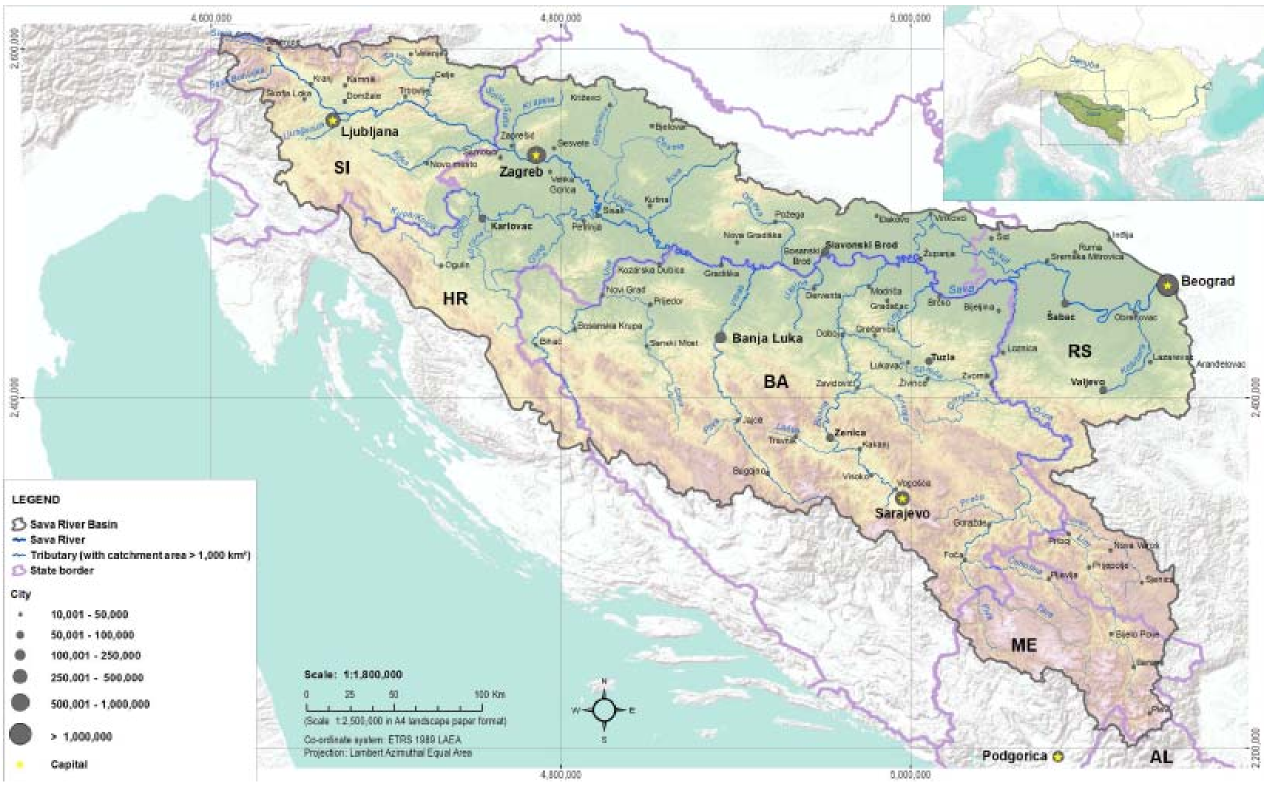
ABBREVIATED SUMMARY

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) (Figure AS 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

Figure AS 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. A review of historical climate data and an analysis of trends as the means for the characterization of future climate scenarios.

[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.

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).

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.

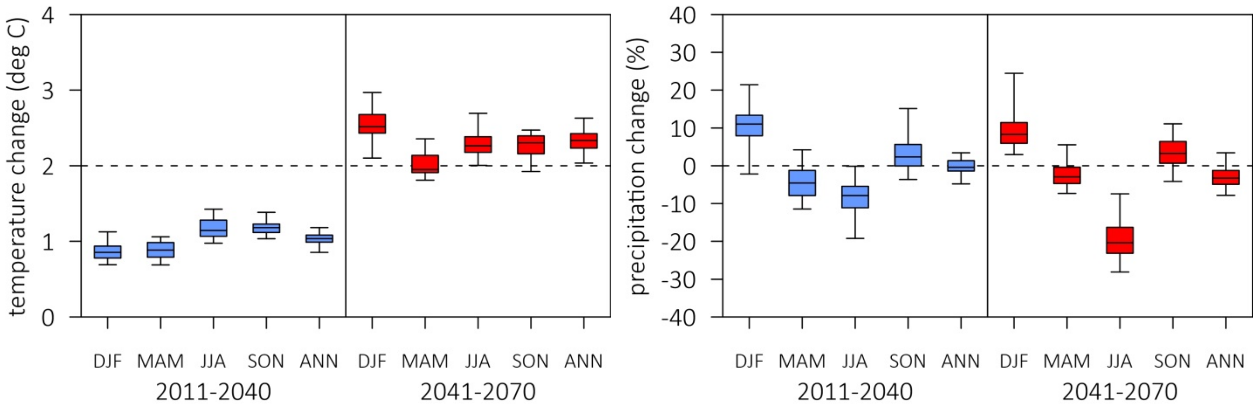
River discharge is declining noticeably even though precipitation is declining little or not at all. The decline in discharge seems to be a consequence of increased evapotranspiration resulting from rising mean temperature and reforestation. Discharge also manifests multi-decade oscillations in mean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

Climate modeling and future climate scenarios

The future climate scenarios resulting from chains of global and regional climate models (GCMs and RCMs) were analyzed on a seasonal and annual basis for the two future periods outlined in the report: 2011–40 and 2041–70 (Figure AS 2). All five GCM/RCM models considered in the study 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.

A 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) was 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, which has proven to produce the largest floods, is expected to 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.

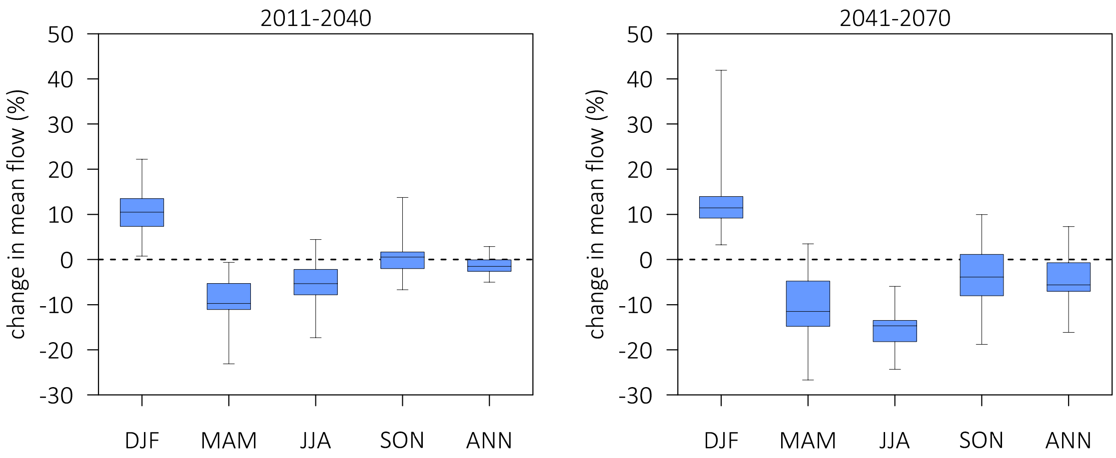


Source: Figure produced by COWI 2014

Figure AS 2: 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

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 (Figure AS 3).



Source: Figure produced by COWI 2014

Figure AS 3: Change in ensemble median values of mean seasonal (DJF, MAM, JJA, SON) and annual (ANN) runoff; box plots indicate variation across the basin

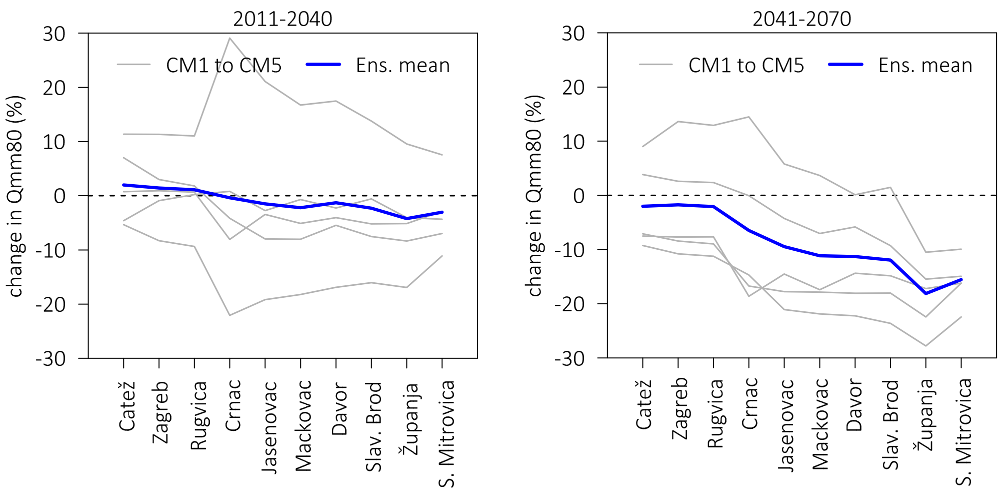
A substantial decrease in river flows is expected in the spring and summer seasons but somewhat differently when considering the near and distant future. The spring decrease is clear in both the near and distant future over the whole basin, though it is projected to be greater in the distant future with 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.[2] The results revealed great variation among the climate models (Figure AS 4) 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 Figure AS 1). The results for Qmm95 are similar.



Source: Figure produced by COWI 2014

Figure AS 4: Change in minimum mean monthly flow of 80% probability of exceedance (Qmm80) for climate models CM1 to CM5 in near future (left) and distant future (right) along the Sava River

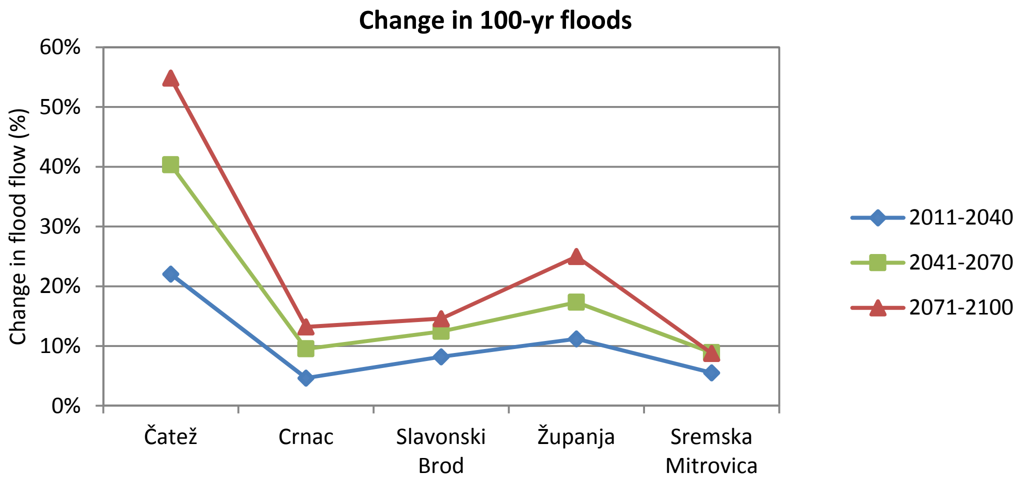
Hydrologic simulations – flood flows

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 floods with a return period of up to 1,000 years. The hydrologic projections plainly indicate that

[2] 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 per-cent 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 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 Figure AS 5. 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

Figure AS 5: 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.

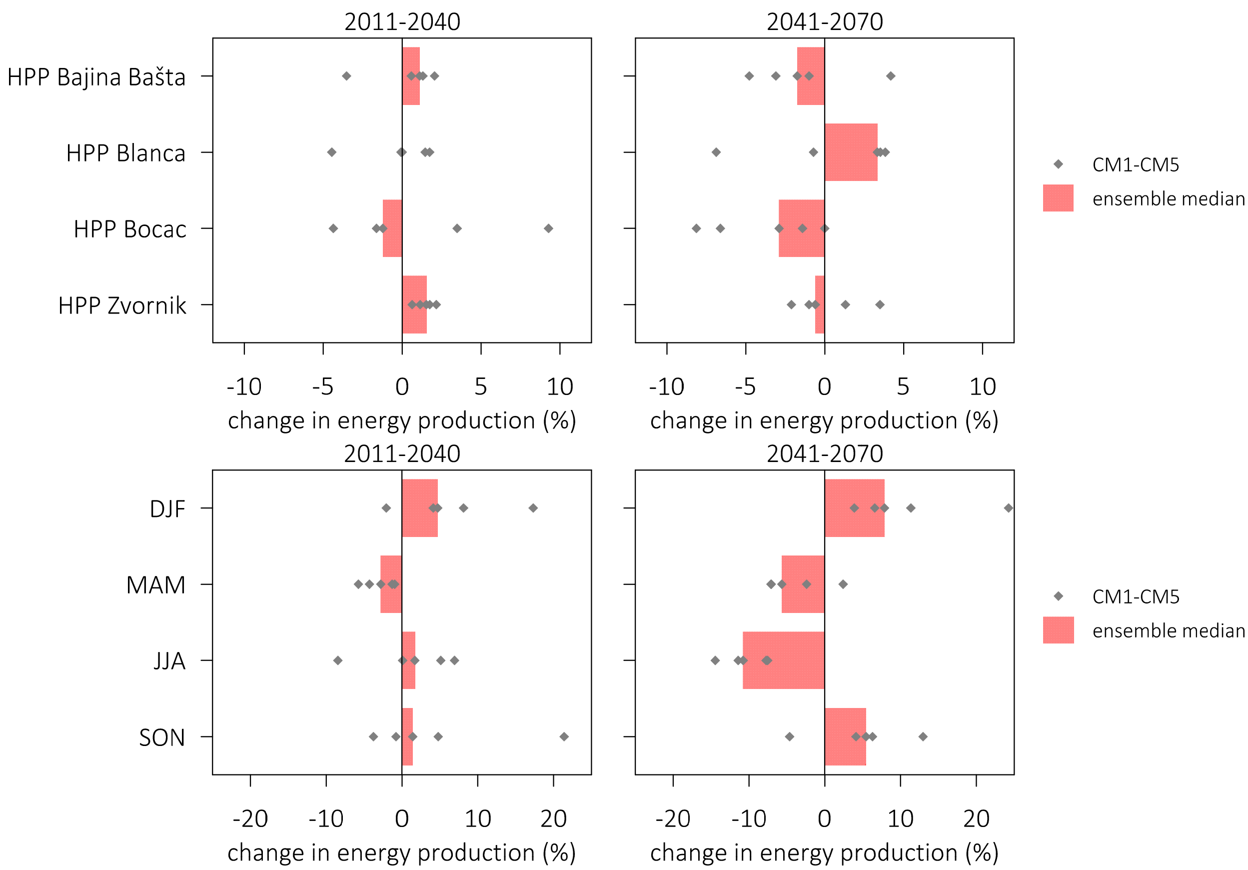
Hydropower

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 (Figure AS 6). 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 Figure AS 6). For the distant future, a greatar 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

Figure AS 6: 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

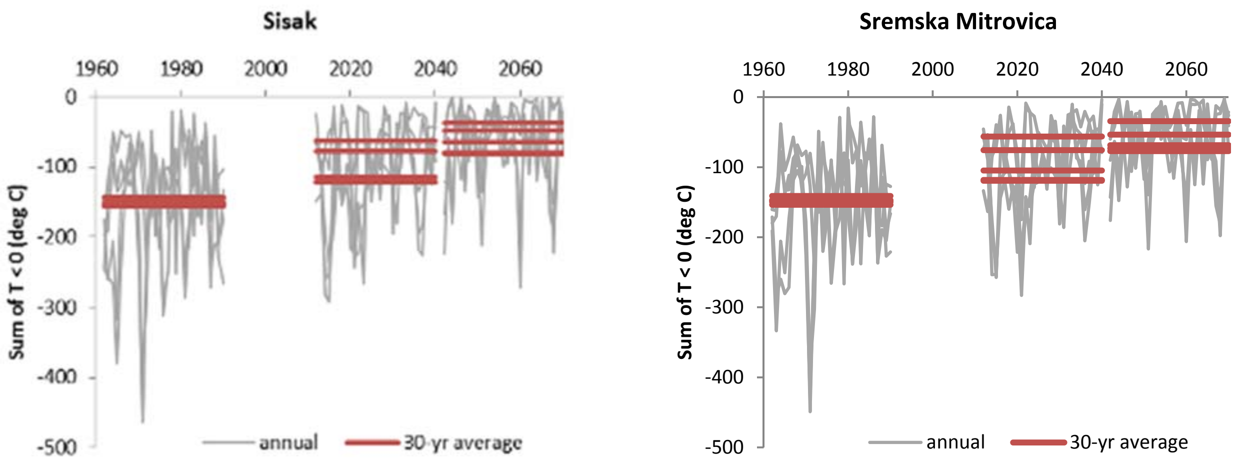
Navigation

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 Figure AS 7. 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

Figure AS 7: 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

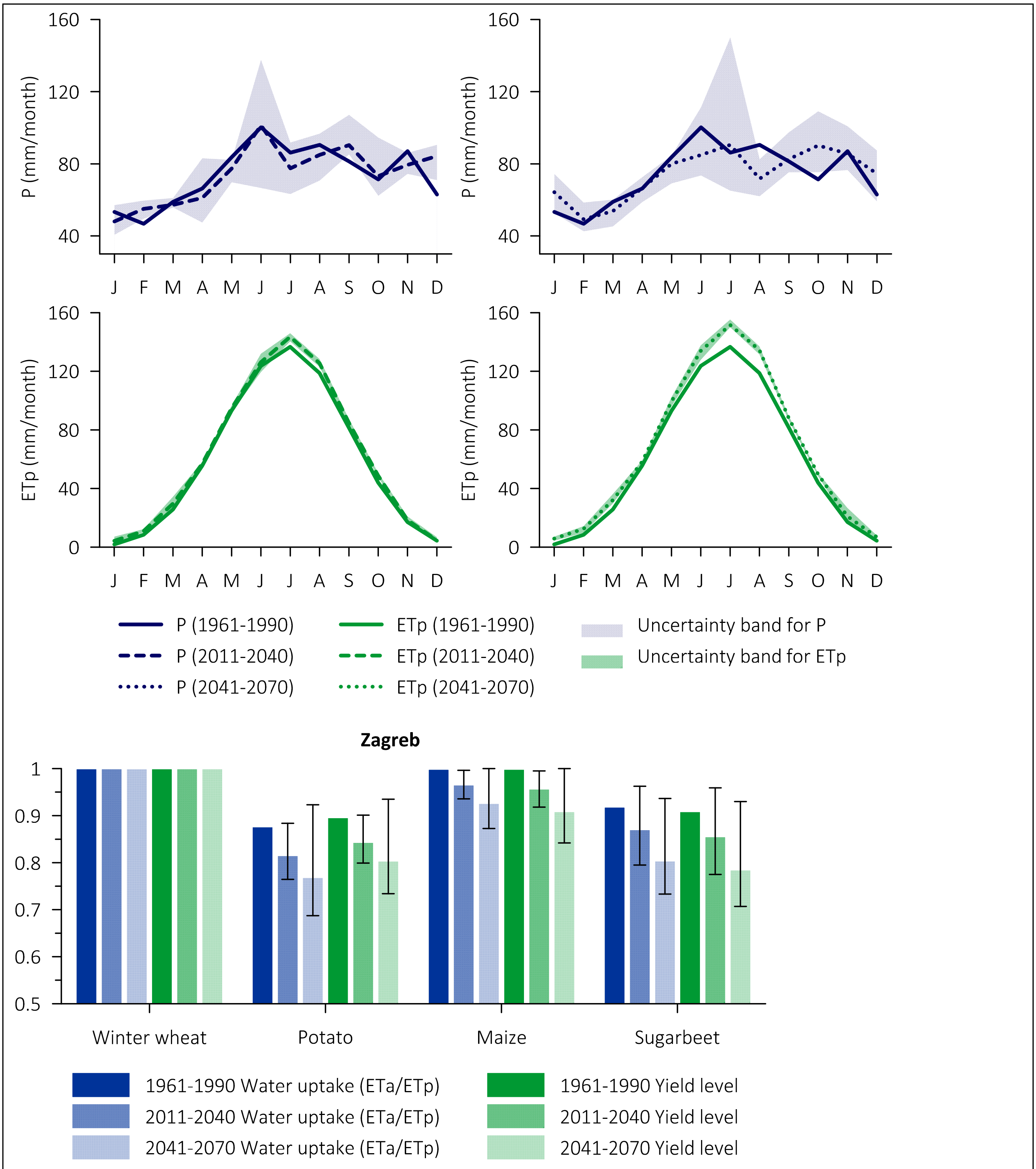
The SRB's food sector lags behind the rest of the economy in growth terms largely because it is undercapitalized, fragmented, and dominated by small producers. In addition, irrigation in the SRB accounts for less than 1 percent of total water withdrawals. A vulnerability analysis was undertaken to assess 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 Figure AS 8. 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

Figure AS 8: 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.

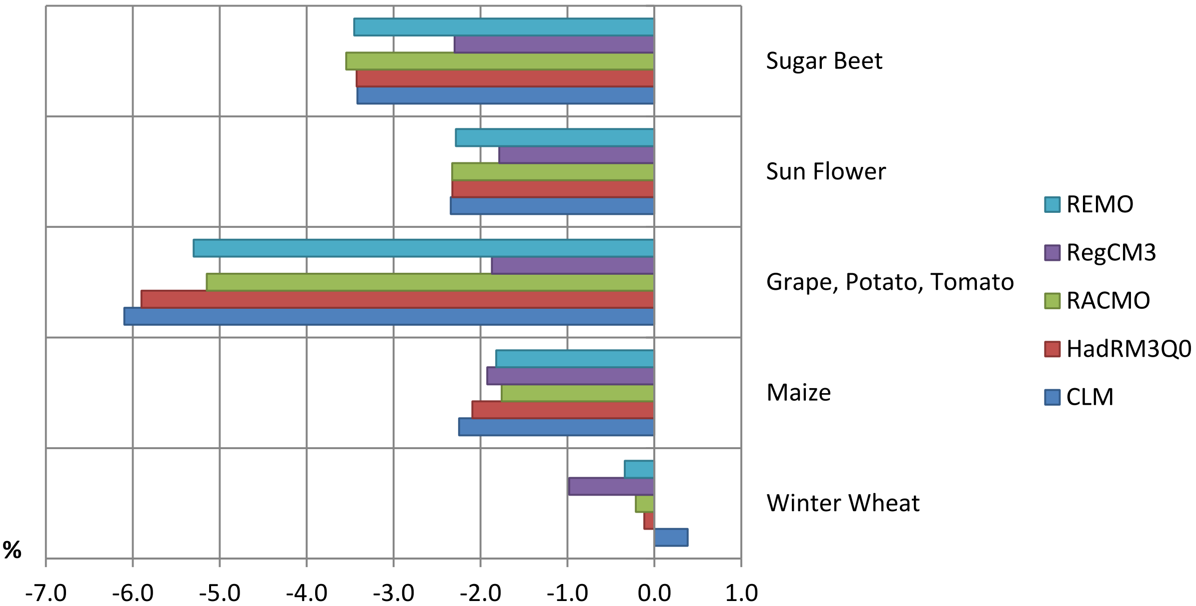
Economic evaluation of climate change impacts on agriculture

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.

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 Figure AS 9.



Source: Figure produced by World Bank 2014

Figure AS 9: Serbia and BiH - Crops in 2070 (% change from the baseline scenario)

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.

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.

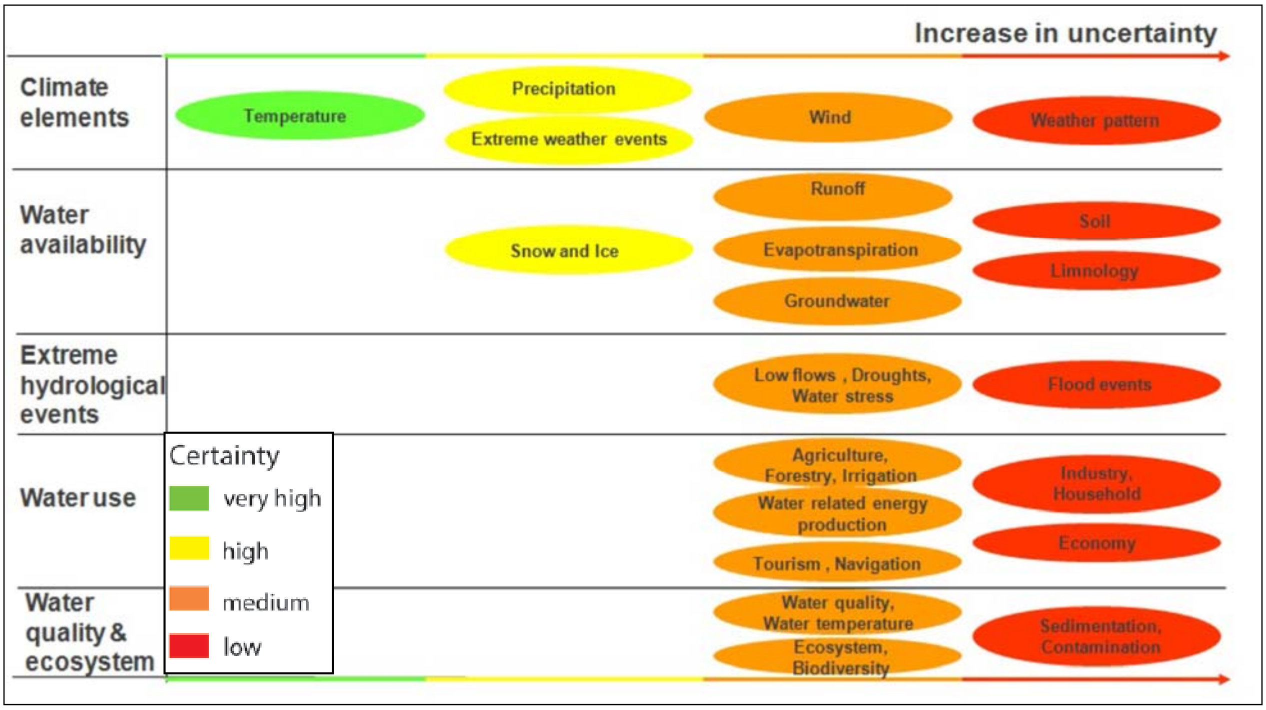
In terms of European policy, the EC White Paper on Adaptation,[3] together with the United Nations Economic Commission for Europe (UNECE) Guidance on Water and Adaptation to Climate Change,[4] are important documents in the effort to address climate change concerns. The latter in particular offers useful 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.

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),[5] 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 Figure AS 10.

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.

[3] European Commission (2009) White Paper: Adapting to climate change: Towards a European framework for action.
[4] United Nations Economic Commission for Europe (2008) Guidance on Water and Adaptation to Climate Change.
[5] International Commission for the Protection of the Danube River (2013) Strategy on Adaptation to Climate Change.



Source: ICPDR Strategy on Adaptation to Climate Change

Figure AS 10: Uncertainty of climate elements and main impacts due to the four certainty categories

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*.

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.