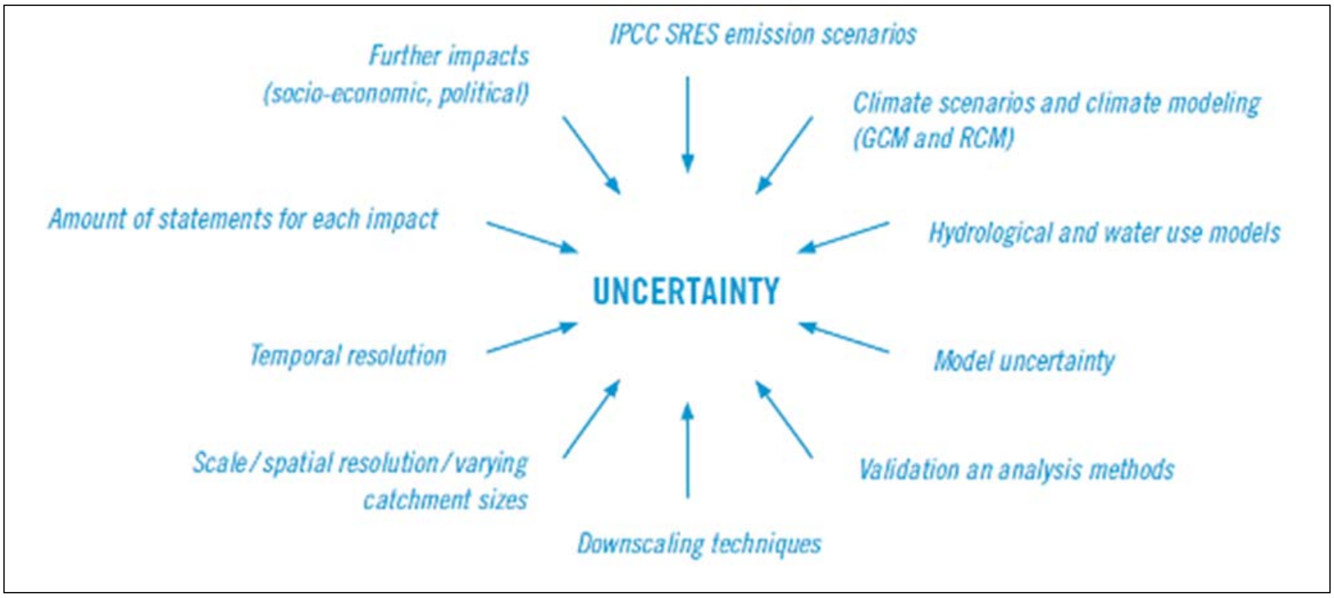
[33] Slovenia and Croatia have fully adopted WFD and EFD as they are already within the EU, other states have partly accepted and partly adopted the directives but will need to fully adopt them before joining the EU.

preparation in Slovenia, BiH and Serbia, whilst there is currently no NAS in Croatia and Montenegro.[34]

In terms of European Policy the EC White Paper on Adaptation (European Commission, 2009), together with the UNECE Guidance on Water and Adaptation to Climate Change are important for climate change. The latter is a useful support to decision makers by providing advice on challenges caused by climate change to water management, water related activities and for developing adaptation strategies (UNECE, 2009).

8.2 Dealing with Uncertainty

Making predictions on the fact that climate change will occur is not an exact science and there are elements of uncertainty. There are a number of factors that influence the certainty of statements concerning climate projections and climate change related impacts. The ICPDR has undertaken research into this topic for the Danube Basin and this was presented at the 3rd Consultation Workshop on the UNECE Sava Pilot Project, in Zagreb, 5-6 June 2013. The Figure 8-1 below shows the main factors influencing uncertainty in climate change analysis.



Source: ICPDR Strategyon Adaptaiton to Climate Change

Figure 8-1: Main Factors influencing uncertainty in climate change analysis

Picking at random specific topics of uncertainty from Figure 8-1, for example, there are different RCM used and in some catchments different hydrological models used also. There are different methods applied for validation and analysis of projections. In order to obtain climate change data, different downscaling techniques are used from the global level to regional and local scale. In addition, other factors such as socio-economic and political impacts can influence climate change.

To give "uncertainty" some tangibility, three variables were used 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 analyzed studies.

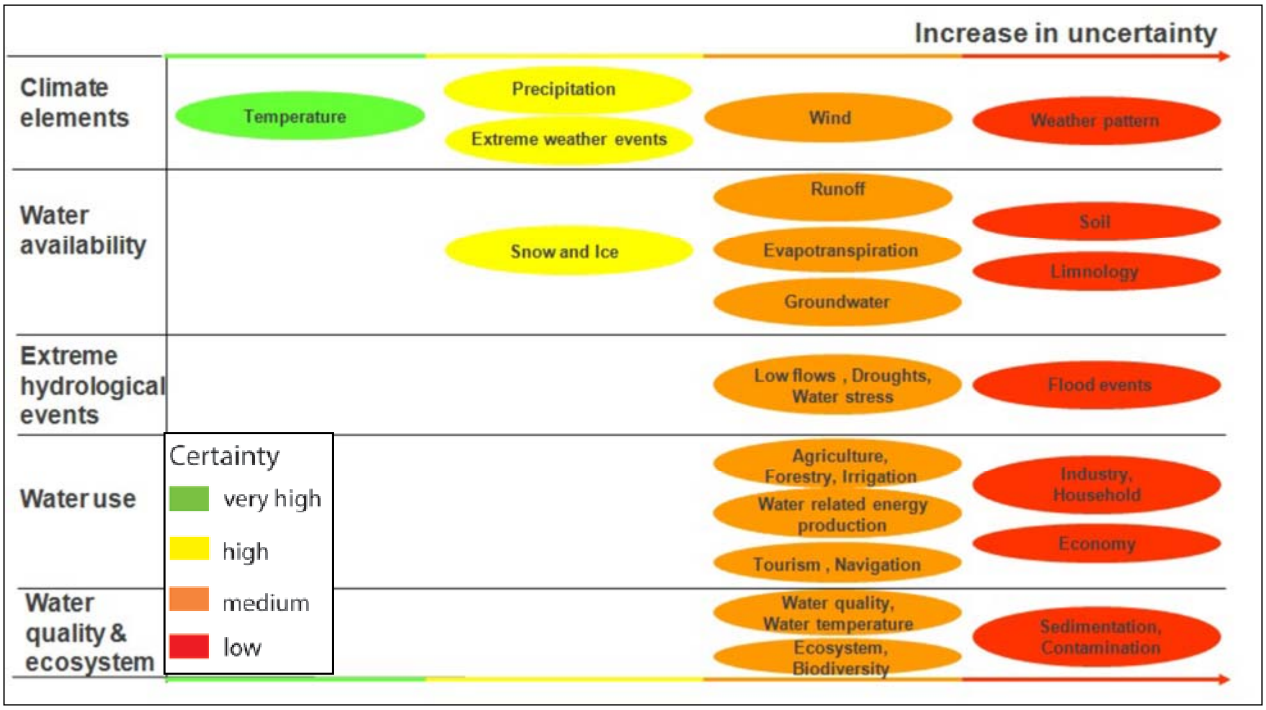
For each of the three variables, four certainty-categories were defined: very high (green), high (yellow), medium (orange), and low (red). If for example, the amount of all projects and studies considering one special impact is large and the agreement and certainty assessment is high, the certainty-category indicates a high overall certainty. However, if the amount of all projects and

[34] In Croatia and in Montenegro, there are National Action Plans as well as other communications under UNFCCC that mention and deal with climate change

studies is high, but the agreement or the certainty assessment of the statements and results is low, the certainty-category shows a medium-ranged overall certainty.

The following Figure 8-2 gives an overview about the degree of uncertainty of the climate elements and the main impacts considered in this ICPDR study and it is clear that such uncertainties hold true for the SRB. The impacts are assigned to five impact areas covering:

- Climate elements,
- Water availability,
- Extreme hydrological events,
- Water use, and
- Water quality and ecosystems.



Source: ICPDR Strategy on Adaptation to Climate Change

Figure 8-2: Uncertainty of climate elements and main impacts due to the four certainty-categories

So for climate elements, changes in temperature are classified with very high certainty (green), because many studies predict increases in mean annual and seasonal temperature. The certainty of the future development of precipitation is high (yellow), however this is not as reliable as temperature changes. Similarly in the future, extreme weather events are classified with a high certainty, and are likely to show more variability in quantity, seasonality and space.

In terms of water availability; certainty of changes in water storage through snow and ice is high, due to predicted changes in winter precipitation from snow to more rain, but predictions in quantity are less reliable. The impacts, runoff, evapotranspiration and groundwater are all rather uncertain and classified with a medium (orange) certainty. Changes in water availability depend largely on precipitation, which shows indications of decrease in the SRB. There are only few reliable findings on changes in soil water and limnology; hence these impacts were classified with low certainty (red).

Projections of extreme hydrological event are more uncertain than the changes in the mean water availability. Climate change impacts on low flows, droughts and water scarcity have a medium rating but are considered more reliable than flood events which have a low certainty. For example, as discussed in the previous chapter, navigation could benefit in winter due to less icing, but in summer shipping may be restricted due to more days with low water conditions. Similarly for hydropower production, power generation might possibly increase in winter with greater water availability and decrease in summer. The impacts on industry, household and economy are categorized with low certainty due to little available information.

Uncertainty related to climate change impacts on agriculture are embedded into the models by using estimates of climate induced crop yields from five different climate model chains. The uncertainty from temperature and precipitation projections propagates to the crop yield projections and can therefore be classified as a medium uncertainty (orange). Additional uncertainty is introduced in the economic evaluation of the impacts in agriculture from the assumed economic parameters, resulting in very high (red) uncertainty class.

Water quality and ecosystems are classified as medium certainty (orange), as climate change could cause water quality to deteriorate as water temperatures increase. This could also imply that aquatic ecosystems and biodiversity may become more vulnerable with medium certainty. There is little available information on sedimentation and contamination, hence this impact area has been designated a low certainty. Notwithstanding, for all the impacts within the water quality and ecosystems quality are open to conjecture as quantitative, seasonal and spatial changes are not clear.

8.3 Preparatory Steps for Adaptation Measures

The following preparatory steps need to be considered and undertaken for adaptation:

- Overall vulnerability of sectors to climate change should be determined.
- Existing monitoring networks should be enlarged by adding further measuring stations or increasing the amount of observed parameters, particularly with regard to climate change.
- The observed data need to be provided and stored in homogenous data formats so that they can be easily exchanged by the riparian countries within the SRB.
- Based on these monitoring observations, information systems, forecasting and early warning systems should be implemented in different water related fields, e.g. floods, droughts or water quality.
- There is also a common agreement in the activities on the demand for further research to identify knowledge gaps and to reduce the uncertainty as mentioned in section 8.2 above.
- Development of hydrologic and hydraulic models capable of integrating impacts of existing and in development hydraulic structures and storages on the river flow regime into the model.
- Education, training and information campaigns should be carried out to raise public awareness. This also includes capacity building and strengthening the exchange among institutions on local, regional, and transboundary levels.
- The implementation of integrated RBMPs is supposed to involve coordinated management of the protection and use of all water bodies so that ecosystems functions are also taken into account, which provides options for transboundary cooperation, but challenges among different groups and water users might also arise.
- In addition cooperation in risk management systems and an intensified dialogue with knowledge transfer among institutions seems to be an important adaptation measure.
- Increase of flood protection in major urban areas.
- Water saving measures or other behavioral measures.
- Construction or modification of infrastructure, e.g. dams, reservoirs, river beds, retention areas, as technological measures.

8.4 Sector Specific Adaptation Measures

In the following sections, the climate change impacts on water related issues mentioned in earlier chapters and their possible adaptation measures resulting from the analytical work in the guidance notes of the sectors are considered. This deals with the specific topic case studies covering navigation, flood control, hydropower and agriculture/irrigation covered in the guidance notes in Annex 2 to Annex 6 inclusive.

Following on from the public consultation in July 2014, the adaptation measures were discussed at a stakeholder workshop on 10th November 2014 in Zagreb. Following the workshop, the stakeholders were requested to make their own prioritization for the WATCAP main report and for the sector specific guidance notes.

Responses were received from the following six organizations that represent a good cross section of stakeholders:

- Republic Hydro-Meteorological Services of Serbia
- Lonsko Polje Nature Park Institution
- Public Company "Luka Brčko" Doo
- Ministry of Agriculture, Water Management and Forestry , FBiH
- Centre for Environment
- Green Home

The scores provided from the above stakeholders were combined with the mean score from the WATCAP consultant (seven stakeholders in total). The combined scores were then totaled and an average score for each adaptation measure was then calculated.

The scoring system used three levels – "high - 1", "medium - 2" and "low-3". The average score was then obtained from the combined scores to establish the final prioritized list and ranking of recommended adaptation measures for the WATCAP main report and for the guidance notes.

The scores from the stakeholders for the WATCAP report and sector specific guidance notes are summarized in Appendix A.

The following subsections review the adaptation measures from the Guidance Notes and the main WATCAP report which are highly ranked by stakeholders. Some measures proposed in the analytical work presented in Guidance Notes were given low priority by stakeholders, but they are also presented for completeness.

8.4.1 From Flood Protection Sector

Highly ranked adaptation measures by stakeholders are:

1. Development of Sava flood forecasting system.
2. Further development of Strategies and Plans on climate change.
3. Protect and restore water retention areas, including natural retentions.

The Flood Guidance Note strongly emphasizes the need to give more space to rivers not only by using the natural wetlands and floodplains for flood control, but also by deepening and/or widening the river channels. Introducing the flood hazard maps into the spatial plans and prohibited or controlled development in flood plains is also considered of primary importance. The Flood Guidance Note also recommends increasing the level of protection of towns along the Sava River which are facing the increased risk due to migration and urbanization.

8.4.2 From Hydropower Sector

Highly ranked adaptation measures by stakeholders are:

1. Assess consequences for the ecology of rivers from HPP and ensure adequate environmental flow downstream at all times; consider the location of power plants in relation to the natural environment, especially the aquatic environment downstream.
2. Risk assessment concerning climate change effects for the hydroelectric sector.
3. Move towards mandatory reporting for hydropower companies for river flow and discharge to improve future monitoring.

8.4.3 From Navigation Sector

Highly ranked adaptation measures by stakeholders are:

1. Better monitoring of meteorological and other variables of interest for ice and fog formation (air temperature, air humidity, wind; water temperatures), and better monitoring of river water levels.
2. More research into a River Information System to improve forecasting.
3. Better reservoir management in low-flow conditions, combining any increased water storage for navigation with habitat creation initiatives, and establishing a sustainable and well-coordinated approach to ship waste management based on the "polluter-pays" principle.

Measures related to adaptation of transportation and fleet proposed in the Navigation Guidance Note (e.g. making better use of the season with high river flow; support container shipping with shallow draft vessels) were given low priority by stakeholders. Structural measures also proposed in the Navigation Guidance Note involving dredging to ensure sufficient water depth, and upgrading and expansion of river and port infrastructure were given the lowest priority by stakeholders.

8.4.4 From Agriculture Sector

Highly ranked adaptation measures by stakeholders are:

1. Establish/enhance early warning systems for droughts and other extreme climate episodes of importance to agriculture.
2. Promote water retention in the agricultural landscape especially in drought prone areas.
3. Introduce sustainable resource and land management systems.

Adaptation through the agricultural technology is seen by stakeholders in encouraging more environmentally compatible farming methods to preserve and improve biodiversity rather than in selecting more resilient crop species or adapting sowing patterns and harvest dates to changing climate conditions.

The stakeholders failed to recognize increased irrigation as an important adaptation measure in spite that the analytical work has indicated that irrigation is an adequate adaptation mechanism to mitigate water stress of crops induced by climate change.

8.4.5 From Main Report

Highly ranked adaptation measures by stakeholders are:

1. Ensure that all infrastructure has adequate capacity to deal with the full range of precipitation levels
2. Undertake modeling of Sava tributaries for evaluating flood risk and vulnerability.
3. Fast track planning process and seeking additional funding for wastewater treatment plants in the SRB.
4. Undertake an updated hydrologic study of the SRB (including for droughts).
5. Improve data records by promoting mandatory reporting procedures (through a legislative process) from riparian governments.
6. Further development of the HEC-HMS hydrological model developed for WATCAP.
7. Undertake digitization of the substantial historical data that exists from the past century.

The main report also advocated improvements to data collection, data sharing and better coordination in the basin as well as improvements in analysis. However, the stakeholders did not consider these issues as high priority.

It is important to emphasize that many of the recommended adaption measures mentioned above are not dependent upon future climate prediction; hence, there is no reason to delay their implementation. This is especially true for flood prediction and flood management measures. Since the devastating May 2014 floods, the IFIs including the World Bank and the EU have planned and started implementation on projects valued at more than Euro 410 million (DG ELARG 2014) in the West Balkans. This includes an enhanced flood prediction and weather forecasting system for the ISRBC for the SRB, flood risk mapping and flood hazard mapping projects in BiH, Croatia and Serbia along with a number of initiatives on improved flood protection and flood management.

Uncertainty related to the climate change impacts introduces some level of risk to implementation of the adaptation measures. This is especially true for the long-term measures, the effects of which extend to the distant future where the uncertainties are the highest. The uncertainties are therefore an important factor for decision making about the irreversible investments in the adaptation measures. For example, there might be a smaller investment risk for flood management by providing additional storage for excess water in the natural retention areas than by building man-made reservoirs. However, with the improved climate and impact modelling over time, and with some measures already in effect, the uncertainties could be reduced. Therefore, an important point is that adaptation planning must be regularly reassessed, so that any new developments and new modelling work are taken into consideration.

9 Conclusions and Recommendation

9.1 Summary of the results

A WATCAP has been successfully prepared for the Sava River Basin using trust funds from the World Bank's WPP and the Trust Fund for Environmentally & Socially Sustainable Development (TFESSD).

A review of background data from the Basin and a water resources overview has indicated that:

- The Sava River is very important for the overall Danube River Basin system and hosts the largest complex of alluvial wetlands together with large lowland forest complexes. These areas are cradles of biological diversity, providing the means upon which countless species of plants and animals depend for survival.
- The SRB is also especially sensitive to climate change not only due to socio-economic factors (that are particularly bad since the time of the global financial crisis of 2007 and a general migration of the population away from agricultural areas towards cities), but also due to the past legacy of the former Federal Republic of Yugoslavia that provided poor environmental management.
- Consequently, the SRB bears the aging infrastructure, which is poorly constructed and badly maintained, and housing, which is ill-suited to cope with storms, floods or heat waves, or to protect its people from the impacts of such extreme events.
- Core issues within the SRB that have been found to be important in the context of climate change are navigation, flood protection, agricultural water management/irrigation, hydropower and public water supply, as the sectors that are most vulnerable to the impacts of the increasing temperature and decreasing river discharges.

The following subsections summarize the results from the main tasks of the WATCAP study.

9.1.1 Trend Analysis

The trends analysis has shown the following conclusions:

- The analysis of the historical climate data generally shows warming trends in temperature, a changing hydrology and more extremes of weather such as floods, droughts, heat waves, windstorms, forest fires and other forms of climate-induced natural disaster.
- Overall, the precipitation data are showing small or negligible long-term trends that do not validate the downscaled GCM outputs, suggesting a need for caution in employing model outputs as the basis for large scale planning. Experts agree however, that local influences and multi-decadal oscillations are at work affecting precipitation.
- Although discharge is declining on an annual basis, it appears that the declining trend affects mean more than it affects minimum flows. This suggests that infrastructure aimed particularly at managing minima does not necessarily need rehabilitation, but rather an ability to store additional water.
- The probability of flooding will increase significantly principally in the Alpine and the Dinaric mountain regions that will increase flood hazards along the main stream of the Sava River. Protection against flood risk should therefore be increased for large urban areas.
- That historic hydro-meteorological data and resulting trends can benefit water management in terms of planning for infrastructure and IWRM within the basin; however, the results of the analysis should be treated with caution.
- That within the SRB, the Pannonian Plain is the main region where water resources are at highest risk, where precipitation occurs in the warmest part of the year. These areas are particularly exposed to rising evapotranspiration as an outcome of rising mean temperature.

Runoff may decrease significantly under these circumstances, potentially affecting rain-fed agriculture directly and altering the demand for irrigation water.
- That agriculture is likely to be affected by rising mean temperatures. If crop species are selected for planting in light of climate change, care should be taken to ensure that species selected are adapted to the change that is actually occurring: namely a reduction in the occurrence of low temperatures and an increase in the occurrence of high temperatures. .

9.1.2 Climate Modeling and Future Climate Scenarios

Work on future climate modeling found the following conclusions:

- The results of the future climate analysis based on the methodology involving probability distribution functions (PDF) developed in the Bayesian framework have shown that future precipitation showed a change consistent with those found in other climate change studies using GCM, whilst predictions in temperature and evapotranspiration were completely out of the climate variability range observed and were not found useful. Therefore, the approach was not applied in the subsequent tasks.
- The future climate scenarios are developed by using the bias-corrected and downscaled outputs from publically available GCMs. An ensemble of five GCM/RCM outputs was developed, driven by the same A1B IPCC/SRES scenario of GHG emissions which is a mid-level intensity scenario and is commonly used for many climate change analysis and impact studies.
- All five GCM/RCM model chains showed a temperature increase at all stations and for all seasons for the future timeframes 2011-2040 and 2041-2070, with the latter period showing greater temperature increase values.
- The precipitation change is more complex. It shows only a slight decrease on the annual level, but in general it shows an increase during the winter and a decrease for the summer months. Summer precipitation deficit is more pronounced in the 2041-2070 period. Very similar conclusions were drawn from the separate study by the University of Ljubljana that was based on 16 GCM/RCM model chains from the same gas emission scenario (A1B).
- The climate modeling by the University of Ljubljana was also used to analyze changes in maximum daily precipitation in autumn across the basin as one of the indicators of flood hazard. The analysis has shown that maximum daily precipitation in autumn will increase till the end of 21st century on average by 22% for the 20-year return period and by 32% for the 100-year return period. Greater increase is characteristic for the edge of the SRB from the northwest to the southeast and in the area of the Dinaric Mountains, and smaller increase for the central part of the SRB.
- The historical trends in temperatures agree with those predicted by GCM outputs only in trend direction (rising temperatures), but the two approaches quantify this increase differently. Precipitation tendencies as given by trends and by GCM outputs do not correlate highly, but the spatial patterns of these tendencies across the basin are so variable both from trends and from GCMs thus indicating presence of a very high uncertainty in future precipitation.

9.1.3 Hydrologic Modeling and Future Hydrologic Regime

Using the HEC-HMS modeling software, a hydrologic model for the SRB has been successfully developed that is capable of reproducing month-to-month or year-to-year runoff variations reasonably well across the basin. The following conclusions can be made:

- The model is built to simulate natural runoff only and due to the limitation on the quality of data, the anthropogenic effects on stream flow (e.g. from dams) are not included.
- Poorer results are related to the locations where a doubt exists about validity of measurements and/or good representation of precipitation over the sub-basin, or where complex geological structures (e.g. karst) would require more complex runoff estimation methods.

Simulations of the future hydrologic regime by the hydrologic model with future climate scenarios provided the following conclusions:

- The most notable change in both near and distant future is the increase of winter runoff for 11% and 13% respectively on average. Higher winter temperatures and increased winter precipitation suggest that there would be either a smaller share of snow compared to rainfall or more snowmelt. This increase is evident from all five climate scenarios in both future time frames and over the whole basin.
- A substantial decrease of spring and summer runoff is expected. The spring decrease is clear in both near and distant future over the whole basin, being greater in the distant future with greater variation over the basin. The summer runoff decrease is less clear in the near future (one climate scenarios indicate an opposite trend), but evident in the distant future with a substantial reduction by about 15% on average over the basin.
- The autumn season exhibits a very small change on average for both near and distant future. There is no clear signal from five climate scenarios, resulting in an almost negligible change in ensemble median runoff in the near future (on average +0.4%) and a slightly more pronounced change in the distant future (on average -3.3%).
- The overall change in mean annual runoff is small as a result of opposite winter and spring/summer trends. The five climate scenarios produce different signals across the basin, resulting in a small decrease of 1.4% on average in ensemble median runoff for the near future and of 4.7% on average for the distant future.
- Low and high annual flows, defined as the flow with 10% and 90% respective probability of exceedance in the 30-year series of mean annual flows, are both subject to a reduction, smaller for low flows and slightly greater for high flows. This means that the proportion of very dry years would slightly increase, while the proportion of very wet years would decrease.
- Future extreme low flows are assessed using the minimum mean monthly flows with 80% and 95% probability of exceedance (denoted Qmm80 and Qmm95) as indicators, with an assumption that there is no influence of any water management controls on low flows, such as storage or withdrawal. The results indicate that the extreme low flows are not likely to change in the near future, while a significant decrease could be expected in the distant future downstream of Jasenovac for less than 14%.

Another hydrologic model, developed earlier by University of Ljubljana in Slovenia using the HBV modeling software, was also used to simulate climate change impacts on floods in the SRB. Un-like the model developed in HEC-HMS, the HBV-based model was specifically calibrated for flood flows and its results served to develop the Flood Guidance Note. Based on the output of this hydrologic model, the probability distributions of future floods were derived for hydrologic stations along the Sava River to enable estimation of future floods. The conclusions about the future flood flows are:

- The hydrologic projections indicate that the floods will increase in future due to climate change. The increase has been shown to be greater for 100-year floods than for the 20-year floods, thus suggesting an overall increase of the flood risk.
- The greatest increase of floods is expected in the head part of the Sava River Basin, i.e. in Slovenia (the Čatež hydrologic station) and in the main right tributaries (Kupa, Una and Bosna). By the end of 21st century, the 100-year floods along the Sava River will increase for more than 50% at Čatež, for about 15% between Zagreb and Slavonski Brod, for 25% at Županja, and for 9% at Sremska Mitrovica.
- The predicted floods on the Drina River and in the lower Sava downstream of Sremska Mitrovica are smaller for late 21st century than for middle 21st century; however, this could be a result of fewer precipitation projections used for 2071–2100.

9.1.4 Sector Specific Climate Change Impacts

Impacts from climate change scenarios have then been assessed across the main sectors covering floods, hydropower, navigation and agriculture.

Floods

The analysis of climate change on floods provided the following conclusions:

- The climate change impact on floods is significant and should not be neglected. The flood impact differs significantly within the Basin; decreasing in the mountainous regions to the plain, but also from the west to the east. However, the role of the flood protection infrastructure should not be ignored since the infrastructure protecting the upstream regions is at the same time increasing the downstream risk.
- The main predicted flood impacts are associated with future social and economic infrastructure development; essentially through urbanization.
- The floods affecting the SRB in May 2014 have been registered as the worst on record with damage estimates of between 2.5 to 3 billion Euro. Therefore the costs of dealing with floods and other natural disasters have risen dramatically due to increased urban expansion on floodplains, degradation of flood protection systems, as well as because of insufficient funding for system maintenance and reconstruction.

Hydropower

The assessment of impacts due to climate change on the hydropower sector provided the following conclusions:

- That the impacts are principally associated with direct effects on power generating potential, but also indirectly through increased demand for energy for heating and cooling due to higher or lower temperatures.
- With increasing evaporation/ET due to future temperature increase, a larger decrease of hydropower production is expected to occur on reservoir type and pumped storage type dams that have high storage area/volume ratio and small reservoirs. Other types of HPP would show smaller effects, but still experience a decrease in hydropower generation.
- A decrease in river runoff would affect power generation with a reduction on all hydropower facilities, but in particular of the run-of-river schemes that are solely dependent on river runoff.
- Floods in the autumn/winter and droughts in the spring/summer would mostly affect run-of-river HPPs and HPPs with small reservoirs. With this climate change parameter an overall power generation decrease is expected.

Case studies were made at four HPPs, chosen by their significance in the power sector and their close proximity to existing hydrological stations with reliable data. The following conclusions can be made:

- For annual energy production, all results in the near future showed a small change of less than ±5%, with the exception of one climate model that predicts an increase of 9% for HPP Bočac.
- Results for the distant future showed larger variance between the climate models. Energy production would change between -8% for HPP Bočac and +4% for HPP Bajina Bašta, although the order of the magnitude of these changes is still in the range of the modelling and measurement uncertainties. The general trend in most cases, however, was a decreasing hydropower production.
- From an analysis of the seasonal energy production, the general trend is that for the near future there would be more energy available in winter and autumn whilst there would be a small decrease in spring. For the distant future a decrease in the spring and summer energy production is expected by 4% and 10% on average, respectively, whilst the winter and fall energy production is expected to increase by 11% and 5% on average, respectively.
- In general it can be concluded that although impacts of climate scenarios vary over the SRB, this is unlikely to affect the hydropower sector in the near future, whilst in the distant future water availability is likely to decrease and with it the energy produced from the hydropower facilities. Nonetheless, this is not expected to be severe and is highly unlikely to cause detrimental effects on anthropogenic activities.

Navigation
Climate change impacts on navigation are described using the following indicators: (a) low flows, (b) high flows, and (c) river ice. However, there was no data to support an analysis of changes in visibility (fog) and their influence on navigation. The following conclusions on the impacts due to climate change on navigation can be made:

- The number of days with flows below the thresholds for navigation with reduced and maximum draft is likely to increase very little in the near future (on average for 2-3 days), but a significant increase could be expected in the distant future downstream of Sisak (on average for 8-13 days).
- The number of days in which navigation would be restricted or suspended due to high flows are not likely to change significantly in both near and distant future (on average for less than 1 day).
- Given the general trend in rising temperatures, the potential for ice formation along the whole navigable part of the Sava River is reduced comparing to the baseline period. This would have a beneficial impact for inland navigation since the number of days per year with navigation suspended due to ice is expected to decrease.

Agriculture
For the agricultural sector the SRB food sector lags behind the rest of the Sava region economy in growth terms, due to being undercapitalized, fragmented, and dominated by small producers. Irrigation accounts for less than 1% of total water withdrawals in the Basin. A vulnerability analysis has been undertaken to assess the impact of changing climate on the crop water status and crop yield using the crop water balance to determine the water stress and subsequent crop yield changes. Selections of representative crops for the different riparian states were used as case studies. Consequently, the following conclusions concerning the agriculture sector can be made:

- Extreme event will occur more often or with more intensity that will test the current systems and impact the economy of SRB countries.
- Resulting evaporation from temperature rises will create more aridity and increase the probability of forest fires occurring. Higher temperatures will also affect crop development, cause heat stress in livestock, and increase the likelihood of pests and diseases in crops and animals. There may also be phenological (plant cycle) changes leading to altitude and latitudinal shifts of plant ranges.
- Predicted lower flows will also have more impact on agriculture (more stress on irrigation) and more probability of drought and frost occurring. These impacts of vulnerability will increase further south and east within the Basin.
- On a positive note, the predicted temperature rises may provide an increase to the growing season with longer summers and warmer winters that may provide a potential for increase in agricultural production for selected crops that require less watering.

Economic Evaluation of Climate Change Impacts on Agriculture
Following on from the agriculture analysis, a partial and preliminary economic evaluation was made that combined crop modeling with an economy-wide analysis. The main conclusions from this preliminary economic analysis are as follows:

- Countries facing a severe impact of climate change on the agricultural sector will witness rising agricultural prices that will be reflected in higher consumer prices.
- Rising prices will negatively affect consumers' disposable income and incentivize them to substitute the consumption of agricultural goods with less expensive commodities or imported agricultural products.

- Simulation results for yields from a 2007 baseline show a marked variation depending on the model scenario used. Results indicate that yields may vary from the baseline condition ranging from -6% to +3.5% for each crop and producing country through time.
- Simulated results for crop prices show a rise with respect to the baseline scenario except for winter wheat.
- Serbia and BiH are the most vulnerable regions where the price hikes are predicted to be the highest.
- The modeling shows different price changes according to the choice of the GCM climate model: the lowest and highest values are predicted as 8%-18% for Winter Wheat; 15%-80% for Potato, Grape, Tomato; Maize and Sun Flower; and 5%-100% for Sugar Beet. Thus, the predicted price variation between regions is the highest for Winter Wheat and the lowest for Sugar Beet.
- For a majority of the crops the price variation varies between 15% and 80% compared to their 2010 prices.

9.2 Recommendations for Adaptation

One of the main outcomes from the WATCAP study is the outline of an adaptation plan covering in part the sectors that have been the subject of guidance notes e.g. floods, navigation, hydropower and agriculture as well as issues concerning low flows/droughts, groundwater, snow and ice.

The outline adaption plan covers preparatory topics such as monitoring, modeling and mapping, followed by suggestions for general adaptation of ecological based measures, management measures and technological measures before finally considering any revised approach to policy.

Notwithstanding, the principal framework policies for climate change adaptation are the EU WFD and the EFD that have been recognized in the respective riparian states legislation. Dealing with uncertainty regarding climate change, however, is also an important consideration and this report has followed the ICPDR lead regarding the expected impacts and the degree of uncertainty in this assessment.

The recommended adaptation measures are described for the four water sectors. The recommendations are given taking into account prioritization and comments given by stakeholders, and the measures recommended based on the analytical work presented in Guidance Notes.

Floods

- Development of flood forecasting and warning systems is considered top priority for management of the increasing flood risk in the SRB. This is also closely related to improving monitoring networks through expanding and modernizing the monitoring equipment, development of hydrologic and hydraulic simulation models, strengthening of institutions responsible for forecasting and emergency response, and improving cooperation between the riparian countries on the operational level.
- Development of strategic documents and policies is also considered of high importance, including those related to flood risk management and implementation of EU Flood Directive, as well as the plans and strategies on climate change.
- The Flood Guidance Note, as well as the stakeholders, emphasizes the need to give more space to rivers especially by using the natural wetlands and floodplains both for flood control and biodiversity conservation, but also by deepening and/or widening the river channels. Introducing the flood hazard maps into the spatial plans and prohibited or controlled development in flood plains is also of primary importance. The Flood Guidance Note also recommends increasing the level of protection of towns along the Sava River which are facing the increased risk due to migration and urbanization.
- Following the devastating impact of the recent floods of May 2014 and resulting from the Flood Guidance Notes, there is need to ensure that infrastructure has adequate capacity to deal with the full range of precipitation levels that have been seen in the past forty years and that are

predicted in the future. Furthermore, there is urgent need to inspect all infrastructures prone to flooding and to ensure that adequate measures are taken to strengthen them to deal with extreme events. Lessons learned from the May 2014 event should be a guideline for improving the flood control and response measures.

Hydropower

- Reducing impact of hydropower schemes on ecosystems is recognized as top priority in this sector. This need is emphasized by multiple stakeholders, including development of guidelines and criteria for integrating environmental aspects into the hydropower development, limiting hydropower schemes in streams having the first class water quality, ensuring adequate environmental flows at all times, and assessing consequences of exclusion of ecologically most important small- and medium-scale floods by hydropower schemes.
- Although risk assessment concerning climate change effects for the hydropower sector is also considered a priority, the stakeholders indicate quite a low priority to proposed structural and non-structural measures for coping with decreasing supply for hydropower (improving hydrological forecasting to improve operational rules and utilization of HPP capacity; building robust dams with large reservoirs that can cope with extreme events; flexible design for installed capacity; etc.). Low priority was also given to the reduction in energy demand and consideration of the alternative energy sources.

Navigation

- Better monitoring of river water levels and of meteorological parameters related to ice and fog formation (air temperature, air humidity, wind; water temperatures) and improved hydrological forecasting are considered the most important measure, followed by development of River Information Systems.
- Water management is generally considered important for navigation: low flow augmentation by better reservoir management, combining increased water storage for navigation with habitat creation initiatives, and ship waste management based on the "polluter pays" principle.
- Measures related to adaptation of transportation and fleet proposed in the Navigation Guidance Note (e.g. making better use of the season with high river flow; support container shipping with shallow draft vessels) were given low priority by stakeholders.
- Structural measures also proposed in the Navigation Guidance Note involving dredging to ensure sufficient water depth, and upgrading and expansion of river and port infrastructure were given the lowest priority by stakeholders.

Agriculture

- Drought management is the top priority for agriculture. Establishment of early warning systems for droughts and other extreme climate episodes is considered of the greatest importance, followed by the need to promote water retention in drought prone agricultural areas.
- Policy measures that would introduce sustainable resource and land management systems are also considered a top priority, followed by the need for increased coordination between water and agricultural policies.
- More detailed assessment of vulnerability to climate change for agriculture is needed, including improvement of climate modeling and scenarios and climate change impact on droughts.
- Adaptation in agricultural technology is seen by stakeholders in encouraging more environmentally compatible farming methods to preserve and improve biodiversity rather than in selecting more resilient crop species or adapting sowing patterns and harvest dates to changing climate conditions.
- Due to poor current status of irrigation schemes, the stakeholders fail to recognize them as an adaptation measure. However, the analytical work has indicated that irrigation is an adequate adaptation mechanism to mitigate water stress induced by climate changes.

Recommendations related to knowledge about the basin

The consultation process during the preparation of the WATCAP report also resulted in a number of general recommendations for the SRB, which are not necessarily associated with climate change.

However, these recommendations address well known problems in the basin that are of importance for integrated water resources management in the basin and consequently for its overall development.

- *Hydro-meteorological and water resources data*. Improved organization and coordination of data records, data collection, analysis and storage is needed. Substantial historical data exists from the past century that has not been digitized, such as data in hydrologic year books of the former Federal Hydro-meteorological Service of Yugoslavia. This data is valuable for investigating cli-mate and hydrology in the region, especially having in mind that large gaps during 1990's prevent having continuous records of acceptable lengths. In order to make this data available for various analyses, it needs to be digitized. A possible solution can be provision of a central repository for this data, possibly with the ISRBC, which could be accessible online to users for a small charge to cover upkeep of the web site and maintenance of the data records.

  In addition, data on water resources management, such as withdrawals, discharges, reservoir levels and releases, are extremely difficult to collect and therefore hinder any water balance assessments in the basin. Data and information from hydropower operators is also important for flood forecasting.

  The riparian countries should build upon the existing valuable data record by promoting mandatory reporting procedures (even through a legislative process) for essential data from riparian governments. For example, hydropower operators should be requested to provide all their operational data so that modeling tasks could be successfully completed. This could be implemented by inviting hydropower plant owners/operators to join a working group to study, analyze, plan or mainstream climate change considerations in their business operations. ISRBC could facilitate the institutional space for such an exchange of experiences and technical economic and policy options to incorporate the perspectives of power plant operators. Furthermore, provision of hydropower operational licenses could be tied to provision of operational data to ISRBC and others.

- *New hydrological study*. A new hydrological study of the basin should be undertaken. It should use longer time series, including recent years. The results of such a study will be of invaluable importance for water balance analysis and water management studies.

- *Hydrologic modeling*. The HEC-HMS hydrological model developed for WATCAP is distributed among the riparian countries and could be further developed by undertaking modeling of the tributaries to the Sava River. This work needs to be coordinated by the ISRBC with the planned utilization of the USACE in the further development of the hydraulic (HEC-RAS) model for the Sava River.

9.3 Conclusions

The climate change impacts on the four important water sectors (floods, navigation, hydropower and agriculture) in the Sava River Basin are evaluated and presented and the adaptation measures are prioritized and recommended.

There is obviously a need to effectively plan for the climate induced changes in the basin. Rising mean temperature has a very high certainty of occurring. Precipitation that is highly variable across the basin and seems to have a changing seasonal distribution propagates its uncertainty into the hydrologic trends within the basin. Therefore, options to reduce the severity of the impacts associated with rising mean temperatures and variable precipitation need to be identified by careful planning and by promoting adaptation measures than can cope with such changes. In this regard, the results of this study should provide a basis for stakeholders and decision makers for future developments in the basin.

In the adaptation process, an improved management and coordination (institutional strengthening) would be beneficial for institutions and stakeholders within the basin that understand the specific details of climate change and its effects and what specifically can be done in the basin in order to manage and adapt to such changes.

While there is no doubt that the four sectors could heavily be affected by climate change, this study should also be used to gain an insight into the uncertainties associated with such a comprehensive methodology and to understand how can they be dealt with on either a planning or an operational level. The results presented here are therefore not intended for use in a detailed design projects, but rather to support decisions about the scope and extent of necessary analyses to be carried out in specific projects.

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92	World Bank, June 2013. Implementation Completion Report for the Inland Waters Project : http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/07/12/000333037_20130712111335/Rendered/PDF/ICR25690ICR0Cr00Box377377B00PUBLIC0.pdf
93	World Bank, July 2012. West Balkan Flood and Drought Management Initiative – Drina River Basin, Rapid Regional Diagnostic And Investment Scan Study. Authors - Aleksandra Sucur-Ploco, Miroslav Tomin,Walter Klemm, and Zdenka Ivanovic

11 Appendix A – Ranking of Adaptation Measures

The results of the average scores and ranking for the main WATCAP report and the sector specific guidance notes are shown on the pages below.

Main Report

		1= HIGH PRIORITY			2 = MEDIUM PRIORITY			3 = LOW PRIORITY		
		STAKEHOLDERS								
		A	B	C	D	E	F	G		
No	Recommendation from the main WATCAP Report	RHMS Serbia	Lonsko Polje NP Inst	WATCAP Consultant Average Score	Javno PREDUZEĆE "LUKA BRČKO" doo	FBiH MAWMF	CENTRE FOR ENVIRNT	GREEN HOME	Average Score	Ranking
1	Ensure that all infrastructure has adequate capacity to deal with the full range of precipitation levels	1	2	1	1	1	1	1	1.14	1
11	Undertake modelling of Sava tributaries for evaluating flood risk and vulnerability.	2	1	1	2	1	1	2	1.43	2
13	Fast track planning process and seeking additional funding for waterwater treatment plants in the SRB	2	1	2	2	1	1	1	1.43	2
16	Use natural water retention measures to mitigate floods and droughts		1	2					1.50	3
5	Undertake an updated hydrologic study of the SRB (including for droughts).	1	1	1	2	2	2	2	1.57	4
7	Improve data records by promoting mandatory reporting procedures (through a legislative process) from riparian governments	1	3	1	2	1	2	1	1.57	4
14	Better control of solid waste disposal sites as uncontrolled sources of water pollution in the SRB.	2	1	2	2	2	1	1	1.57	4
2	Improved management from institutions and stakeholders within the SRB that understand the specific details of climate change.	1	3	1	2	2	2	1	1.71	7
4	Collect more monitoring data on large water storages (reservoirs) and water use from stakeholders and align to climate change.	1	3	1	3	2	1	1	1.71	7
9	Further embellish the HEC-HMS hydrological model developed for WATCAP	1	3	1	2	2	2	1	1.71	7
10	Use recently developed HEC-HMS model to create discharge inputs to the HEC-RAS model	1	3	2	2	1	2	2	1.86	10
15	Better control from diffuse points of pollution from agriculture (nutrients from fertilization and plant protection products).	2	1	2	3	2	1	2	1.86	10
6	Undertake digitisation of the substantial historical data that exists from the past century	1	3	1	2	2	2	3	2.00	12
8	Hydropower operational licences should be tied to provision of operational data to ISRBC and others .	2	3	2	2	2	2	1	2.00	12
12	Undertake a renewed information strategy for the SRB with enhanced focus on groundwater	2	2	3	2	3	1	1	2.00	12
3	Institutional strengthening and training in stakeholder institutions especially with remote sensing techniques	1	3	2	2	3	2	2	2.14	15

Stake-holder	Comment to the Draft WATCAP Report
B	Natural water retention measures (NWRM) to be considered as an appropriate tool to mitigate floods and droughts. Their implementation to be based on a masterplan for the entire catchment area taking into account disaster and climate change scenarios and hydrological models. The findings of the masterplan should then lead to a re-drafting of national spatial plans. Where necessary, the masterplan should point up land purchase and exchange policies.

Navigation Guidance Note

No	Recommendation regarding Navigation - WATCAP Report	1= HIGH PRIORITY		2 = MEDIUM PRIORITY			3 = LOW PRIORITY			
		STAKEHOLDERS							Average Score	Ranking
		A	B	C	D	E	F	G		
		RHMS Serbia	Lonsko Polje NP Inst	WATCAP Consultant Average Score	Javno PREDUZEĆE "LUKA BRČKO" doo	FBiH MAWMF	CENTRE FOR ENVIRNT	GREEN HOME		
2	Better monitoring of meteorological and other variables of interest for ice and fog formation (air temperature, air humidity, wind; water temperatures)	1		1		1	2	1	1.20	1
1	Better monitoring of river water levels.	1		2		1	2	1	1.40	2
3	More research into a River Information System to improve forecasting.	2		2		1	2	1	1.60	3
6	Better reservoir management in low-flow cases.	1	3	1		3	2	2	2.00	4
7	Combine any increased water storage for navigation with habitat creation initiatives.	2	1	3		3	2	1	2.00	4
8	Establish a sustainable and well coordinated approach to ship waste management based on "polluter-pays" principle.	2	2	2		3	2	1	2.00	4
13	Avoid redundant transportation by making better use of the season with high river flow.	2	2	3		2	2	1	2.00	4
14	Support container shipping with shallow draft vessels.	2	2	2		2	2	2	2.00	4
4	Undertake dredging to ensure sufficient water depth in times of low water flow.	2	3	2		2	2	2	2.17	9
16	Improved education for the Sava navigation sector	1	3	2		3	3	1	2.17	9
9	Adopt and modernize river infrastructure	2	3	2		3	2	2	2.33	11
11	Improvement to river navigation legislation.	2	3	2		3	2	2	2.33	11
10	Upgrading and expansion of port infrastructure.	2	3	2		2	3	3	2.50	13
12	Support waterway transport over other forms of transport such as heavy vehicles	2	3	2		3	3	2	2.50	13
15	Modernization of the river fleet for better environmental and economic benefits, e.g. optimise fuel consumption.	3	3	2		3	2	2	2.50	13
5	More detailed assessment for deepening traffic routes.	3	3	2		2	3	3	2.67	16

Stake-holder	Comment to the Guidance Note for Navigation
	None

Floods Guidance Note

No	Recommendation regarding floods - WATCAP Report	1= HIGH PRIORITY		2 = MEDIUM PRIORITY			3 = LOW PRIORITY			
		STAKEHOLDERS							Average Score	Ranking
		A	B	C	D	E	F	G		
		RHMS Serbia	Lonsko Polje NP Inst	WATCAP Consultant Average Score	Javno PREDUZEĆE "LUKA BRČKO" doo	FBiH MAWMF	CENTRE FOR ENVIRNT	GREEN HOME		
1	Development of Sava flood forecasting system .	1	2	1		1	1	1	1.17	1
2	Further development of Strategies and Plans on climate change	1	1	1		2	1	1	1.17	1
12	Protect and restore water retention areas, including natural reservoirs.	1	1	1		2	1	1	1.17	1
5	Further development of hydrologic and hydraulic models.	1	2	1		1	2	1	1.33	4
7	Implementation of effective public communication systems for managing crisis situations.	2	2	1		1	1	1	1.33	4
21	Implementation of the EU Floods Directive including the impacts of CC on the management of floods	1	1	2		1	1	2	1.33	4
23	Development of a strategy for flood protection.	1	2	1		1	1	2	1.33	4
25	Strengthen operational cooperation between emergency response authorities in SRB riparian states + improve asset sharing	1	2	2		1	1	1	1.33	4
6	Creation of forums for exchange of expert knowledge.	2	1	1		2	1	2	1.50	9
13	Provide planning support for flood restoration.	1	1	2		3	1	1	1.50	9
14	Conduct spatial planning and construction activities in the context of CC and increased threats of floods.	1	2	2		2	1	1	1.50	9
18	Create local flood storages (ponds, building storages, groundwater cisterns).	1	2	2		1	1	2	1.50	9
4	Development of an expanded monitoring network with modern measuring equipment + remote sensing	1	3	2		1	1	2	1.67	13
10	Improve flood resistance by institutional capacity building and by flod prevention programms	1	2	2		1	2	2	1.67	13
15	Install dewatering pumps for water extraction at sites of the floods events.	1	3	1		1	1	3	1.67	13
24	Institutionalize of civil protection system as a part of protection and rescue in emergency situations.	2	2	2		1	1	2	1.67	13
26	Establish, maintain and update agreements and procedures among riparian countries for critical situations.	1	2	3		1	1	2	1.67	13
8	Re- evaluation of flood protection design values and water structures taking into account climate change impacts.	2	1	2		2	1	3	1.83	18
11	Mitigate against accidental pollution during floods	2	2	2		2	1	2	1.83	18
20	Elaborate new design standards for the protection of works /buildings against floods including new codes and regulations.	2	1	2		3	2	1	1.83	18
22	Legal endorsement of proposed flood retention areas.	2	1	3		3	1	1	1.83	18
3	Development of a “past floods database at European level”.	1	3	1		3	2	2	2.00	22
16	Install non-return valves in all building connections to the public sewage network.	2	3	2		1	1	3	2.00	22
17	Modify transport infrastructure such as pavements to allow more infiltration of the rain water.	2	3	3		1	1	3	2.17	24
19	Consider roof planting to slow runoff.	2	3	3		3	1	2	2.33	24
9	Promote/extend insurance systems to protect goods /persons against floods.	3	3	3		3	1	3	2.67	26

Stake-holder	Comment to the Guidance Note for Floods
B	Protection of urbanised areas and infrastructure yes, but based on natural water retention measures and prohibition of further urbanisation of natural retentions like Ljubljansko barje. Do not agree with the conclusion. Statement that hydropower stations between SLO and CRO will improve flood protection is very questionable, particularly under the aspect of predicted increas of flash flood events. Inclusion of the Ramsar statement adopted at the 8th European Ramsar Meeting in Kufstein (Oct. 2014): AWARE about the fact that during disastrous flood events across Europe, such as in 2014 in the Western Balkans, which have caused many human casualties and economic damages, the importance of natural wetlands and floodplains and the questionable role of hydropower schemes in mitigating extreme flood events became obvious The Ramsar Contracting Parties gathered on the occasion of the 8th European Regional Meeting in Kufstein, Austria: CALL ON the International Sava River Basin Commission (ISRBC) and its Member States to take into account the high potential of natural water retention measures (NWRM) in the region. RECOGNISE that maintaining the significant capacity of existing and rehabilitating former natural floodplains and periodically flooded karst poljes, including Ramsar sites, make NWRM the most appropriate tool to mitigate the impacts of both disastrous floods and droughts. URGE the International Sava River Basin Commission and its Member States to develop and implement where necessary together with the International Commission on the Protection of the Danube River a strategy on NWRM, taking into account the negative impact of hydropower generation, predicted disaster and climate change scenarios and hydrological modelling for the catchment area of the Sava River and adjacent catchments. HIGHLIGHT the need to build on lessons learnt to contribute to NWRM approaches across Europe to combat extreme weather events linked to predicted impacts of climate change.
E	To develop methods of preventive measures on all states levels. All above proposed measures require a longer period of time, and I think that one recommendation should be devoted to the development of preventive measures.
F	Development and promotion of practical advices for general public in critical situations of flood/landslides events.
F	Usage of natural retentions as a measure for flood control but also for nature conservation activities, as priority.

Hydropower Guidance Notes

		1= HIGH PRIORITY			2 = MEDIUM PRIORITY			3 = LOW PRIORITY		
		STAKEHOLDERS								
		A	B	C	D	E	F	G		
No	Recommendation regarding hydropower - WATCAP Report	RHMS Serbia	Lonsko Polje NP Inst	WATCAP Consultant Average Score	Javno PREDUZEĆE "LUKA BRČKO" doo	FBiH MAWMF	CENTRE FOR ENVIRNT	GREEN HOME	Average Score	Ranking
6	Assess consequences for the ecology of rivers from HPP and ensure adequate environmental flow downstream at all times	2	1	1		1	1	1	1.17	1
9	Consider the location of power plants in relation to the natural environment, especially the aquatic environment downstream.	1	1	2		1	1	1	1.17	1
3	Risk assessment concerning climate change effects for the hydroelectric sector.	1	1	2		2	1	1	1.33	3
24	Move towards mandatory reporting for hydropower companies for river flow and discharge to improve future monitoring.	1	3	1		1	1	1	1.33	3
2	Improve monitoring to assess effect on the aquatic environment.	1		2		1	1	2	1.40	5
22	Develop guidelines for integrating environmental aspects in the use of existing HPP e.g. in HPP efficiency, flow regulation, etc.	2	1	2		2	1	1	1.50	6
23	Develop/implement stricter rules for discharge of water into rivers and for water withdrawal.	1	2	2		2	1	1	1.50	6
1	Research on key parameters of hydrologic cycle: e.g. water demand-supply, energy storage, renewable energy use, discharge to rivers etc,	1		2		2	1	2	1.60	8
8	Move towards less water consumptive energy sources: e.g. solar or wind power.	1	1	2		3	1	2	1.67	9
11	Implement load management, such as reducing peak demand in periods of short supply.	2	3	2		1	1	1	1.67	9
20	Undertake regular reviews of permitting and licencing and relate to the RBMPs and data gathering.	1	3	1		1	2	2	1.67	9
12	Promote information exchange by better co-ordination and monitoring.	2	3	2		2	1	1	1.83	12
7	Introduce IWRM practices in hydropower based operations	2	1	2		3	1	3	2.00	13
10	Promote decentralised sustainable energy generation (e.g. SHPP) where appropriate to local conditions to reduce risk.	2	3	2		2	1	2	2.00	13
13	Reduce energy demand by promoting public awareness campaigns and training in energy efficiency	2	3	2		2	1	2	2.00	13
19	Create multipurpose dams in order to have a positive effect reducing local floods	2	3	1		1	2	3	2.00	13
21	Incorporate climate change adaptation into existing codes and guidelines concerning hydropower.	2	3	2		2	2	1	2.00	13
14	Consider optimization of storage and sediment management to reduce time for preventive maintenance	1	3	2		2	2	3	2.17	18
4	Assess and optimize of the energy grid, i.e. Power Optimisation Study.	2	3	2		2	2	3	2.33	19
5	Consider decentralised electricity production and/or an interconnected "European Grid".	2	3	2		3	2	3	2.50	20
16	Consider using more pumped storage hydropower technology to cover peak loads.	2	3	2		3	2	3	2.50	20
17	Introduce technological solutions for low flow/drought events through for example better/more efficient turbines	2	3	3		2	3	2	2.50	20
18	Increase water storage capacity by enlarging existing reservoirs and/or creation of new one to enable HPP during summer.	2	3	2		2	3	3	2.50	20
15	Promote HPP to reduce carbon emissions.	2	3	3		3	3	3	2.83	24

Stake-holder	Comment to the Guidance Note for Hydropower
B	assess the impact of hydropower schemes during extreme flood events and the exclusion of ecologically most important small- and medium-scale floods which is caused by such schemes
E	During the period of flood system of exchange of hydrological data should be mandatory for owners of accumulation
F	Development of criteria for selection of rivers for hydro power use. Rivers with first water quality and/or with high biological diversity/importance should stay untouched.
F	Development of mechanism for measuring the cumulative effect of hydro power plants along Sava River.

Agriculture/Irrigation Guidance Note

No	Recommendation regarding agriculture/irrigation - WATCAP Report	1= HIGH PRIORITY		2 = MEDIUM PRIORITY			3 = LOW PRIORITY		Average Score	Ranking
		STAKEHOLDERS								
		A	B	C	D	E	F	G		
		RHMS Serbia	Lonsko Polje NP Inst	WATCAP Consultant Average Score	Javno PREDUZEĆE "LUKA BRČKO" doo	FBiH MAWMF	CENTRE FOR ENVIRNT	GREEN HOME		
6	Establish/enhance early warning systems for droughts and other extreme climate episodes of importance to agriculture.		1	2		1	1	1	1.20	1
9	Promote water retention in the agricultural landscape especially in drought prone areas		1	2		1	1	1	1.20	1
11	Introduce sustainable resource and land management systems.		1	2		1	1	1	1.20	1
4	Improvement of climate change regional models and climate scenarios.		1	2		2	1	1	1.40	4
5	Undertake detailed assessment of vulnerability to CC for agriculture		2	2		1	1	1	1.40	4
10	Encourage more environmentally compatible farming methods to preserve and improve biodiversity.		1	2		2	1	1	1.40	4
18	Build buffer zones in the vicinity of sensitive areas to reduce run-off.		1	2		2	1	1	1.40	4
21	Increase coordination between water and agricultural policies.		3	1		1	1	1	1.40	4
1	Improved monitoring of all parameters (e.g. weather data, soil, etc).		3	1		1	2	1	1.60	9
3	More research on the impact of climate change and droughts on the quantity and quality of water resources.		2	1		2	1	2	1.60	9
17	Better education, awareness raising, knowledge transfer and cooperation between authorities responsible for agriculture.		3	2		1	1	1	1.60	9
22	Use water pricing according to consumption as an effective economic instrument.		3	2		1	1	1	1.60	9
16	Improve water management to prevent water logging, erosion and leaching.		3	1		1	2	2	1.80	13
20	Use existing irrigation infrastructure more efficiently, build more reservoirs, and rehabilitate pump stations.		3	1		2	1	2	1.80	13
2	More research on new plant species resistant to CC, pesticides and water efficiency.		3	2		2	1	2	2.00	15
7	Improvement in energy demand for irrigation systems.		3	2		2	1	2	2.00	15
12	Improve planning between sectors and IWRM practices.		2	2		2	1	3	2.00	15
14	Adapt sowing patterns/ harvest dates to the new climate conditions		3	2		1	2	2	2.00	15
23	Improve and adapt insurance systems such as "bad weather insurance" or "multiple risk insurance" policies		3	2		1	1	3	2.00	15
25	Improve efficiency of legislation and regulation in the irrigation sector.		3	2		2	1	2	2.00	15
8	Develop/adopt the agricultural infrastructure by improving protection to irrigation schemes.		3	2		2	2	2	2.20	21
13	Maintain soil-fertility and soil-water-saving techniques through testing, mulching, etc.		3	2		2	1	3	2.20	21
19	Develop/apply new, water-use efficiency related techniques such as use of drip irrigation		2	2		3	2	2	2.20	21
24	Implement Best Agricultural Practices (BAP).		3	2		2	1	3	2.20	21
15	Develop/adopt pest eradication system and fertiliser management		3	2		2	2	3	2.40	25

Stake-holder	Comment to the Guidance Note for Agriculture/ Irrigation
B	When it comes to the implementation of subsidies and development policies, floodplain areas ought to receive a special status similar to what islands and mountain areas have got in many European countries.

SEPARATE REPORTS IN ANNEXES:

ANNEX 1 - Development of the Hydrologic Model for the Sava River Basin

ANNEX 2 – Guidance Note on Floods

ANNEX 3 - Guidance Note on Hydropower

ANNEX 4 – Guidance Note on Navigation

ANNEX 5 – Guidance Note on Agriculture

ANNEX 6 – Guidance Note on Economic Evaluation of Climate Change Impacts in Sava River Basin