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Current state and perspective of water management policy in terms of climate change

Case study of the Velika Morava River

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Abstract

Purpose – The purpose of this paper is to set out the policy guidelines and recommendations to harmonise the Serbian water legislation with European Union standards in the area of water system management as impacted by climate change.

Design/methodology/approach – The EU Water Framework Directive is analysed in the context of implementation of the integrated water management policy presented in the Serbian Water Law (2010), as well as the National Water Management Strategy (2016). It has been found that the water management legislation that deals with the impact of climate change on water resources is incomplete. Although there are numerous challenges related to research of climate change and water systems, water policy and legal aspects cannot be neglected. The so-called soft law instruments represented in a form of strategy documents could be a valuable response in terms of an adaptive and integrated water policy approach.

Findings – The research is applied to a case study of the Velika Morava River Basin, at Ljubicevski Most hydrological station. Long-term projections suggest a decrease in annual precipitation levels and annual flows up to the year 2100 for climatic scenarios A1B and A2, accompanied by a rapid increase in air temperatures.

Originality/value – This study proposes a water management policy and provides recommendations for the Velika Morava River Basin as impacted by climate change, according to the European Union legislation.

Keywords Climate change, Hydrological projections, Integrated water management, Serbian water policy, Velika Morava river

Paper type Research paper

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1. Introduction

Water management parties are continuously facing many challenges related to the future water demand and availability. Problems related to the impacts of climate change on water resources are the most important issues today, which involve scientists (particularly hydrologists, experts in environmental sciences, as well as experts in social and related scientific areas), decision-makers, stakeholders and the affected population. Considering climate change, the perception of the people located in certain areas corresponds to observed increasing long-term temperature trends, while the perception of decreasing rainfall does not match records because they do not show any clear pattern (Sada *et al.*, 2014).

Climate change continues to occur more rapidly in several aspects because observed changes frequently exceed earlier projections (Somervill, 2012). Observations suggest that the Greenland and Artic ice sheets are losing mass and contributing to sea level rise. Also, greenhouse gas emission from fossil fuels are increasing rather than decreasing. The assessment of long-term changes in water resources can usually be expressed as a gradual trend in the records. It is suggested that streamflow trends in Europe have occurred mainly at the seasonal level, with the strongest regional coherence of increasing winter and decreasing summer streamflows (Stahl *et al.*, 2010). In particular, it has been found that the annual and seasonal trends need to be carefully distinguished because the annual trends reflect the trend over the winter season. To assess the changes in the annual and seasonal streamflows in Serbia, Kovačević-Majkić and Urošev (2014) analysed records from 94 stations between 1961 and 2010 in many Serbian regions with heterogenic climatic and morphological conditions. Decreasing trends are registered over the winter, spring and summer seasons, while the majority of stations exhibit increasing trends in autumn. At the annual level, the results indicate that 25 stations have statistically significant trends which are negative at 24 stations and positive at only one station.

To simulate the future climate in Serbia, the coupled regional climate model EBU-POM (Eta Belgrade University – Princeton Ocean Model) has been applied to 17 climatic stations (Kržić *et al.*, 2011). The simulations were conducted according to the A1B and A2 climate scenarios, suggesting a significant change in the temperature and precipitation pattern for the future time frame of 2071-2100, with reference to the baseline period 1961-1990. Particularly, the maximum increase in mean and maximum temperatures is expected for 17 stations in summer, in the range from 4.8°C to 5.1°C. For the spring, autumn and winter seasons, an increase in temperature within the range of 2-3°C is expected. In addition, a decrease in precipitation for the A1B scenario is likely to be in the range from 10 to 20per cent for all seasons, except in spring with a slight increase of 2per cent. The simulation under the A2 scenario suggests a decrease in precipitation for the seasons analysed, apart from the spring which shows an increase of 10 per cent.

The main drivers of water cycle changes are variations in temperature, precipitation and other influential climatic parameters in the river basin. Changes in these parameters are expected to have significant impacts on the hydrologic balance and will trigger future changes in water availability (ICPDR, 2012; IPCC, 2013). Changes in the seasonal pattern in the Danube River Basin because of an increase in flows in winter and a decrease in summer can be expected. The main reason is the rising temperature in the winter season, which brings about a decrease in snowfall and snow accumulation. Consequently, the hydrologic response due to higher temperatures in the winter season is likely to be an earlier snow melt, which leads to a shift in the runoff regime. Climate change impact on the runoff regime is commonly assessed by run-off models, fed by climatic inputs from regional climate models. The results of hydrological modelling under future climate conditions are summarised in the draft version of the Serbia's First National Adaptation Plan (SFNAP, 2015). This plan sums up the impacts of climate change on water resources for the basins of the following Serbian rivers: the Sava, the Kolubara, the Toplica, the Raška and the Mlava. The results show that significant reductions in the annual flows are expected in the distant future, by the end of the twenty-first century, where these changes at the annual level range from a few per cent to about –30 per cent. Seasonally, the runoff regimes of the rivers in Serbia are generally characterised by higher flows in spring and lower flows in summer, autumn and early winter. One should note that the reduction in the summer flows is strongly correlated with an increase in the number of days with the absolute maximum temperature >30°C and longer dry periods (Kržić *et al.*, 2011).

The outlined negative impacts of climate change on the runoff regime in Serbia require improvements in water management so as to adapt national ecosystems and the national environmental policy, including water policy and legislation, to the emerging global water crisis (Middelkoop *et al.*, 2001; Pahl-Wostl, 2007; Kundzewicz *et al.*, 2008). A multidisciplinary, multinational and integrated/holistic approach is, therefore, needed to cope with the adverse effects of climate change on water resources. It should be noted that "holistic" is represented in the introduction of the human component (Jonch-Clausen and Fugl, 2001), i.e. the development of a coordinated policy and legislation in the area of water management at all levels – international, regional and national.

The objective of this paper is to present the results of research carried out in respect of the Velika Morava River Basin. The paper aims to set out a legal framework for integrated water management in terms of adaptive policy and climate change aspects in Serbia, taking into account EU standards (both legally binding and non-binding). In addition, the paper intends to provide recommendations in legal terms for the mitigation of diverse effects of climate change on water resources in the Velika Morava River Basin based on climatic and hydrological projections under future climate conditions.

2. Regulation of water management

2.1 Legal framework of water management in the EU

The European Union Water Framework Directive (WFD), which was adopted in 2000, represents a fundamental EU legal instrument for the water sector. The WFD is an instrument of the so-called EU hard law (HSLEU, 2006), meaning that it is expected to have a significant influence on the water and environmental legislation of all member states (MSs). Hard law instruments in the EU are legally binding acts of Union and Community law that encompass regulations, directives and decisions. In contrast to regulations which are directly applicable in all MSs, directives set objectives, results to be achieved, but leave national authorities to choose the appropriate form and methods to address issues.

There are significant difficulties in water governance at international and national levels, meaning that there are differences in the normative framework and institutional organisation among states from an international perspective and a low level of coordination of activities amongst different national authorities from the national perspective (Vatn and Vedeld, 2012). Young (2003) recognises that as the problem of fit, interplay and scale, where fit is a matter of (in)congruity between properties of the relevant ecosystems and attributes of the institutions in an environmental area. To overcome the aforementioned issues, the WFD introduces a sustainable and adaptive water management system and comprehensive provisions of integrated, coordinated and holistic water management in Europe (Griffiths, 2002). An integrated approach in water management implies that all factors – environmental, human and technological – should be taken into consideration (Pahl-Wostl, 2007). Water problems are considered to be multi-dimensional, multi-sectoral and multi-regional, filled with multiple interests and multiple agendas that can be resolved only through proper multi-institutional and multi-stakeholder coordination. Therefore, the integrated approach is closely related to the application of a multidisciplinary method in water management policy. A holistic institutional approach is represented in the human component of water management, i.e. the development of coordinated social activities to create sustainable management of entire water systems (Jonch-Clausen and Fugl, 2001).

The achievement of "good water status" of both surface water and groundwater and of "good ecological status" are the core objectives of the WFD. MSs are responsible for the adoption of appropriate measures to achieve these objectives. Although there are no explicit provisions on climate change and the adaptation of water policy measures to climate change, the WFD stipulates the need for a greater integration of qualitative and quantitative aspects of surface water and groundwater for the purpose of environmental protection. There is compelling evidence that climate change affects water management practices and the management of water infrastructure, requiring water quality systems to be re-designed (Kundzewicz *et al.*, 2008). In this regard, addressing the qualitative and quantitative aspects of surface water and groundwater, the WFD gives a valuable response to climate change in the water sector.

In general terms, the WFD aims to ensure long-term protection of available water resources, enhancement of the protection of the aquatic environment, reduction in water pollution and mitigation of the effects of floods and droughts. Global climate change could alter hydrologic conditions and affect ecological systems, including changes in water systems as well. Actually, the issue of climate change and adaptation measures must already be taken into consideration. The EU Commission in defining adaptation uses the following terminology: adaptation aims at reducing risk and damage from current and future harmful effects, cost-effectively or by exploiting potential benefits.

The WFD requires the European Parliament and Council to adopt specific measures against pollution of water in the form of strategies, for both surface water and groundwater (WFD, 2000). This resulted in the adoption of Directive 2008/105/EC (the Environmental Quality Standards Directive), which sets environmental quality standards in the field of water policy. River basin-specific pollutants are considered part of the ecological status.

To achieve the directive objectives, each MS is required to identify river basin districts within its territory, analyse their characteristics, review the impact of human activity on the status of surface water and groundwater and conduct an economic analysis of water use (WFD, 2000), and then appoint a competent authority for each river basin district to coordinate the implementation of the directive (Griffiths, 2002). Moreover, MSs need to establish a register of all areas within each river basin district that require special protection measures. River Basin Management Plans (RBMPs) need to be established for each river basin district (WFD, 2000).

The provisions of the WFD apply to all MSs but have wider application as well. If the river basin district extends beyond the territory of the EU, the MS needs to establish appropriate coordination with the relevant non-MS, aimed at achieving the objectives of the directive throughout the river basin district. This comes from the river basin management approach incorporated in the WFD where the principle of a natural geographical and hydrological unit overcomes the principle of national political boundaries. A good example is the case of the Rhine River, where state cooperation goes even beyond the EU territory (Knepper, 2006). Additionally, the case of the Danube River Basin could not be disregarded from the standpoint of this research. International cooperation in water management in the Danube River Basin is based on the Danube River Protection Convention (signed in 1994, came into force in 1998), followed up by the activities of the International Commission for the Protection of the Danube River. After the adoption of the WFD, all states (including MSs and non-MSs) that signed the Danube River Protection Convention (DRPC) agreed to coordinate their activities to comply with the WFD. It should be noted that Serbia signed the DRPC in 2003.

Climate change impacts water resources (e.g. limited freshwater availability and degraded water quality), and consequently, water management policy, so the adaptation of the policy and legislation is necessary on both regional (EU) and national levels. Adaptation assumes the implementation of water policy measures to mitigate the effects of climate change on water resource systems. These measures are already embedded in the WFD and represented in water pollution standards and water quality standards. The purpose of the WFD is environmental protection that should be accomplished by setting out qualitative and quantitative standards of both surface water and groundwater, considering the close link between natural flow conditions and the climate system.

2.2 Climate change policy integration in EU water management – breaking the glass ceiling

By contrast with ordinary EU harmonisation instruments such as directives, regulation and decisions, the EU widely uses relatively new mechanisms, so-called soft law instruments, aimed at integrating into the law of each MS the provisions of general interest for the community. The new forms of the EU integration process use non-binding legal instruments that create a moral and political obligation for MSs to accept and integrate the common EU policy in a particular field of interest. Soft law instruments that encompass guidelines, recommendations, codes of conduct, action plans, strategies and green and white papers emerged in the early 1980s, when the European Commission introduced a new community mechanism represented in a form of self-regulation and voluntary standardisation instruments (Egan, 2001). This new form of integration and decision-making at the EU level was primary motivated by the search for flexibility and adaptability of regulation to distinctive territorial, economic, environmental, administrative and social conditions (Koutalakis *et al.*, 2010), and also as a tool to incorporate fields outside the jurisdiction of the EU hard law. The EU law is based on the principle of subsidiarity, meaning that decisions need to be taken as close as possible to the citizen. Hence, the tasks should be performed on the national rather than international or regional levels. According to the founding treaties of the EU, the principle of subsidiarity was expanded, becoming a guiding rule for all EU activities, including those in the field of environmental policy where the EU Commission gets a "substantial role in addressing such international issues as climate change and ozone depletion" (Jordan, 2000). To overcame the boundaries of the subsidiarity principle in the areas of general interest, such as climate change and environmental (and water) policy, soft law instruments became the more appropriate tool, i.e. a more flexible regulatory EU approach that allows MSs to adapt EU laws to their specific national or supranational conditions or both (Koutalakis *et al.*, 2010). Although water management is regulated on the EU level by the WFD (2000), as a EU hard law instrument, the subsidiarity principle is still represented within the provisions of the directive, stating that RBMPs will be drawn up by national authorities (Koutalakis *et al.*, 2010).

The EU environmental policy and law in the field of climate change is significantly more ambiguous because the research of the impacts of climate change on water resources is still being carried out, aimed at reducing uncertainty based on both climatic and hydrological modelling (Kundzewicz *et al.*, 2008). Additionally, the different economic conditions of MSs unfavourably affect the adoption of an environmental policy and law that address the issue of climate change. The soft law instruments become much more politically attractive, leaving a lot of discretion to MSs (Palmer, 1992), especially about issues that are politically and scientifically sensitive to cope with. Soft law instruments represent a step forward to harmonisation and a way to fill the regulatory gaps in politically delicate but internationally significant fields.

In the area of climate change, the EU adopted two core soft law documents: Green Paper on adapting to climate change in Europe – options for EU action (2007), and White Paper "Adapting to climate change: Towards a European framework for action" (2009). The latter has the form of an "invitation document" aimed at encouraging a discussion about necessary actions in a particular field, which need to be taken at the EU, national, regional and local levels of both MSs and non-MSs. The document underlined the international dimension of climate change, emphasising the importance of coordination activities and exchange of information with partners, including candidate countries. Public and non-public sectors should be engaged in the development of adaptation technologies and products to stimulate innovation in the water sector. Thus, coordinated and comprehensive adaptation strategies to climate change based on an integrated and holistic approach need to be adopted. Policy adaptation measures that address the issue of climate change could be incorporated into the existing strategies and legislation of the sector affected, in a new strategic document that encompasses all sectors affected by climate change. It should be noted that national strategies also represent a soft law, non-binding instrument that sets out a legal framework for the future adoption of legally binding documents in a particular area.

On the grounds of the former document, the EU adopted in 2009 the letter one, which sets out a framework for community action in the field of climate change addressing, inter alia, the impact of climate change on the quality and availability of water resources. MSs are invited to adopt national strategies to ensure an optimal level of adaptation, by improving water resource management and ecosystems. The role of the EU institution should be supportive, i.e. the EU needs to facilitate coordination and the exchange of best practices between MSs on climate change. To prepare the EU adaptation strategy to climate change, four pillars of action have been introduced:

(1) developing the knowledge base on the impact of climate change;
(2) setting out the integrated adaptation into EU policies in the water sector;
(3) ensuring effective delivery of adaptation using different policy measures; and
(4) supporting international cooperation.

2.3 Serbia water management policy and law – current state and perspectives

The Republic of Serbia has the status of a candidate country in the process of accession to the EU, which was granted in March 2012. In June 2013, the European Council opened accession negotiations with Serbia. Apart from this, Serbia belongs to the region of UNESCO countries with more than 90 per cent of its territory falling within the basin of the Danube River as an international river that requires multilateral coordination and cooperation regarding water management and compliance with EU standards in the water sector. Additionally, Serbia is a member of the International Commission for the Protection of the Danube River (ICPDR).

The core hard law document that addresses the issue of water management in Serbia is the Water Law enacted in 2010, regulating the legal status of water, integrated water management, sources and methods of financing water activities. Water management is under the jurisdiction of the Republic, but it is realized through the competent authority (the Ministry of Agriculture and Environmental Protection), regional and local public bodies and public water companies.

The Water law (2010) provides for the adoption of a National Water Management Strategy (Strategy, 2016) for a time period of 10 years minimum, representing a basic tool for the introduction of integrated water management. The integrated water management approach has been introduced, and objectives relating to sustainable water use, water pollution control and protection from extreme events (floods and droughts) have been set. To establish integrated water management, water resources and social development are considered to be strongly linked, where the accomplishment of a good environmental status (quality and quantity standards) of both surface water and groundwater, apart from the aforementioned objectives, is stressed by the strategy. The basic elements are included in the scope and presented as follows: current state of water management, goals, guidelines, perspective of water management development and actions for the achievement of goals and objectives.

There are significant disadvantages regarding the current situation in water management in Serbia, particularly those related to economics issues (reduced funding of the water sector, insufficient investment activity), followed by institutional and administrative problems, surface water and groundwater monitoring issues and insufficient international and regional cooperation, especially with neighbouring countries. Bilateral agreements with neighbouring countries have not been signed. Accomplishment of the strategy objectives requires steady funding of the water sector, primarily setting of economic prices of water based on full cost recovery and the "user pays" and "polluter pays" principles, along with the principle of public-private partnership, meaning that funding needs to come from different sources, i.e. public water funds, revenues of local administrations, water prices, IPA and other funds, project owners' resources and loans. Furthermore, the delineation of responsibilities amongst different government agencies and other stakeholders, with greater involvement of scientific and research organisations, is important for the implementation of the principle of integrated water management. Coordinated and comprehensive monitoring of surface water and groundwater and the establishment of the Water Pollution Control Plan are, inter alia, essential for the achievement of the strategy objectives.

The Water law (2010) also provides for the establishment of RBMPs for seven specific water areas, including national (Velika Morava River and Kolubara River) and international rivers (Danube, Sava and Tisza). Serbia has participated in the adoption of the Danube, the Tisza and the Sava RBMPs. The RBMPs for specific national water areas, including that of the Velika Morava River, as the largest national river, are expected to be prepared by public water management companies. These plans need to address the issue of environmental protection, where each RBMP has to be accompanied by a report on strategic environmental assessment, which is an integral part of the plan.

The issue of climate change impact on water resources and management practices was not directly emphasised by the Water law (2010) or by the strategy, and there are no activities towards future adoption of a specific strategy addressing the climate change impact in the water sector. Nevertheless, the Water Law (2010) requires the preparation of a report on strategic environmental assessment (Report, 2015) for the purposes of implementation of the strategy, as well as the RBMPs. In October 2015, the Ministry of Agriculture and Environmental Protection produced the report, aimed at implementing integrated water management and creating a system adaptive to environmental changes. Climate change and its potential impact on water resources are not directly addressed. The report has found the monitoring of water parameters incomplete (water quality and quantity), where groundwater was not included in the overall monitoring process. Moreover, the locations of surface water monitoring sites, as well as the number and frequency of measurement, are not applicable to all rivers. The observations on small and medium rivers are too limited, which affects the reliability of assessment of the quality of surface water and groundwater. The Environmental Information System is also riddled with deficiencies; the Environmental Protection Agency, as a part of the Ministry of Agriculture and Environmental Protection, collects data on air emissions, emissions to water and waste management, where environmental indicator systems suitable for planning purposes have still not been established (Report, 2015).

Fortunately, the Ministry of Agriculture and Environmental Protection published in 2015 a draft of Serbia's First National Adaptation Plan relating to climate change (SFNAP, 2015). The adaptation plan will ensure assessments of climate change vulnerability and risk and define possible adaptation options in the short and long term. Methodologically, the plan follows the framework defined by the guidelines of the United Nations Convention on Climate Change. It is based on the assessment damage as a result of long-term changes in climate conditions in Serbia, and as a result of climate extremes observed over the past decades. The plan analyses future risks and vulnerabilities and ensures synergies between future development and proposed measures in the following sectors: water resources, agriculture, forestry and biodiversity.

3. Case study of the Velika Morava River Basin (Serbia)

The research addressed the Velika Morava River Basin which represents the major river system in Serbia, located in South East Europe (Figure 1). The Velika Morava River is the longest tributary of the Danube, with a total length of 493 km and a basin area of 37,444 km^2, which is 42.4 per cent of the land area of Serbia. The specific water yield for the Velika Morava River Basin is 6.27 $l/s/km^2$, while that of the Zapadna and Južna Morava is 7.15 $l/s/km^2$ and 6.08 $l/s/km^2$, respectively. One should note that the distribution of water yield in the Velika Morava River Basin is non-homogeneous, with a decreasing gradient from the west to the south.

The hydrologic regime of the Velika Morava River was analysed at the Ljubičevski Most hydrologic station (h.s.), with a basin area of 37,320 km^2, as illustrated in Figure 1. Also, Figure 1 shows the locations of the selected climatic stations needed for hydrological simulation. The used records were obtained from the Republic Hydrometeorological Service of Serbia.

3.1 Climatic projections

For the purposes of this research, long-term projections of precipitation and temperature in the Velika Morava River Basin have been simulated applying the coupled regional climate model EBU-POM (Đurđević and Rajković, 2008). Most of the future projections analysed within the Danube River Basin, including the basins in Serbia, are based on the IPCC SRES scenarios A1B and A2 (ICPDR, 2012), as they cover a wide range of the main driving forces of future emissions, as well as demographic, technological and economic developments. For this reason, the future projections at the climatic stations within the Velika Morava River Basin were derived in accordance with the A1B and A2 climate scenarios.

The climatic projections for the future time frame of 2013-2100 were analysed for three different perennial periods: near future 2013-2040, mid-distant future 2041-2070 and distant future 2071-2100. The mean annual and seasonal precipitation and temperature in the Velika Morava River Basin were determined using Thiessen polygons for climatic sites analysed (Figure 1). Relative changes in the median of annual precipitation and temperature with reference to the baseline period 1961-1990 are shown in Table I. Changes in the median of

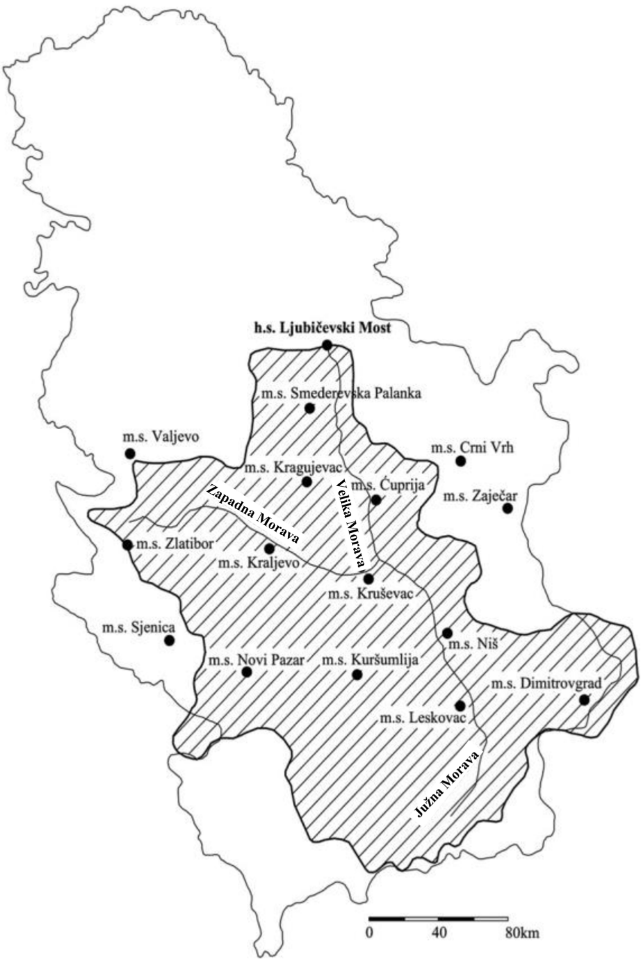


Figure 1.
The Velika Morava River Basin with hydrograph network and locations of chosen climatic and hydrological stations

seasonal precipitation and temperature in accordance with the A1B and A2 climate scenarios are illustrated in Figure 2.

Based on the results of climate modelling, annual precipitation can be reduced in both climatic scenarios by 2100, except of a slight increase in precipitation (1.4 per cent) for the A2 scenario in the near future (Table I). In addition, the results indicate less annual precipitation for the A1B scenario than it should be with the A2 scenario. The largest decrease in precipitation for both scenarios is expected in the distant future (2071-2100), with a reduction in the range of 14.5-20.8 per cent, accompanied by a rapid increase in temperatures (~4°C) in the considered climate scenarios (Table I).

Also, the climate projections of precipitation and temperature suggest changes in their seasonal distributions. The seasonal changes of future climate with reference to the baseline period are illustrated in Figure 2, as a relative and absolute change in seasonal values of precipitation and temperature, respectively. Climate modelling results within in the Velika

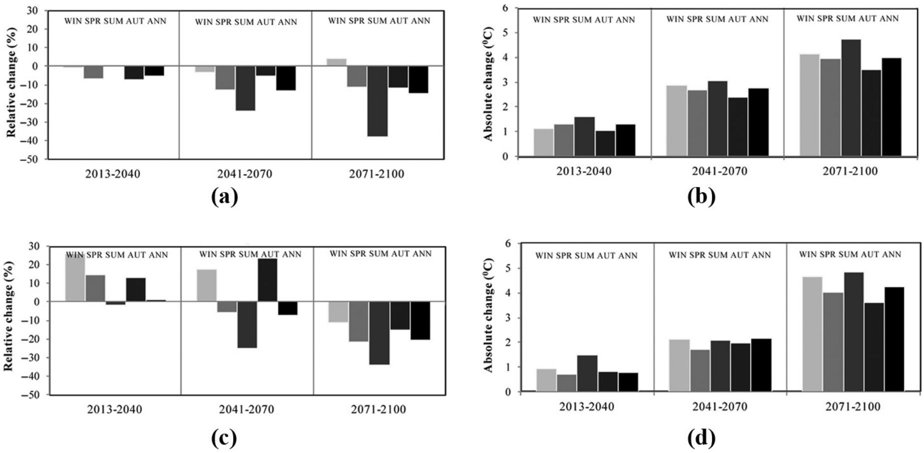
Morava River Basin indicate an overall increase in temperature during all seasons for both climatic scenarios, with emphasis on summer temperatures. A reduction in seasonal precipitation is expected for the seasons analysed in the A1B scenario, while climate modelling under the A2 scenario suggests an increase in precipitation in the winter, spring and autumn seasons for the near future (2013-2040) and mid-distant future (2041-2070) (Figure 2). The most pronounced decrease in precipitation, greater than 40 per cent in both scenarios, is expected for summer seasons in the distant future (2071-2100).

3.2 Hydrological projection

Monthly flows at h.s. Ljubičevski Most were estimated using a deterministic-stochastic time series model (Stojković *et al.*, 2015). The model is founded upon two-stage time series modelling, which consists of the following components: trend component, long-term periodic component, seasonal component and stochastic component. The first stage includes estimation of annual flows based on annual precipitation and temperature under a certain

Table I. Changes in the median of annual climatic drivers (precipitation and temperature) and flows for the Velika Morava River at h.s. Ljubičevski Most for the future time frame with the reference to the baseline period 1961-1990

	Temperature		Precipitation	
Periods	A1B°C	A2°C	A1B (%)	A2 (%)
2013-2040	+0.8	+1.3	–5.5	+1.4
2041-2070	+2.2	+2.8	–13.2	–7.4
2071-2100	+4.0	+4.2	–14.5	–20.8
Periods	Flows			
	A1B (%)		A2 (%)	
2013-2040	–5.7		+3.0	
2041-2070	–14.9		–6.2	
2071-2100	–17.2		–22.3	



Notes: (a) Precipitation A1B; (b) precipitation A2; (c) Temperature A1B; (d) Temperature A2; WIN – winter, SPR – spring, SUM – summer, AUT – autumn, ANN – annual

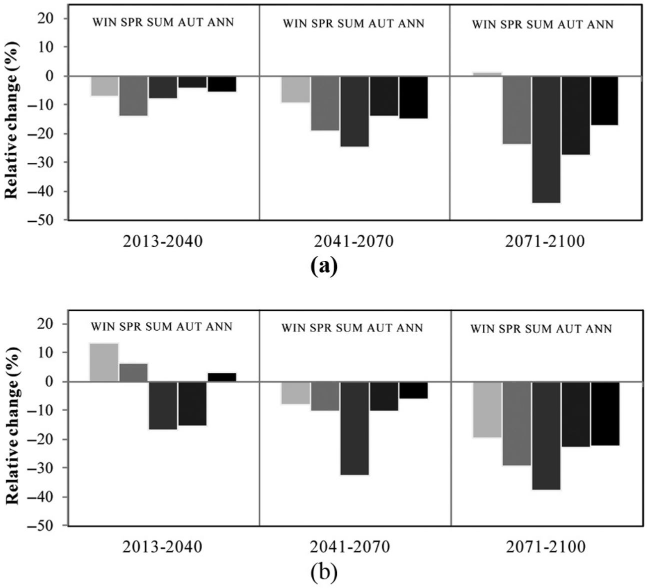
Figure 2. Relative changes in the median of seasonal precipitation (a, b) and absolute change in the median of seasonal temperature (c, d) for the Velika Morava River Basin with the reference to the baseline period 1961-1990

climate change scenario, while the second stage includes hydrologic predictions summing up all estimated components at monthly level.

The projections of monthly flows were determined on the basis of precipitation and temperatures from climatic modelling in the A1B and A2 climate scenarios for the future time frame of 2013-2100. The results expressed as the relative change of the annual and seasonal projections at h.s. Ljubičevski Most are given in Table I and Figure 3, respectively.

As apparent in Table I, the projection of annual flows indicates a decrease up to the year 2100, where the expected decrease in the median of annual flows for climate scenario A1B and A2 stands at 12.6 per cent and 8.5 per cent, respectively. Moreover, there were different changes in annual flow predictions during the three perennial intervals (near, mid-distant and distant future). The results from Table I imply that a moderate decrease in annual flows, according to the A1B scenario, can be expected in the near future (2013-2040). Also, the A2 climate scenario suggested a slight increase in annual flows for the period 2013-2040. A more pronounced decrease in annual flows was suggested for the mid-distant future (2041-2070), while a plunge of annual flows was projected for the last decades of the twenty-first century, according to both climate scenarios.

Apart from the changes in the hydrological projections at the annual level, a significant change in seasonal flow distribution can be expected (Figure 3). However, seasonal flow changes are a result of a rise in temperature during all seasons of the year, along with a distinct decrease in precipitation in the summer months. The greatest decrease in annual flows is expected in the summer season, according to both climate scenarios, and there is also a significant reduction in the autumn and spring seasons (Figure 3). Besides flow reduction, a slight increase in seasonal flows was projected in the winter and spring seasons



Notes: (a) FLows A1B; (b) flows A2; WIN – winter, SPR – spring, SUM – summer, AUT – autumn, ANN – annual

Figure 3.
Relative changes in the median of annual and seasonal flows at h.s. Ljubičevski Most under the A1B (a) and A2 (b) climate scenarios with the reference to the baseline period 1961-1990

for the A2 climate scenario in the near future, which is attributable to an increase in precipitation (Figure 2b).

4. Recommendations for integrated water management as impacted by climate change

The hydrological projection for the Velika Morava River indicates a significant change in the annual flow pattern and seasonal flow distribution (Table I, Figure 3). The decreasing future flows and precipitation, on one hand, and increasing air temperature, on the other hand, might have some consequences on the water demand and ecological functioning of aquatic ecosystems. Thus, there is a need to involve measures to enhance water management practices, with particular emphasis on water-use efficiency in agriculture and households (Bates *et al.*, 2008).

The Morava Valley is a fertile agricultural region which accounts for a significant share in the gross domestic product in Serbia. Agriculture in the Morava Valley is in general sensitive to extreme weather conditions and has suffered significant losses in the past decades due to unfavourable climate conditions, such as severe droughts (SFNAP, 2015). On the other hand, a warm climate in late winter and early spring is dangerous for crops. In addition, it is more likely that the potential reduction in precipitation and the expected increase in air temperature within the Velika Morava River Basin (Table I, Figure 2) will intensify the existing agricultural production risks. As such, an overall decrease in annual flows and hydrologic cycle changes are to be expected (Table I, Figure 3), resulting in the water demand for agriculture becoming a more significant issue. Also, the intensification of agricultural production in the lower Danube countries will bring about an increase in water demand compared to the current state (DRBM, 2009). Taking these facts into account, the currently unfavourable spatial and temporal distribution of water resources in the Velika Morava River Basin needs to be improved, primarily by building new water facilities where water could be stored during wet periods and used in the summer season (IJC, 2002).

Serbia has 797 protected plant and animal species and 464 protected areas. Many of them are located in the Velika Morava River Basin (SFNAP, 2015). The Biodiversity Strategy of the Republic of Serbia for the period 2011-2018 (BSRS, 2011) supports biodiversity and ecosystem adaptation to climate change, as well as strengthening of knowledge about the conservation and sustainable use of biodiversity. It is predicted that climate change will affect ecosystems globally, but it is difficult to predict local impacts. Different impacts are expected for the main tree species in Serbia, as they primarily depend on groundwater which has exhibited a general decline in recent decades (SFNAP, 2015). Also, aquatic ecosystems have been increasingly threatened by land-use changes, environmental pollution, and water diversion. Lately, climate change has altered the main ecological processes of aquatic species and become a major concern (Poff *et al.*, 2002). As a consequence of a rapid increase in temperature due to climate change, a rise in water temperatures can alter fundamental ecological processes and the geographic distribution of aquatic species in the Morava Valley. The expected seasonal changes in the precipitation pattern in the Velika Morava River Basin (Figure 2) will alter the hydrologic characteristics of aquatic systems. This will likely have a significant impact on the reproduction of many aquatic species because they are sensitive to changes in the frequency, duration and timing of extreme hydrologic events (Poff *et al.*, 2002). On the other hand, a rise in water temperature in the Velika Morava River Basin can bring about a rapid increase in oxygen consumption rates, leading to oxygen stress of the aquatic species. Also, ecological indicators of streams can indicate a deterioration of stream health (Woznicki *et al.*, 2016), whereas the temperature regime of the Velika Morava River Basin is expected to change from cold to warm. One should note that a warm temperature regime can impair the current ecological condition of the Velika Morava River, which is categorised as moderate to poor (Marković *et al.*, 2016).

Robust water management is required in the Velika Morava River Basin to cope with both water scarcity and increased water demand. For this purpose, the EU has endorsed the strategy on adaptation to climate change, which sets out a framework for EU's preparedness for future climate impacts (EUACC, 2013). The document stipulates that global warming must be kept below 2°C, compared to the pre-industrial air temperature. To fill the gaps in EU water policy, the European Commission has adopted the blueprint to safeguard Europe's water resources, considering the needs of people and the natural ecosystems (WBE, 2013). Also, the Danube River Basin District Management Plan (DRBMP, 2009) has been established to cover the Danube River Basin, including the Velika Morava River Basin. The DRBMP considers the impact of climate change on water resources by stipulating that future infrastructure projects need to be holistic and coherent in their approach, linking all relevant sectors and needs to provide flexible management tools.

In accordance with national and international legislation, the response of potential water scarcity of due to climate change in the Velika Morava River Basin and its negative effects on the environment should be overcome by adequate policy guidelines. Therefore, the recommendations for integrated water management, taking into account the considered river basin, are as given below. Such recommendations are divided into three general categories according to the form of adaptation, i.e. the measures required (Fussel, 2007):

(1) Technical recommendations:
   - Detailed assessment of the risks associated with climate change in the water sector in the Velika Morava River Basin, providing for cooperation between government bodies and scientific and research organisations.
   - Setting out of indicators for water quality assessment so as to solve pollution problems in the Velika Morava River Basin (observe changes in water quality due to human activity and changes in the hydrologic regime);
   - Better monitoring of the quality and quantity of both surface water and groundwater by increasing the number of measurement points in the monitoring system. The current monitoring network in the Velika Morava River Basin consists of 97 surface water stations and 99 groundwater stations (Hydrometeorological Yearbooks, 2016).
   - Development of integrated water management and an environmental information system.
   - Designing of new water systems, as well as upgrading of existing ones in the Velika Morava River Basin. This measure will enhance flood protection in Serbia, as it is estimated that 18 per cent of the territory is potentially vulnerable to floods (SFNAP, 2015). Also, these facilities can improve the currently unfavourable spatial and temporal distribution of water resources within the Velika Morava River Basin.
   - Construction of wastewater treatment plants for settlements and industrial centres, because the quality of water in watercourses is not satisfactory, primarily along the course of the Velika Morava.

(2) Legal recommendations:
   - Extensive use of a flexible legal framework based on soft law instruments, i.e. adoption of a specific national strategy to deal with the impacts of climate change on water resources as a part of the concept of integrated and adaptive

water management, instead of hard law instruments represented in the form of laws and by-laws.

- Establishment of RBMPs for each river basin, starting from the largest national river (the Velika Morava), accompanied by Water Pollution Control Plans.

(3) Institutional recommendations:

- Strengthening of institutional capacity for water management and environmental protection.
- Inter-sectoral coordination between bodies of the Ministry of Agriculture and Environmental Protection (Environmental Protection Agency and Republic Water Directorate), as well as cooperation with specific public entities – Republic Hydrometeorological Service and public water companies.
- Boosting of the national scientific sector by funding projects that deal with climate change impact on water resources.

5. Conclusion

The paper provides a detailed comparative analysis of international and national legislation in the water sector. In water regulation, Serbia follows the EU policy trends in the field of water management introduced by the WFD. Integrated water management is established by the Water Law (2010), but climate change impacts on water management are not addressed directly. Moreover, the adverse effects of climate change on the water sector have not been considered in the National Water Management Strategy (Strategy, 2016), although the impact of activities in the water sector on environmental protection has been analysed and presented in the report on strategic environmental assessment (2015). Additionally, a summary review of adaptation measures in selected sectors (water resources, agriculture, forestry and biodiversity) due to climate change is provided in the draft version of Serbia's First National Adaptation Plan (2015). The integrated water management policy could be interpreted as an adaptive water policy that could include impacts of climate change on water resource management, particularly the issue of water quality and quantity standards and water pollution control.

In Serbia, mechanisms for the assessment and monitoring of water quality and water pollution are not fully developed. The RBMP for the Velika Morava River has not yet been prepared, so there is no report on strategic environmental assessment for this significant national river basin. This means that the climate change impact on this river basin has not been assessed, while the study provides evidence that future changes in the climatic and hydrologic patterns are to be expected. Actually, the climatic projections from the EBU-POM model under climate scenarios A1B and A2 are used as inputs to assess annual and seasonal flow projections. The results indicate a decrease in precipitation up to the year 2100 for both climatic scenarios, accompanied by a rapid increase in air temperature. Moreover, a significant change in seasonal flow distribution with a distinct decrease in the summer and autumn seasons is suggested. Considering the negative effects of climate change on water resources and related sectors in the Velika Morava River Basin, technical, legal and institutional recommendations have been formulated. It should be noted that the adoption of an RBMP for each river basin, including that of the Velika Morava, which deals with the impacts of climate change on water resources, can be a tool for overcoming current regulatory gaps that will be the topic of further research.

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