Climate Change Management

Walter Leal Filho
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Climate Change Adaptation in Eastern Europe

Managing Risks and Building Resilience to Climate Change

Springer

Climate Change Management

Series editor

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The aim of this book series is to provide an authoritative source of information on climate change management, with an emphasis on projects, case studies and practical initiatives—all of which may help to address a problem with a global scope, but the impacts of which are mostly local. As the world actively seeks ways to cope with the effects of climate change and global warming, such as floods, droughts, rising sea levels and landscape changes, there is a vital need for reliable information and data to support the efforts pursued by local governments, NGOs and other organizations to address the problems associated with climate change. This series welcomes monographs and contributed volumes written for an academic and professional audience, as well as peer-reviewed conference proceedings. Relevant topics include but are not limited to water conservation, disaster prevention and management, and agriculture, as well as regional studies and documentation of trends. Thanks to its interdisciplinary focus, the series aims to concretely contribute to a better understanding of the state-of-the-art of climate change adaptation, and of the tools with which it can be implemented on the ground.

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Preface

Climate change affects countries in Eastern Europe, i.e. the Western Balkans and Southeast Europe in a variety of ways. Apart from severe floods, there are records of decreasing water reserves in the southern part and of gradual changes in biodiversity and agricultural production. In the South Caucasus area, for instance, climate change models project a decline in precipitation by the end of the century and suggest that it will continue to become drier this century.

Many Eastern European countries, especially the non-EU ones, are characterized by the fact that national climate policies on the one hand and transboundary collaboration on the other are rather weak and by the fact that the engagement of the general public on matters related to climate change is still rather limited. Climate change thus poses a serious threat to the economic stability and development of many Eastern European countries and to the sustainable development of the region.

The above state of affairs illustrates the need for a better understanding of how climate change influences Eastern Europe and for the identification of processes, methods and tools which may help the countries and the communities in the region to adapt. There is also a perceived need to showcase successful examples of how to cope with the social, economic and political problems posed by floods/droughts in the region, especially the ways of increasing the resilience of agricultural systems and of communities.

It is against this background that this book has been prepared. It contains a set of papers presented at the "International Scientific Conference on Climate Change Adaptation in Eastern Europe" being organized by the University of Banja Luka, University of Belgrade, the Research and Transfer Centre "Sustainable Development and Climate Change Management" of the Hamburg University of Applied Sciences (Germany), the International Climate Change Information Programme (ICCIP), Fund for Environmental Protection and Energy Efficiency of the Republika Srpska and Center for Climatic Research (CCR Banja Luka), as well as additional contributions. The book is a very interdisciplinary piece, mobilizing scholars, social movements, practitioners and members of governmental agencies, undertaking research and/or executing projects focusing on climate change in Eastern Europe.

Thanks to its scope, the book will serve the purpose of showcasing experiences from research, field projects and best practice to foster climate change adaptation among countries in the region, which may be useful or implemented elsewhere.

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Contents

Towards Resilient Cities in Serbia

Branko Protić, Velimir Šećerov, Bogdan Lukić and Marija Jeftić

Abstract The problems of climate change and the concepts of resilient cities and resilience to climate change have gained considerable attention and interest in Serbia over recent years, especially after the catastrophic floods that hit Serbia in 2014. Now the improvement of resilience in the face of natural, socioeconomic, and political uncertainty and risks has captured the attention of researchers and decision-makers in almost all disciplines and sectors. This paper, through an analysis of the literature on climate change, with a special focus on Serbia, as well as Serbian legal regulations, strategies and planning documents, will show the awareness and understanding of resilience in the Serbian planning policy arena. Special attention is paid to local governments and the issue of climate change, and the problem of how planners, planning policy and decision-makers take into account or deal with the risks that it presents.

Keywords Climate change · Serbia · Resilience · Urban and spatial planning
Local government

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1 Introduction

The population of cities is increasing annually. According to a United Nations estimate, the number of residents in cities will grow from 3.6 billion in 2011 to 6.3 billion by 2050. Most people will live in large cities, while the population of medium-sized towns will increase by about 40% of this number (UN 2014). Also, urban areas are global economic hubs, as a result of which many assets are exposed to climate change hazards (Satterthwaite 2007; Rosenzweig et al. 2011; Revi et al. 2014; Doherty et al. 2016). This trend is also present in Serbia, where the urban population as a share of the total population is constantly on the rise.

However, data by the Intergovernmental Panel on Climate Change (IPCC) show that developed countries are among the largest polluters of the environment and the largest emitters of greenhouse gases, which contributes to the acceleration of climate change (IPCC 2014), while at the same time, cities in developing countries are most at risk of climate change due to poverty, a degraded environment, poor infrastructure, limited resources and limited capacities (Jabareen 2013). These changes have a devastating effect on the environment and economy, and particularly on people (Folke et al. 2010). Disasters most often affect developing countries, since they are the most vulnerable and poorly equipped to deal with them. The lack of capacity and resources is the most common reason why, especially in less developed countries, adaptation measures are not systematically, strategically and preventively implemented prior to dramatic experiences with extreme climatic events (Kern and Alber 2008; Fünfgeld 2010). Almost all countries in the region of the Western Balkans, where Serbia is located, are quite threatened and have similar problems caused by climate change (Spasov et al. 2008; Trbić et al. 2018).

Research results indicate that cities are creating a very significant and ever-growing amount of greenhouse gases—GHG. Consequently, we can expect a manifold increase in the number of extreme climatic events, such as drought, floods and hurricanes (IPCC 2014).

According to a general definition, climate change adaptation involves predicting when and where the consequences of global warming will happen, developing adaptation strategies, and applying definite measures to reduce any vulnerability to the effects of climate change. These measures can range from those that are technical, institutional, legal and educational to those that encourage a change in behavior (Füssel 2007: 267).

Climate change greatly affects urban activities, including town planning, general mobility, construction, the energy sector, public health, waste management and food safety (Đukic and Antonic 2016). Failure in one part can have a domino effect in others, thereby creating further economic losses (Torres 2013). Managers and city leaders understand that climate change is a priority—but many cities are facing what they view as conflicting priorities (Zottis 2014).

However, the resilience and the ability of people and places to withstand these effects and recover quickly are still present. Resilience is defined as the ability of a system, community or society exposed to danger to resist, absorb, adapt and recover in a timely and efficient manner from the consequences of an event, including the preservation and restoration of essential basic structures and functions (UNISDR 2009). Similarly, the resilience of cities refers to the ability of urban systems and all their integral socio-ecological and socio-technical elements and connections to maintain or quickly restore the desired functions to their previous state in the event of certain severe weather and spatial phenomena, i.e. disasters, and to adapt to these new conditions and to transform (Meerow et al. 2015).

The term resilience originates from ecology, and it was created in the 1970s with the goal of explaining the capacity of a system to maintain or restore functionality in stress situations or under the influence of negative factors (Holling 1973). The popularity of "resilience" has exploded in both academic and policy discourse. Resilience theory provides insight into complex socio-ecological systems and their sustainable management (Folke 2006; Pickett et al. 2013), especially with respect to climate change (Leichenko 2011; Pierce et al. 2011; Solecki et al. 2011; Zimmerman and Faris 2011; Meerow et al. 2015).

Resilience is especially important for urban areas. Rapid urbanization threatens urban security through sudden disasters such as floods, heat, and food shortages. It also threatens urban security through slow changes which endanger both the environment and society. Examples of such changes are urban sprawl, lack of urban infrastructure, climate change and loss of biodiversity. Urban areas are especially vulnerable to both acute disasters and the slow effects of development (Falleth 2013). This makes urban planning, as a collective response to urban threats, an important means of improving urban resilience. The academic focus is especially on resilience related to climate change, environmental threats, natural disasters and terrorism (Falleth 2013; Coaffee 2008; Pickett et al. 2004). Unfortunately, very few urban planning tools are being considered by national and local policymakers in the redeployment of resources in a climate change era. It is time to suggest a research and policy paradigm to craft better urban planning systems in response to climate change (Blakely 2007).

In spatial and urban planning, social, environmental and technical resilience is observed in different ways: as a tool for assessing the possibilities and abilities of a system to change, as a conceptual framework for understanding how to achieve sustainable transformation of the system in the event of a major weather disaster, as a mechanism for introducing new directions in thinking, and as a rich source of innovations (Crowe et al. 2016).

The local level is critical for overcoming climate-generated challenges and making environmentally responsible decisions (Albrito 2012; Measham et al. 2011). This is the level at which all factors of significance for climate change are either present or emerging. If the aim is to contribute to the global endeavor to make inhabited areas, and particularly cities, healthier, more sustainable and safer, then major changes should occur at the local level (Bajić-Brković 2013). Planning, and especially local planning, plays an important part in creating change through the transformation of work methods and the implementation of environmentally responsible spatial solutions (Nordgren et al. 2016). Weak and poorly staffed local self-governments that lack the capacity and expertise to invest, and which do not participate in strategic urban and spatial planning on behalf of their low income citizens living in illegally built settlements, will not meet the challenge of resilience, but will instead increase the vulnerability of the majority of the urban population (Lukic and Šecerov 2017). The need for climate change adaptation requires the enhanced control and monitoring of changes in indicators, research into different aspects of climate change, the development of forecasting models, the development of scenarios, economic analyses, monitoring the impact of extreme temperature changes, the modification of existing adaptation strategies and measures, and the inclusion of stakeholders (Carter 2007).

2 Methodology

Starting from the premise that cities and local self-governments are of key importance for facing the challenges that climate change brings, in combination with an increase in the population of potentially endangered/vulnerable areas, the aim of this paper is to draw attention to the possibility of increasing the resilience of Serbian cities to disasters and the importance of acting locally, that is, to point out actions that primarily the state, but also cities, i.e. local communities, can initiate and apply in order to prevent, and in cases when this is not possible, to solve and deal with problems.

The research conducted for this paper covers the period from 2000 until the adoption of key spatial plans in Serbia (2010–2012), and it contains a review of the current situation in Serbian cities. Since the adoption of a set of laws on the environment (Law on Strategic Environmental Impact Assessment, Law on Environmental Protection, Law on Communal Activities, etc., 2003 and 2004) and the merging of several planning and construction laws into one (Law on Planning and Construction), which until 2003 covered the planning, design, construction and maintenance of buildings, the connection between spatial and urban planning and the environment and nature has strengthened formally, too. Simultaneously with this process, the awareness of the significant impact of climate change on space as a whole has grown through, among other things, an increasing number of segments on this subject in spatial plans, but also through a set of sectoral and thematic strategies at the national and local level (between 40 and 50 at the state level). The subject of resilient cities, particularly with an emphasis on climate change resilience, is still new in Serbia. A theoretical understanding of the issue exists and numerous scientific conferences have been held, but the practice and implementation of rare planning guidelines related to urban resilience are almost non-existent. For this reason, this paper represents an attempt to show the objective state and the genesis of the visibility of this phenomenon, as well as the direction in which the future methodological framework of Serbian planning fund will go.

3 Results and Analysis

3.1 Serbia in the Light of Climate Change

Serbia faces severe economic difficulties: the standard of living is lower than in the EU; unemployment rates are high; and economic growth is relatively modest. The acceleration of economic reforms is a huge challenge, but at the same time it can be seen as an opportune moment to integrate climate change aspects into the newly drafted national development plans (REC 2011).

Serbia is increasingly involved in numerous European projects and programs related to sustainable development, resilience and climate change. Because of the turbulent events that Serbia experienced in the 1990s and 2000s, there have been significant delays, Serbia's progress has been slowed down at all levels, and the country is still poor (Pucar et al. 2013). This is best reflected in the average gross domestic product per capita, which amounts to just $5280.[1] A large number of highly educated people are leaving Serbia and this trend is not slowing down. The political situation is not stable and one of the biggest problems is that there are constant changes within the ministries, due to which, with each new government, the responsibility for dealing not only with climate change, but also spatial planning, is being shifted from one ministry to another. Serbia has become an EU membership candidate, which means that many requirements for this sector will have to be met.

The process of adaptation and improvement in the resilience to climate change in Serbia has been backed up by very modest and not fully adequate activities. There is no *National Adaptation Strategy for Climate Change*, neither is there a *National Strategy for Reducing Greenhouse Gas Emissions*, and there are no laws regulating this issue. As a consequence, there is a lack of a clear and synchronized national policy primarily focusing on adapting to climate change. When it comes to assessing vulnerability to climate change, there is no national strategic document to define this area, although, during the ongoing process of joining the EU, a set of laws and bylaws focused on mitigating climate change has been adopted. A constant lack of funds in the state budget prevents the practical application of the measures established so far (Spasov et al. 2008; Pucar et al. 2013).

The Law on the Spatial Plan of the Republic of Serbia, i.e. the Spatial Plan of the Republic of Serbia (SPRS), deals with the issue of climate change and its impact on the built and natural environment, as well as the issue of renewable energy sources and energy efficiency (SPRS 2010).

A large number of non-governmental organizations, whose primary focus is the protection of the environment, deal with this issue, but their influence on politics and practice is insufficient. The construction fund in Serbia is of varied quality and needs to be restored. On the other hand, future construction will take up unoccupied spaces in the existing fabric of cities and beyond. The development of infrastructure, which is the basis for the construction and reconstruction of new physical structures, should

[1] In 2018 according to http://www.doingbusiness.org/data/exploreeconomies/serbia/.

adequately accompany this development. “The rationalization applied through planning and engineering procedures is necessary for the purpose of sustainability of the restoration of old and the construction of new urban space. The introduction of modern standards and technologies is necessary for further development within set goals” (Pucar et al. 2013: 16).

“The topic that gets a lot of attention in Europe and the world, but is almost completely neglected in Serbia, is the promotion of innovation through the cooperation of universities and institutes with the economy by linking research with practice. One of the key problems is the stagnation of the Serbian economy and its slow recovery” (Pucar et al. 2013: 16). Many researchers in Serbia are engaged in research in various areas of climate change (biodiversity, water, air, land, agriculture, forestry, urban and rural areas, cultural heritage, legislation etc.) by taking part in projects financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. The majority of research in this area is theoretical and is published in international and national journals, while its practical application is sporadic and insufficient. The problem of science in Serbia is the lack of equipment, which causes a big delay and results in research being insufficient and incomplete. There are not enough funds for field research, which additionally makes the situation more difficult.

3.2 From National Policies to Local Plans—The Legislative Framework for Achieving Resilience to Climate Change

Many countries deal with the issue of climate change mostly at the national level and this results in various political decisions, state policies and normative solutions (Table 1). At the same time, the issue does not receive a lot of attention, if any, at the local level. However, the real impact of any strategy or spatial planning action is most obvious precisely at the local level. Bajić-Brković (2013) points out that this is where it starts and finishes, and that it is where the results can be seen and experienced. The situation in Serbia in this area is similar to the situation in other countries. On one hand, the state undertakes and implements numerous policies and projects, but on the other hand, the situation in the local communities is such that they are generally lagging behind and are less “progressive” because they do not treat this issue as a priority.

In Serbia, as in many other countries, energy production and consumption present the main threat that causes climate change. The energy sector is therefore the focus of every debate on climate change and it is the manner in which this problem needs to be addressed, and much discussion needs to take place as to what to do in order to improve the current state of affairs.

The state is generally considered as the body with the greatest responsibility for resolving this issue, which is in line with the hierarchical management model (top-down) still dominant in Serbia. “Placing the focus on the highest state level is not

Table 1 National legal and strategic framework related to climate change

Kyoto Protocol
The Paris Agreement
Spatial Plan of the Republic of Serbia 2010–2020
Law on Planning and Construction ("Official Gazette of the Republic of Serbia", No. 72/2009, 81/2009-correction, 64/2010-CC, 24/2011, 121/2012, 42/2013-CC, 50/2013-CC, 98/2013-CC, 132/2014 and 145/2014)
Law on Environmental Protection ("Official Gazette of the Republic of Serbia", No. 135/2004, 36/2009, 43/2011-CC and 14/2016)
Law on Strategic Environmental Impact Assessment ("Official Gazette of the Republic of Serbia", No. 135/2004 and 88/2010)
Law on Environmental Impact Assessment ("Official Gazette of the Republic of Serbia", No. 135/2004 and 36/2009)
Law on Air Protection ("Official Gazette of the Republic of Serbia", No. 36/2009 and 10/2013)
National Strategy for Sustainable Development ("Official Gazette of the Republic of Serbia", No. 57/2008)
National Strategy for Sustainable Use of Natural Goods and Resources ("Official Gazette of the Republic of Serbia", No. 33/2012)
National Program of Environmental Protection ("Official Gazette of the Republic of Serbia", No. 12/2010)
Biodiversity Strategy of the Republic of Serbia for the period 2011–2018 ("Official Gazette of the Republic of Serbia", No. 13/2011)
Energy Sector Development Strategy of the Republic of Serbia for the period up to 2025 with projections up to 2030 ("Official Gazette of the Republic of Serbia", No. 101/2015)
Strategy of Agriculture and Rural development for the period 2014–2024. ("Official Gazette of the Republic of Serbia", No. 85/2014)
Strategy and Policy of industrial development of the Republic of Serbia 2011–2020 ("Official Gazette of the Republic of Serbia", No. 55/2011)

only a reflection of the belief that the state should and must react at the highest level, but also of the inertia in the line of responsibility, as well as the assumption that local communities have necessary capacities and are capable of implementing policies and measures in local practice, where this is needed" (Bajić-Brković 2013: 42). However, many communities do not implement these policies and measures, although some (mostly urban) communities are interested in them. The reasons lie partially in their inefficient management, but also in the traditional understanding of spatial planning, which primarily focuses on the land use, infrastructure systems and physical features of the development, as well as on the lack of available resources, effective enforcement measures and professional capacities.

3.2.1 The National Level

Since energy is the main factor contributing to climate change in Serbia, all activities so far have been directed towards the energy sector and the areas with the highest energy consumption. The state administration deals with this problem through its various departments and agencies, as well as with the help of various political decisions, policies, normative solutions and strategies designed and adopted so far. Serbia signed and ratified the Kyoto Protocol, and the Ministry of Environmental Protection became the focal point of the UN Framework Convention on Climate Change (UNFCCC). The Department of Climate Change was established as a part of the Sector for Nature Protection and Climate Change at the Ministry of Environmental Protection. The Department is authorized to initiate and coordinate activities related to climate change such as: implementation of the UN Framework Convention on Climate Change and related protocols, the monitoring, reporting and coordination of activities on meeting the obligations arising from membership in the UN Framework Convention, cooperation with the Secretariat of the UN Framework Convention, cooperation with other state bodies and institutions, promoting the UN Framework Convention, project approval and monitoring, drafting strategic documents, etc.[2] Serbia is one of the countries not required by the Kyoto Protocol to participate in the quantitative reduction of global greenhouse gas (GHG) emissions. However, Serbia participates in the program through the Clean Development Mechanism, which means that other countries can invest in the production of green electricity (green energy) in Serbia with the aim of reducing greenhouse gas emissions for their own territories.

A project called the Climate Change Strategy and Action Plan, financed by the European Union through its Instrument for Pre-Accession Assistance (IPA II funds), was launched in 2016. The goal of this project is for the Ministry of Environmental Protection to develop a national intersectoral Climate Change Strategy with an Action Plan. The adoption of a national intersectoral *Climate Change Strategy* with *an Action Plan* will help Serbia establish a national strategic and legislative framework for combating climate change (mitigation and adaptation) in line with the international obligations and goals of reducing greenhouse gas emissions (the Paris Agreement and joining the EU).

The Climate Change Strategy and Action Plan will identify priority measures for reducing greenhouse gas (GHG) emissions (mitigation) and identify the institutions in charge of implementing certain options, as well as the timeframe for the implementation and the total financial resources needed. The creation of transparent scenarios will help identify and assess the potential for a cost-effective and long-term reduction of GHG emissions in relevant economic sectors in Serbia by 2020, 2025, 2030 and 2050. These scenarios will provide information on the contribution to reducing emissions and achieving the global target by 2070. The Strategy will also provide a framework for the policy of adapting to altered climatic conditions, with priorities

[2]The Ministry of Environmental Protection of the Republic of Serbia—http://www.ekologija.gov.rs/organizacija/nadleznost/.

being the agriculture, forestry and water management sectors. In addition to helping Serbia meet its goals in the area of combating climate change, the strategy will also contribute to the advancement of the Serbian economy by providing clear guidelines for future investors (in the areas of infrastructure and development) and by creating conditions for improving the competitiveness of the economy (The Climate Strategy and Action Plan 2016).

This issue has also been elaborated in detail by means of relevant recommendations in the Spatial Plan of the Republic of Serbia 2010–2020. The Plan focuses on the relationship between energy and climate change and this relationship is presented as one of the key factors of urban development and an important factor in determining the critical components of spatial availability, communication and the quality of urban life. This has given a new dimension to the role that local communities can have and opened up new opportunities for local spatial planning (SPRS 2010).

3.2.2 The Local Level

Urban and spatial planning is regulated primarily by the Law on Planning and Construction adopted in 2009, but it is also the subject of several other laws and bylaws. There are two categories of plans: spatial plans and urban plans. The first group includes the Spatial Plan of the Republic of Serbia (SPRS), Regional Spatial Plans (RSP), Spatial Plans for Special Purposes (SPSP), which are intended for specific activities or areas (such as protected natural and cultural areas, areas of infrastructure corridors, etc.) and the Spatial Plan for Local Self-government (municipalities and cities) (SPLS), which is the most important plan when it comes to the issue in question. The second group includes several urban development plans, such as the General Urban Plan (GUP), General (GRP) or Detailed Regulation Plan (DRP) and urban plans (Law on Planning and Construction 2009).

The Republic, or rather the state administration, formally initiates spatial plans (SPRS, RSP and SPSP), whereas the state government or the National Assembly/Assembly of the Autonomous Province/Assembly of City of Belgrade are in charge of their adoption. Their preparation can also be initiated by local communities or numerous public institutions. Local self-government units can also initiate and adopt urban plans. When it comes to the City of Belgrade, which consists of 17 municipalities, these responsibilities lie with the City administration. In the case of the General Urban Plan, due to its strategic character and greater importance, the final approval is given by the competent ministry.

In a conceptual and methodological sense, the planning system represents a mixture of the traditional "top-down" approach and some aspects of the "bottom-up" model. There are no explicit requirements with regard to the process and the planning methods themselves, because they are considered to be dependent on the context and can be changed from one plan to another, as well as from one city to another (Bajić-Brković 2012, 2013). The content is defined by the law for each type of plan. Spatial planning regulates land use, road networks, transport and infrastructure corridors, and the use and development of natural and cultural resources; it identifies and protects sensitive areas, and ecological and natural habitats; and it identifies areas for which more detailed plans have to be developed, including urban areas designated for detailed planning. Planning solutions describe and graphically represent the area they occupy, along with a set of proposals for their implementation or more detailed planning. A section concerning energy issues is a mandatory component of each plan, as defined by the Law on Planning and Construction.

The General Urban Plan (GUP), whose function is to guide and control development at the local level, contains general instructions on the use of land, traffic and the development of infrastructure, green areas and outdoor recreation areas, protected areas and areas designated for urban renewal. The GUP must also take into consideration the issues of energy efficiency, issues of sources and the use of renewable energy, as well as the possible impacts of climate change. However, there is no formal requirement for devising energy-responsible planning solutions in terms of land use or transport, nor are these plans obliged to provide solutions which would take into account resilience to climate change.

Both the GRP and DRP focus on the use of land, areas designated for construction, local traffic and infrastructure. However, both plans are required to establish rules for development and construction which would be applied in each spatial section/sector, and whose implementation would be subject to careful monitoring (Šećerov 2012). Additionally, all local plans must provide and guarantee solutions related to energy conservation, the rational use of energy and the use of renewable energy sources. In this area, local planning has many opportunities at its disposal for developing solutions and recommendations for an energy-responsible urban environment and an urban environment sensitive to the implications of climate change. Unfortunately, few communities and planning teams use these opportunities in order to change the situation and make the issue of resilience to climate change relevant to urban development.

The Law on Planning and Construction (2009) envisages a clear division of responsibilities between state authorities at the republic level and local self-government units. Cities/local self-governments have the responsibility to initiate, develop and adopt urban plans and strategies, as well as to implement plans and present actions taken. Furthermore, all local self-governments are obliged to participate in planning and making decisions on the development of larger spatial units, since they are a part of them (Lukic and Šecerov 2017). According to the laws and bylaws regulating spatial and urban planning in Serbia, it is obvious that there are countless possibilities for cities and local communities to change their environments and make them sustainable and environmentally responsible, on their own initiative and in line with the estimated situation and available possibilities. According to Bajić-Brković (2012, 2013) several options are available to cities and local self-governments:

– Developing strategies of spatial development, with the aim of providing the basis for environmentally responsible development;
– Developing sectoral strategies (e.g. in the area of transport, preservation of natural environment and other areas) of local importance;

- Developing and making urban plans that integrate environmentally responsible parameters, criteria and standards, taking into consideration already existing state policies and measures that encourage this;
- Introducing legislation on local construction and providing technical assistance for its implementation;
- Developing urban projects that integrate parameters of resilience to climate change, as well as those aimed at reducing greenhouse gas emissions;
- Supporting education in the area of environmentally responsible behavior;
- Supporting citizens' initiatives, action groups and non-governmental organizations;
- Starting pilot projects, learning from good examples and establishing cooperation with those with more experience who are already successful in implementing changes in their communities.

Despite the numerous possibilities, the response of cities in Serbia is weak and very few local communities are using any of these options. Key constraints are reflected in the lack of knowledge of the law, legislation, techniques and technology, and financial resources. Bajić-Brković (2012) points out that the gap between the actions of the state government and the situation at the local level is obvious and it requires consideration and urgent action.

4 Conclusion

The Republic of Serbia has established an important component of the institutional and legal framework to fight climate change. At the same time, there is still a need for improvement, as well as capacity building, and a need for responsible and competent institutions at the national level to have greater knowledge.

Although the significance of climate change issues, in particular the need for increased resilience and the need for a change of practice in spatial development issues in Serbia, has been recognized, not much has been done at the local level so far. The current state shows us how slow this process is, and that there are a small number of local communities that care about making their environment, in spatial and physical terms, climate-responsible and resilient. The current practice of dealing with spatial development issues is still unchanged because it is based on a deeply rooted traditional approach both in realizing and understanding relevant issues, as well as in terms of working practice and possible outcomes. The issues of climate change and resilience are both very low on the list of priorities of many communities in Serbia. Although the issues of developing infrastructure, transport, housing and urban services and social infrastructure have the highest priority in local development, they are rarely, if ever, linked to the issue of climate change.

There are many opportunities in Serbia to change the understanding of how important climate change is for local development and to change how it is dealt with. Realizing these opportunities is a priority task and a commitment for local communities.

The state has already fulfilled most of its obligations, and relevant ministries should act in compliance with those measures, so it can be expected that their activity in this domain will continue to grow. However, certain steps have to be undertaken by cities, local authorities and local interest groups in order to take advantage of this favorable moment and to achieve a positive shift.

It seems, however, that the importance of climate change and resilience issues is insufficiently recognized by urban and spatial planners. Although there are plenty of opportunities to work differently, planning practice remains unchanged and continues to rely on a pattern that has long since been established. However, redefining the existing planning model and moving towards a more sensitive model of resilience to climate change—which are now key issues of global development—are the primary task for experts in Serbia.

References

Albrito P (2012) Making cities resilient—increasing resilience to disaster at the local level. United Nations International Strategy for Disaster Reduction, UNISDR, Brussels

Bajić-Brković M (2012) Climate change and urban development: what can local self-governments in Serbia In: Šećerov V, Radosavljević Z Đorđević A, Marić M (eds) Local self-government and the planning and designing spaces and settlements: cities in the 21st century. Serbian Spatial Planners Association and the Faculty of Geography University of Belgrade, Belgrade

Bajić-Brković M (2013) Climate change, national policies and local development: meeting the challenge. In: Pucar M, Dimitrijević B, Marić I (eds) Climate change and the built environment—policies and practice in Scotland and Serbia. Institute of Architecture and Urban and Spatial Planning of Serbia, Belgrade, pp 41–56

Blakely JE (2007) Urban planning for climate change. Lincoln Institute of Land Policy, Cambridge, USA

Carter T (2007) Adaptation: local climate change impacts, adaptation and vulnerability. In: The future climatic window: local impacts of climate change. Leibnitz, Austria

Coaffee J (2008) Risk, resilience, and environmentally sustainable cities. Energy Policy 36(12):4633–4638

Crowe Ph, Foley K, Collier M (2016) Operationalizing urban resilience through a framework for adaptive co-management and design: five experiments in urban planning practice and policy. Environ Sci Policy 62:112–119

Doherty M, Klima K, Hellmann JJ (2016) Climate change in the urban environment: advancing, measuring and achieving resiliency. Environ Sci Policy 66:310–313. https://doi.org/10.1016/j.envsci.2016.09.001

Đukić A, Antonić B (2016) Smart city concept as a response to climate change. In: Pucar M, Nenković-Riznić M (eds) Prostorni, ekološki, energetski i društveni aspekti razvoja naselja i klimatske promene/Spatial, ecological, energetic and social aspects of settlement developing and climate changes. Belgrade, IAUS, pp 15–32

Falleth IE (2013) New trends and theories for secured cities: towards a resilient city: urban planning in Oslo. Lonaard Magazine 15(3):36–50

Folke C (2006) Resilience: the emergence of a perspective for social-ecological systems analyses. Glob Environ Change 16(3):253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Folke C, Carpenter SR, Walker BH, Scheffer M, Chapin III FS, Rockstro J (2010) Resilience thinking: Integrating resilience, adaptability and transformability. Ecol Soc 15, 20. http://www.ecologyandsociety.org/vol15/iss4/art20/

Fünfgeld H (2010) Institutional challenges to climate risk management in cities. Curr Opin Environ Sustain 2:156–160

Füssel HM (2007) Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustain Sci 2(2):265–275

Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4:1–23

IPCC (2014) Climate change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri RK, Meyer LA (eds)]. IPCC, Geneva, Switzerland, p 151

Jabareen Y (2013) Planning the resilient city: concepts and strategies for coping with climate change and environmental risk. Cities 31:220–229. https://doi.org/10.1016/j.cities.2012.05.004

Kern K, Alber G (2008) Governing climate trends in cities: modes urban climate trends governance. In: OECD multi-level system in competitive cities and climate change OECD conference proceedings, Milan, Italy, Oct 2008. http://wedocs.unep.org/bitstream/handle/20.500.11822/20072/kern_governing.pdf?sequence=1

Leichenko R (2011) Climate change and urban resilience. Curr Opin Environ Sustain 3(3):164–168. https://doi.org/10.1016/j.cosust.2010.12.014

Lukić B, Šećerov V (2017) Planning at the local level: organization, management, development. Faculty of Geography, University of Belgrade, Beograd

Measham T, Preston B, Smith T, Brooke C, Gorddard R, Withycombe G et al (2011) Adapting to climate change through local municipal planning: barriers and challenges. Mitig Adapt Strat Glob Change 16(8):889–909

Meerow S, Newell JP, Stults M (2015) Defining urban resilience: a review. Landscape Urban Plann 147:38–49. https://doi.org/10.1016/j.landurbplan.2015.11.011

MMR-SERBIA—Twinning project "Establishment of a mechanism for implementation of the MMR"—https://mmr-serbia.info

Nordgren J, Stultsa M, Meerow S (2016) Supporting local climate change adaptation: where we are and where we need to go. Environ Sci Policy 66:344–352. https://doi.org/10.1016/j.envsci.2016.05.006

Official Gazette of the Republic of Serbia (2009) The Law on Planning and Construction "Official Gazette of the Republic of Serbia", No. 72/09, 81/09-correction, 64/10-CC, 24/11, 121/12, 42/13-CC, 50/13-CC, 98/13-CC, 132/14 and 145/14, Belgrade, Serbia

Official Gazette of the Republic of Serbia (2010) Spatial Plan of the Republic of Serbia 2010–2020. "Official Gazette of the Republic of Serbia", No. 88/10, Belgrade, Serbia

Pickett STA, Cadenasso ML, Grove JM (2004) Resilient cities: meaning, models, and metaphor for integrating the ecological, socio-economic, and planning realms. Landscape Urban Plann 69(4):369–384. https://doi.org/10.1016/j.landurbplan.2003.10.035

Pickett STA, Boone CG, McGrath BP, Cadenasso ML, Childers DL, Ogden LA, McHale M, Grove JM (2013) Ecological science and transformation to the sustainable city. Cities 32:S10–S20

Pierce JC, Budd WW, Lovrich NP (2011) Resilience and sustainability in US urban areas. Environ Polit 20(4):566–584. https://doi.org/10.1080/09644016.2011.589580

Pucar M, Dimitrijević B, Marić I (2013) Klimatske promene i izgrađeni prostor: politika i praksa u Škotskoj i Srbiji/Climate change and the built environment—policies and practice in Scotland and Serbia. Special issues 70. Institute of Architecture and Urban and Spatial Planning of Serbia, Belgrade

Revi A, Satterthwaite DE, Aragón-Durand F, Corfee-Morlot J, Kiunsi RBR, Pelling M, Roberts DC, Solecki W (2014) Urban areas. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York, USA, pp 535–612

Rosenzweig C, Solecki WD, Hammer SA, Mehrotra S (2011) Climate change and cities: first assessment report of the urban climate change research network. Cambridge University Press.

http://www.cambridge.org/rs/academic/subjects/earth-and-environmental-science/climatology-and-climate-change/climate-change-and-cities-first-assessmentreport-urban-climate-change-research-network?format=PB

Satterthwaite D (2007) Adapting to climate change in urban areas: the possibilities and constraints in low-and middle-income nations. International Institute for Environment and Development, London

Šećerov V (2012) Strategic urban planning. Faculty of Geography, University of Belgrade, Belgrade

Solecki W, Leichenko R, O'Brien K (2011) Climate change adaptation strategies and disaster risk reduction in cities: connections, contentions, and synergies. Curr Opin Environ Sustain 3(3):135–141. https://doi.org/10.1016/j.cosust.2011.03.001Star

Spasov D, Bruci E, Trbić G et al (2008) The South East European climate change framework action plan for adaptation, SEE/VCCC—South East European virtual climate change center and regional environmental center, Belgrade. http://www.seevccc.rs/CCFAP-A/CCFAP-A.pdf

The Ministry of Environmental Protection of the Republic of Serbia. Official internet presentation. http://www.ekologija.gov.rs (Last Accessed 17 Mar 2018)

The Ministry of Mining and Energy of the Republic of Serbia. Official internet presentation. http://www.mre.gov.rs (Last Accessed 23 Jan 2018)

The National Climate Change Strategy and The Climate Change Strategy and Action Plan (2016). http://www.klimatskastrategija.eu/strategija-klimatskih-promena/

The Regional Environmental Center for Central and Eastern Europe (REC) (2011) The impacts of climate change on food production in the western Balkan region. http://documents.rec.org/topic-areas/Impacts-climage-change-food-production.pdf

The World Bank (2018) DOING BUSINESS, Measuring Business Regulations. http://www.doingbusiness.org/data/exploreeconomies/serbia/

Torres D (2013) ICTs and adaptation to climate change in Telefonica. In: ITU using ICTs for climate change adaptation, conference proceedings. ITU, Naples

Trbić G, Bajic D, Djurdjevic V, Ducic V, Cupac R, Markez Đ, Vukmir G, Dekić R, Popov T (2018) Limits to adaptation on climate change in Bosnia and Herzegovina: insights and experiences. In: Leal Filho W, Nalau J (eds) Limits to climate change adaptation, climate change management. Springer, Cham, Switzerland https://doi.org/10.1007/978-3-319-64599-5_14

UNISDR (2009) 2009 UNISDR terminology on disaster risk reduction. UNISDR: Geneva, Switzerland https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf

United Nations—UN (2014) World urbanization prospects 2014—the United Nations. http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf

Zimmerman R, Faris C (2011) Climate change mitigation and adaptation in North American cities. Curr Opin Environ Sustain 3(3):181–187. https://doi.org/10.1016/j.cosust.2010.12.004Zurlini

Zottis L (2014) Planning for climate change and the urban future. The city fix. World Resources Institute. http://thecityfix.com/blog/planning-climate-change-urban-future-luisa-zottis/

Projected Changes in Multi-day Extreme Precipitation Over the Western Balkan Region

Vladimir Djurdjevic, Goran Trbić, Aleksandra Krzic and Danijela Bozanic

Abstract Based on climate change projections, specifically scenarios without ambitious mitigation, climate change can be expected to continue in the Western Balkan region in the future. Even if the international Paris agreement achieves its goals and the mean global temperature increase remains well below 2 °C, we will face at least one more degree of warming and corresponding changes in other climate variables. Climate change projections show that for the Western Balkan region possible changes in the mean annual temperature, in relation to the period 1971–2000, range from 2 to 5.5 °C, depending on the scenario selected and the part of the region analyzed. Projections results shows that mean annual rainfall decrease can be up to −40%, compared to the reference period 1917–2000, and that most of the territory has negative anomaly. On the other side, many studies identify possible increases in the intensity and frequency of extreme precipitation in warmer climates. In addition, it is interesting that there will be a future change in multi-day episodes with extreme precipitation accumulations. In this paper, changes in the number of episodes with five-day accumulated precipitation over 60 mm and the overall accumulated precipitation during these episodes are analyzed for the Western Balkan region, using dynamically downscaled climate projections with a non-hydrostatic climate model that has an 8 km horizontal resolution.

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Keywords Climate change · Heavy precipitation · Dynamical downscaling
Climate projections

1 Introduction

Continuous anthropogenic emissions of greenhouse gases since the industrial revolution have led to an increase in the global mean surface air temperature, which has caused different changes in the Earth's climate system (IPCC 2014). In addition to the changes in the mean states of different climate variables, of specific importance are the changes in extreme weather and climate events, since these events unavoidably lead to high economic losses and even losses to human lives. If modern society continues to emit greenhouse gases, then the changes in the Earth's climate system in the future will be even more dramatic, and the risks of possible negative consequences for socio-economic sectors and natural systems will increase significantly. To determine these risks on a regional level, dynamical downscaling of global projections of possible future climate change has become a common practice over the past few decades.

The Western Balkans are part of South Eastern Europe (Fig. 1), and the majority of the region has a temperate or continental climate, which belongs to the C or D group of the Köppen climate classification. Like the rest of the world, the region has experienced changes in key climate variables over the past few decades. The linear positive trend in the mean annual temperature, calculated since 1960, is statistically significant for the whole region and ranges from 0.2 to 0.3 °C/decade. On the other hand, the average annual precipitation across the region had a generally negative trend since 1960, but it has not been significant (Kurnik et al. 2017). In addition to the changes in key climate variables over the past few decades, an increase in the frequency and amplitude of different extreme events, such as extreme temperatures, heat waves, droughts and extreme precipitation, have been observed (Marx et al. 2017; Stagge et al. 2017; Stadtherr et al. 2016; Spinoni et al. 2014). In the future, according to climate projections, the region could face further significant changes in the climate especially considering that the Western Balkan area is a part of the wider Mediterranean region, which has been identified as a climate change hotspot (Giorgi 2006). Based on the results of different impact studies for multiple sectors and on climate change projections for scenarios that do not include significant mitigation, the area can be considered highly vulnerable in comparison to most of the European continent (Lung and Hilden 2017).

Recently, most attention has been devoted to the analysis of extreme precipitation in the region, especially because of a series of high impact events, one of which occurred in May 2014 (EC 2014). Based on observations, multi-day precipitation accumulation has a statistically significant positive trend especially for the high quantiles relevant to flooding events (Stadtherr et al. 2016). On the other hand, projections have shown that for the high emission scenarios, such as the RCP 8.5 defined for the fifth assessment report of the Intergovernmental Panel on Climate

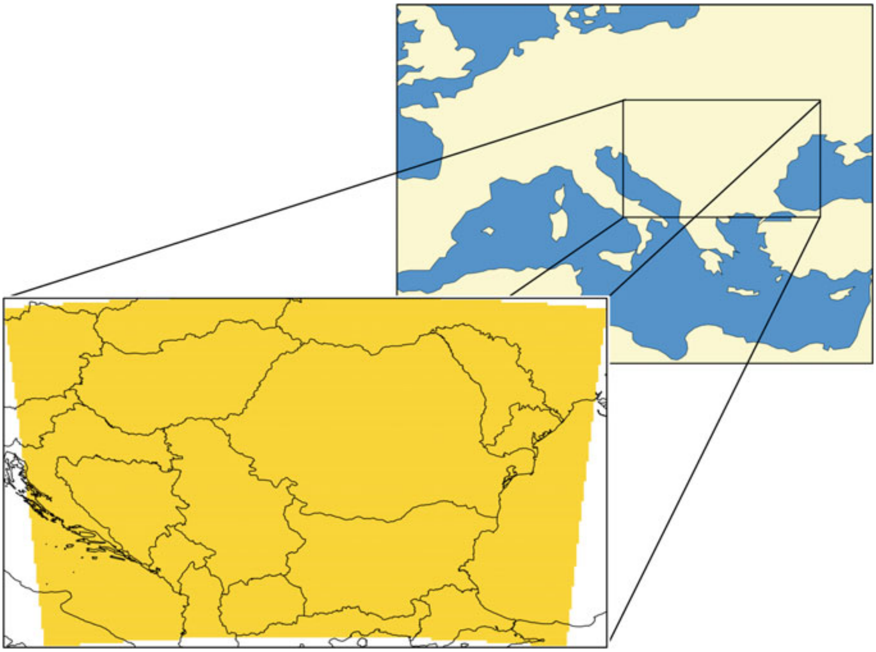

Fig. 1 NMMB model domain (front rectangular yellow area) over the Western Balkan region

Change (Riahi et al. 2011), in the future, we can expect further increases in extreme daily precipitation accumulations for almost all of Europe (Jacob et al. 2014). This increase in extreme precipitation events is even expected for the regions where climate projections show a decrease in annual mean accumulations (Polade et al. 2017). One of the reasons for this result is the well-known fact that based on the Clausius—Clapeyron relation warmer air is capable of holding more water vapor. Based on this relation and different analyses, one degree of temperature increase is associated with an approximately 7% increase in extreme precipitation (Lehmann et al. 2015; Trenberth 2011). On the other hand, it has also been shown that changes in large-scale hemispheric circulation can additionally contribute to the increase in extreme precipitation beyond 7% (Stadtherr et al. 2016). In this paper, we will examine the changes in multi-day episodes of extreme precipitation, using regional climate projections obtained from the regional non-hydrostatic high-resolution climate model.

2 Regional Climate Model and Experiments Setup

The NMMB is a Non-hydrostatic Multi-scale Model defined on the Arakawa B grid (Janjic and Gall 2012; Janjic et al. 2011, 2013). This model was developed at the United States National Centers for Environmental Prediction (NCEP). The model can be run both as a global and regional model. Dynamical core preserves many important properties of differential operators and conserves a variety of basic and derived quantities including energy and enstrophy (Janjic and Gall 2012), and a novel implementation of the nonhydrostatic dynamics is also applied (Janjic et al. 2001; Janjic 2003). For vertical coordinate models use sigma p-hybrid coordinate. For grid-scale convection parameterization, the Betts-Miller-Janjic scheme is implemented (Betts and Miller 1986; Janjic 1994), and for turbulence, the Mellor-Yamada-Janjic turbulence closure sub-model is used (Mellor and Yamada 1982; Janjic 1990). For radiation, a user can choose between two radiation schemes, the Rapid Radiative Transfer Model (RRTM) (Mlawer et al. 1997) and Geophysical fluid dynamics laboratory radiation (GFDL) model (Fels and Schwarzkopf 1975). Additionally, two land surface packages are available, the NOAH land surface model (Ek et al. 2003) and the Land Ice Seas Surface (LISS) model (Vukovic et al. 2010). Finally, for cloud microphysics, two packages are available as well, the cloud microphysics scheme of Ferrier et al. (2002) and microphysics from Zhao and Carr (1997). The regional version of the NMMB recently replaced the WRF NMM as the main NCEP operational short-range forecasting model for North America (NAM). In recent years, the model has also been used for a number of operational and research applications in Serbia (Djurdjevic et al. 2013).

In this paper, we will present the results of three model integrations. The first integration involves downscaling the reanalysis data set over the period 1971–2000. The second and third integrations involve downscaling of the results of a global climate model for a historical run and a scenario run. The downscaling of the historical run was conducted for the same period as the downscaling of the reanalysis, 1971–2000, and the downscaling of the RCP 8.5 scenario was conducted for the period 2011–2100. During the historical run, the concentrations of greenhouse gases were established to correspond to the observed values, and for the scenario run, the concentrations were established to correspond to the RCP 8.5 scenario (Riahi et al. 2011). The model domain that was used in all three experiments is presented in Fig. 1, and the model horizontal resolution was 8 km.

3 Model Verification Over the Period 1971–2000

The period 1971–2000 was used for model verification, and for this period, two downscaling experiments were conducted. For the first experiment, the experiment with a perfect boundary condition, the ERA40 reanalysis (Uppala et al. 2005), was used for the initial and lateral boundary conditions for the NMMB model (NMMB-E40 experiment). For the second experiment, for the initial and boundary conditions, outputs from the historical integration of the CMCC-CM global climate model (Scoccimarro et al. 2011) were used (NMMB-CMCC experiment). The model results over this period were verified using available observed values of the corresponding key climate variables and gridded data sets.

Table 1 Average scores of daily and monthly mean temperature and precipitation for the NMMB-E40 experiment

Temperature

Score	BIAS (°C)	MAE (°C)	RMSE (°C)	CC
Daily	0.06	1.7	2.2	0.98
Monthly	0.06	1.0	1.2	0.99

Precipitation

Score	BIAS (mm)	BIAS (%)	CC
Daily	−0.08	−4.6	0.53
Monthly	−2.5	−4.6	0.86

BIAS bias score, *MAE* mean absolute error, *RMSE* root mean square error, *CC* correlation coefficient

In Table 1, verification scores for daily and monthly mean temperatures and daily and monthly accumulated precipitation for the NMMB-E40 experiment over the territory of Serbia are presented. To calculate scores the observations from 46 stations that are part of the national observational network were used. Presented scores for temperatures are calculated as the mean difference between the model results and observations, averaged over a period of 30 years, or for precipitation as a ratio of the difference and the long-term mean of the corresponding observation that is presented as the percent of deviation. We can see that for both daily and monthly temperatures the correlation coefficients are very high, 0.98 and 0.99, respectively. On the other hand, the bias scores are very low with values of 0.06 °C for both the daily and monthly temperatures. For both, daily and monthly precipitation, bias is −4.6%, and for monthly precipitation correlation coefficient is 0.86 and can be considered high for this kind of experiment.

Model results for the annual mean temperature and annual mean precipitation from the NMMB-E40 experiment, are piloted on Fig. 2. Additional two panels of Fig. 2 are EOBS and CARPATCLIM data sets, which are gridded observations. The EOBS gridded climatology (Haylock et al. 2008) with a horizontal resolution of 25 km is used for the mean annual temperature plot, and CARPATCLIM data (Spinoni et al. 2014), with a horizontal resolution of 10 km, are for the annual accumulated precipitation plot. CARPATCLIM data have been selected for precipitation, because this data set has better spatial resolution and because more meteorological stations were used in the gridding process in comparison to EOBS data (Djurdjevic and Krzic 2013). As we can observe, model biases can be higher locally then the one noted in Table 1, but still model results capture the main spatial characteristics of both fields. The presented results show that the model is capable of reproducing observed climate characteristics at a level comparable to the results of other similar experiments performed with state-of-the-art regional climate models (Heikkilä et al. 2010; Soares et al. 2012).

Finally, the advantage of the high horizontal resolution of the regional model is presented in Fig. 3, that shows distributions of the daily precipitation accumulations

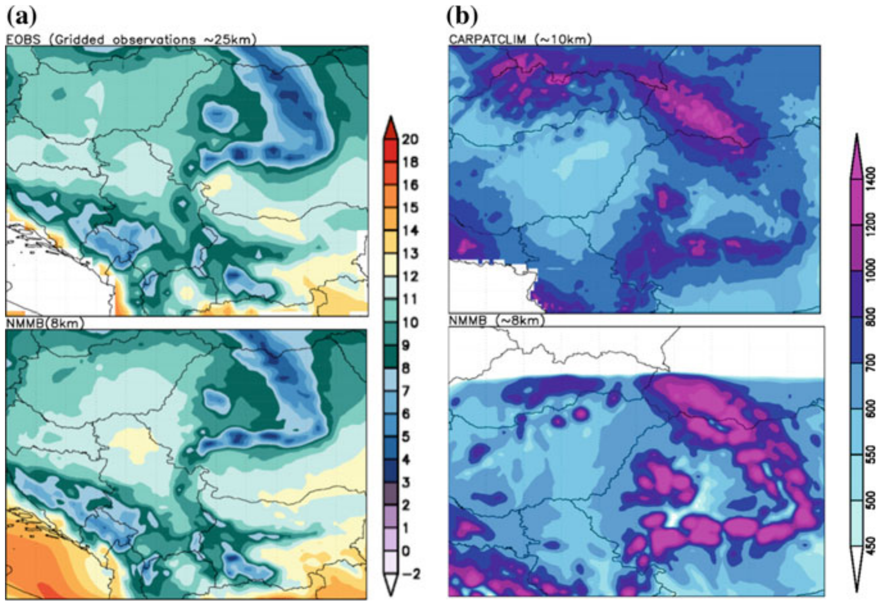

Fig. 2 **a** Annual mean temperature for the period 1971–2000 from EOBS data (upper panel) and dynamical downscaling of ERA40 reanalysis with the NMMB model (lower panel). **b** Annual mean precipitation for the period 1971–2000 from CARPATCLIM data (upper panel) and dynamical downscaling of ERA40 reanalysis with the NMMB model (lower panel)

over Serbia for the summer months (June–July–August). As we can see, the results from the experiment with the NMMB model with an 8 km horizontal resolution are closer to the observations, in comparison to driving data set ERA40, especially for high daily precipitation accumulations with values above 20 mm/day. The reason for this result is probably due to the fact that high resolution non-hydrostatic models are capable of better representing convective processes during the summer months (Djurdjevic and Krzic 2015), which are the main contributors to summer precipitation in the region (Tošić and Unkašević 2012). Additional details about the verification of the NMMB-E40 experiment can be found in Djurdjevic and Krzic (2013, 2014, 2015).

The left panel in Fig. 4 depicts the annual cycle of monthly mean temperatures from the NMMB-CMCC experiment and the observations obtained from the Serbian national meteorological observation network from 1971–2000. The monthly mean temperatures are calculated as averages over the whole territory of Serbia. The annual cycle is well represented but has a negative bias of 1 to approximately 3 °C throughout the entire year for all the months. The bias is lower for the summer months in comparison to the winter months. Similarly, the monthly means are calculated for the mean accumulated precipitation (right panel) for the same period.

Precipitation has a positive bias from January to May and November and December, and a negative bias was found for June, August and September. For July and

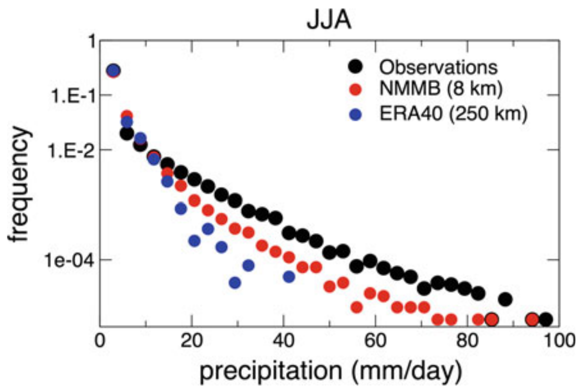

Fig. 3 Distribution of daily accumulated precipitation for season Jun–July–August obtained from the observations from the meteorological stations in Serbia (black), dynamical downscaling of the ERA40 reanalysis with the NMMB model using horizontal resolutions of 8 km (red) from the ERA40 reanalysis data set with resolution of approximately 250 km (blue)

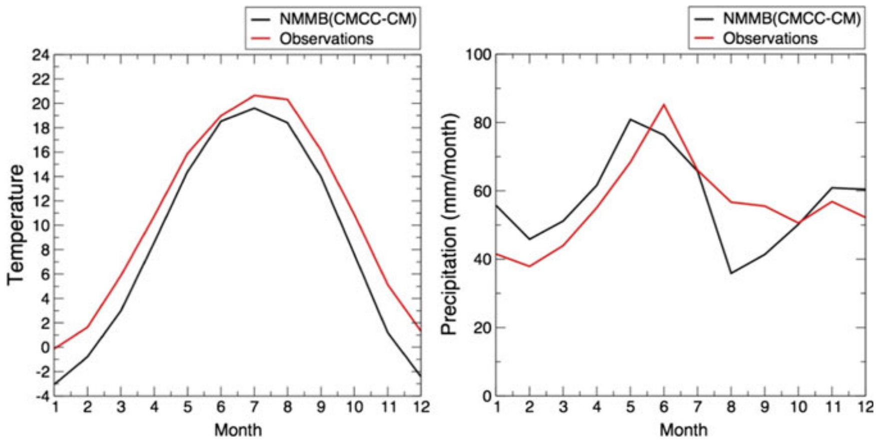

Fig. 4 Average annual cycle for temperature (left) and precipitation (right) for the period 1971–2000 over Serbia obtained from the observations from the meteorological stations in Serbia (red) and from dynamical downscaling of the CMCC-CM model results with the NMMB model

October, the long-term mean for monthly precipitation is very close to the observed values with biases less than 1%. The largest positive bias is for January, and the largest negative bias is for August. In comparison to the NMMB-E40 experiment, in this experiment, the biases are significantly higher, which is expected since much of the increase in the biases is coming from the biases in the historical run of the global model. This conclusion is supported by the fact that a similar bias distribution can also be found for the downscaling of the same historical run with the COSMO-CLM regional climate model (Montesarchio et al. 2013).

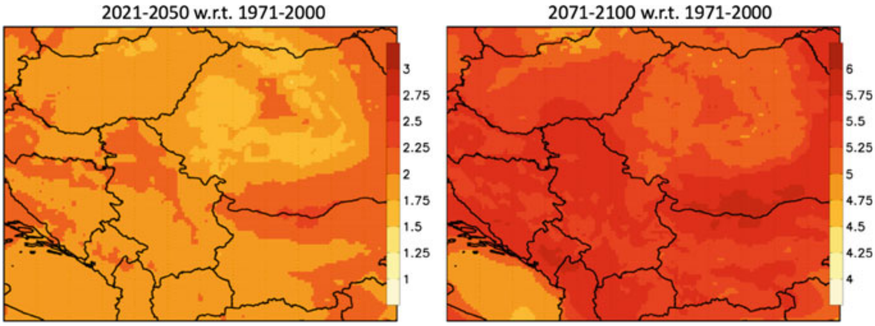

Fig. 5 Change in surface air temperature (°C) for the periods 2021–2050 (left panel) and 2071–2100 (right panel) with respect to the period 1971–2000 for the RCP 8.5 scenario from the downscaling of the CMCC-CC integration with the NMMB model

4 Projections for the RCP 8.5 Scenario

In this section, we present the annual temperature and annual accumulated precipitation changes over the model domain for two future periods, 2021–2050 and 2071–2100. Figure 5 shows the anomaly maps of the surface air temperature for periods 2021–2050 (left panel) and 2071–2100 (right panel) with respect to the period 1971–2000 for the RCP 8.5 scenario from the NMMB model downscaling of the CMCC-CC integration of this scenario. For the first period, 2021–2050, the annual temperature increase is from 2 to 2.5 °C, and for the second period, the average increase in the mean annual temperature is approximately 5.5 °C over most the domain. Figure 6 depicts the maps of precipitation changes (in %) for the RCP 8.5 scenario for the periods 2021–2050 (left panel) and 2071–2100 (right panel) with respect to 1971–2000. For the first period, over the southern parts of the domain, the change is mainly negative with maximum values of −10%, while in the central part of domain, the change is between −5 and 5%, and over the northern parts of the domain, the anomalies are up to 20%.

For the second period, 2071–2100, over most of the domain, the change is negative, up to −40%, and in general, a stronger negative change is present in the southern parts of the domain.

The precipitation changes are slightly more complex in comparison to the temperature changes, but the general projection is that over the course of this century the precipitation regime, in the case of long-term averages, will shift to more arid conditions, especially for the southern parts of the analyzed region. Both temperature and precipitation changes are in line with the results obtained from other global and regional climate models for this region (IPCC 2014; Jacob et al. 2014).

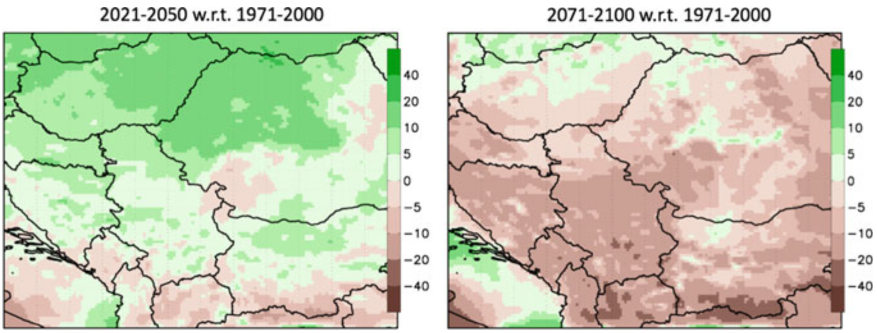

Fig. 6 Change in annual accumulated precipitation (%) for the periods 2021–2050 (left panel) and 2071–2100 (right panel) with respect to the period 1971–2000 for the RCP 8.5 scenario from the downscaling of the CMCC-CC integration with the NMMB model

5 Changes in Extreme Precipitation

In addition to the changes in the long-term averages of key climate variables, changes in different climate and weather extremes are very important to analyze in terms of future climate change. In this section, we analyze multi-day episodes with extreme precipitation accumulation. Three indices associated with 5 day precipitation accumulations are introduced:

- RR5D60—number of episodes when the 5 day accumulation was above 60 mm
- RR5D60et—average accumulation per episode when the 5 day accumulation was above 60 mm
- RR5D60e—total accumulation over all the episodes when the 5-day accumulation was above 60 mm.

In Fig. 7, we present changes in these three indices for two future periods, 2021–2050 and 2071–2100, with respect to the reference period 1971–2000. The RR5D60 index has a positive change with up to 3 more events in the future for both analyzed periods in most of the region, while some parts of the region have a negative change of −1, and for the first analyzed period, only the southern parts of southeastern part of the Adriatic coast have negative changes with up to −3 events. For the second period, the areas with negative changes up to −3 events are slightly wider, but still, positive change dominates in the region. For the RR5D60et index, positive change is dominant again, and for the period 2071–2100, the index change is up to 40%. A similar situation also occurs for the RR5D60t index, and total accumulations during the 5 day events with accumulations above 60 mm based on this scenario may increase up to 80% in the future. Based on the presented results, despite a deficit in the total annual precipitation accumulation for the second analyzed period, changes in the analyzed extreme indices will be positive.

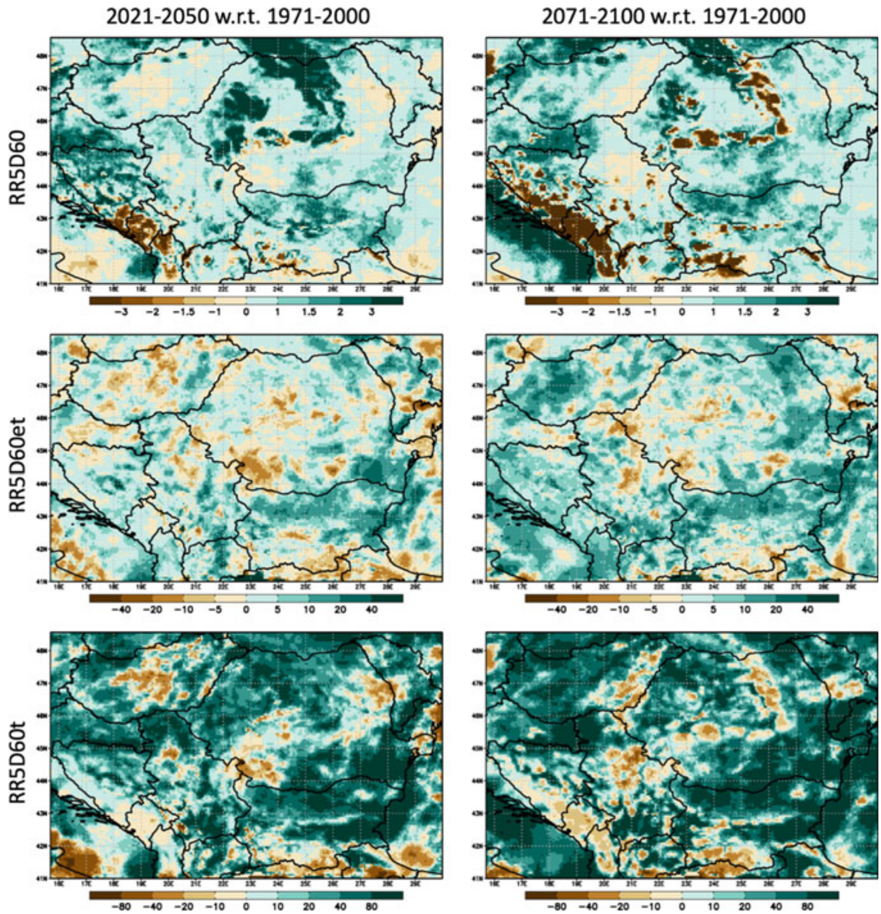

Fig. 7 Changes in the RR5D60, RR5D60et, RR5D60t indices for two future periods 2021–2050 and 2071–2100 with respect to the reference period 1971–2000, for the RCP 8.5 scenario downscaled with the NMMB model

6 Conclusions

Due to global climate change over the past few decades in the Western Balkan region, a positive trend in extreme precipitation has been observed. Extreme precipitation has been a trigger for flood events, landslides and other impacts associated with these events. Based on projections, this trend will continue in the future. The non-hydrostatic regional model NMMB was used to determine possible future changes in multi-day episodes with extreme precipitation accumulation. An assessment of the capability of the model to simulate climate conditions over the region of interest was conducted through an experiment with perfect boundary conditions. For this experiment, the ERA40 reanalysis was used as the initial and boundary condition for the regional model. Verification scores are of the same order as the scores calculated for other regional climate models used for similar experiments. The advantage of high horizontal resolution and non-hydrostatic dynamics in the model is clearly visible in its better representation of daily precipitation distribution tails over extreme values. This advantage is particularly important since the main analysis was related specifically to episodes of extreme precipitation. Based on the results of dynamical downscaling using the NMMB model, temperatures will continue to increase in the region of interest over this century, if emissions follow the RCP 8.5 scenario. The projected temperature increase for the last thirty years of this century is approximately 5.5 °C for most of the domain. On the other hand, in the second half of the century, it can be expected that climate will shift to more arid conditions, especially in the southern parts of the region. The expected maximum change in precipitation for the end of century is an up to −40% change with a stronger negative change in south. Finally, according to the analysis of the three 5 day extreme precipitation indices, in addition to the fact that arid conditions are expected, all three defined indices for extreme precipitation show positive anomalies for two future periods, 2021–2050 and 2071–2100. Thus, in the future under warmer climate conditions, it can be expected that the number of episodes with 5 day precipitation accumulations above 60 mm will increase to 3 more events for both analyzed periods and for most of the region. In addition, accumulations during individual precipitation episodes will increase and maximum increase for period 2071–2100 is 40%. A similar situation is also revealed for the total accumulations during 5 day events with accumulations above 60 mm, and based on this scenario, these accumulations will increase up to 80% in the future. To minimize the possible negative consequences that can arise from potential future changes in extreme precipitation, international mitigation efforts are crucially important. On the other hand, for reduction of potential risks and negative impacts associated with multi-day precipitation events some level of adaptation will also be necessary.

References

Betts AK, Miller MJ (1986) A new convective adjustment scheme. Part II: Single column tests using GATE wave, BOMEX, ATEX and arctic air-mass data sets. Q J R Meteorol Soc 112:693–709. https://doi.org/10.1002/qj.49711247308

Djurdjevic V, Krzic A (2013) Analysis of the downscaled ERA40 reanalysis performed with the NMMB model. A structured network for integration of climate knowledge into policy and territorial planning—ORIENTGATE project, deliverable WP3 Mapping and Harmonising Data & Downscaling, Retrieved from http://www.seevccc.rs/ORIENTGATE/Dwnsc-ERA40-NMMB.pdf

Djurdjevic V, Krzic A (2014) Analysis of the downscaled CMCC-CM projections performed with the NMMB model. A structured network for integration of climate knowledge into policy and territorial planning—ORIENTGATE project, deliverable WP3 Mapping and Harmonising Data & Downscaling. Retrieved from http://www.seevccc.rs/ORIENTGATE/Dwnsc_CMCC-CM_NMMB.pdf

Djurdjevic V, Krzic A (2015) High-resolution downscaling of ERA40 for region of South East Europe with NMMB model. In: Joint regional climate system modelling for the European sea regions, HyMex-Baltic Earth Workshop. International Baltic Earth Secretariat Publication No. 7, ISSN 2198-4247, ENEA, Rome, Italy, 5–6 Nov 2015

Djurdjevic V, Janjic Z, Pejanovic G, Vasic R, Rajkovic B, Djordjevic M, Vujadinovic M, Vukovic A, Lompar M (2013) NCEP's multi-scale NMMB model in the Hydrometeorological Service of Serbia: experiences and recent model developments, EGU General Assembly, Geophysical Research Abstracts, vol. 15, EGU2013-8217, Vienna, 7–12 Apr 2013

Ek MB, Mitchell KE, Lin Y, Rogers E, Grunmann P, Koren V, Gayno G, and Tarpley JD (2003) Implementation of Noah land surface model advances in the National Centers for Environmental Prediction operational mesoscale Eta model. J Geophys Res 108(D22). https://doi.org/10.1029/2002jd003296

Europen Commision (EC) (2014) Floods in Serbia and BIH. European commission United Nations Serbia, World Bank Group. Retrieved from http://ec.europa.eu/echo/files/aid/countries/factsheets/serbia_floods_bih_en.pdf

Fels SB, Schwarzkopf MD (1975) The simplified exchange approximation: a new method for radiative transfer calculations. J Atmos Sci 32:1475–1488. https://doi.org/10.1175/1520-0469(1975)032%3c1475:tseaan%3e2.0.co;2

Ferrier BS, Jin Y, Lin Y, Black T, Rogers E, DiMego G (2002) Implementation of a new grid-scale cloud and precipitation scheme in the NCEP Eta model. In: Proceedings of the 15th conference on numerical weather prediction, pp 280–283

Giorgi F (2006) Climate change hot-spots. Geophys Res Lett 33. https://doi.org/10.1029/2006gl025734

Haylock MR, Hofstra N, Klein Tank AMG, Klok EJ, Jones PD, New M (2008) A European daily high-resolution gridded data set of surface temperature and precipitation for 1950–2006. J Geophys Res 113. https://doi.org/10.1029/2008jd010201

Heikkilä U, Sandvik A, Sorteberg A (2010) Dynamical downscaling of ERA-40 in complex terrain using the WRF regional climate model. Clim Dyn 37:1551–1564. https://doi.org/10.1007/s00382-010-0928-6

IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

Jacob D, Petersen J, Eggert B, Alias A, Christensen OB, Bouwer LM, Braun A, Colette A, Déqué M, Georgievski G, Georgopoulou E, Gobiet A, Menut L, Nikulin G, Haensler A, Hempelmann N, Jones C, Keuler K, Kovats S, Kröner N, Kotlarski S, Kriegsmann A, Martin E, van Meijgaard E, Moseley C, Pfeifer S, Preuschmann S, Radermacher C, Radtke K, Rechid D, Rounsevell M, Samuelsson P, Somot S, Soussana J-F, Teichmann C, Valentini R, Vautard R, Weber B, Yiou P (2014) EURO-CORDEX: new high-resolution climate change projections for European impact research. Reg Environ Change 14:563–578. https://doi.org/10.1007/s10113-013-0499-2

Janjic ZI (2003) A nonhydrostatic model based on a new approach. Meteorol Atmos Phys 82:271–285. https://doi.org/10.1007/s00703-001-0587-6

Janjić ZI (1990) The step-mountain coordinate: physical package. Mon Weather Rev 118:1429–1443. https://doi.org/10.1175/1520-0493(1990)118%3c1429:tsmcpp%3e2.0.co;2

Janjić ZI (1994) The step-mountain eta coordinate model: further developments of the convection, viscous sublayer, and turbulence closure schemes. Mon Weather Rev 122:927–945. https://doi.org/10.1175/1520-0493(1994)122%3c0927:tsmecm%3e2.0.co;2

Janjic Z, Gall R (2012) Scientific documentation of the NCEP nonhydrostatic multiscale model on the B grid (NMMB). Part 1 Dynamics. UCAR/NCAR. https://doi.org/10.5065/d6wh2mzx

Janjic ZI, Gerrity JP Jr, Nickovic S (2001) An alternative approach to nonhydrostatic modeling. Mon Weather Rev 129:1164–1178. https://doi.org/10.1175/1520-0493(2001)129%3c1164:aaatnm%3e2.0.co;2

Janjic Z, Janjic T, Vasic R (2011) A class of conservative fourth-order advection schemes and impact of enhanced formal accuracy on extended-range forecasts. Mon Weather Rev 139:1556–1568. https://doi.org/10.1175/2010mwr3448.1

Janjic Z, Djurdjevic V, Vasic R, Ferrier B, Lin H-M (2013) NCEP's Multi-scale Eulerian NMMB model, EGU General Assembly, Geophysical Research Abstracts, vol 15, EGU2013-6557, Vienna, 7–12 Apr 2013

Kurnik B, Füssel HM, van der Linden P, Simmons A (2017) Changes in the climate system, atmosphere. In: Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. EEA report, No 1/2017

Lehmann J, Coumou D, Frieler K (2015) Increased record-breaking precipitation events under global warming. Clim Change 132:501–515. https://doi.org/10.1007/s10584-015-1434-y

Lung T, Hilden M (2017) Multi-sectoral vulnerability and risks: socioeconomic scenarios for Europe. In: Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. EEA report, No 1/2017

Marx A, Bastrup-Birk A, Louwagie G, Wugt-Larsen F, Biala K, Fussel HM, Kurnik B, Schweiger O, Settele J, Civic K, Delbaere B, Borelli P, Jones A, Lugato E, Panagos P, Barredo J (2017) Terrestrial ecosystems, soil and forests. In: Climate Change, Impacts and Vulnerability in Europe 2016. An indicator-based report. EEA report, No 1/2017, pp. 153–157

Mellor GL, Yamada T (1982) Development of a turbulence closure model for geophysical fluid problems. Rev Geophys 20:851. https://doi.org/10.1029/rg020i004p00851

Montesarchio M, Zollo AL, Cavicchia L and Mercogliano P (2013) Analysis of the downscaled climate simulations performed with the COSMO-CLM model, including assessment of the bias, ORIENTGATE project report. http://m.orientgateproject.org/uploads/Press%20releases/results%20docs/WP3_report%20performance_Analysis%20of%20the%20downscaled%20climate%20simulations_CMCC.pdf

Mlawer EJ, Taubman SJ, Brown PD, Iacono MJ, Clough SA (1997) Radiative transfer for inhomogeneous atmospheres: RRTM, a validated correlated-k model for the longwave. J Geophys Res: Atmos 102:16663–16682. https://doi.org/10.1029/97jd00237

Polade SD, Gershunov A, Cayan DR, Dettinger MD, Pierce DW (2017) Precipitation in a warming world: assessing projected hydro-climate changes in California and other Mediterranean climate regions. Scientific Reports 7. https://doi.org/10.1038/s41598-017-11285-y

Riahi K, Rao S, Krey V, Cho C, Chirkov V, Fischer G, Kindermann G, Nakicenovic N, Rafaj P (2011) RCP 8.5—a scenario of comparatively high greenhouse gas emissions. Clim Change 109:33–57. https://doi.org/10.1007/s10584-011-0149-y

Scoccimarro E, Gualdi S, Bellucci A, Sanna A, Giuseppe Fogli P, Manzini E, Vichi M, Oddo P, Navarra A (2011) Effects of tropical cyclones on ocean heat transport in a high-resolution coupled general circulation model. J Clim 24:4368–4384. https://doi.org/10.1175/2011jcli4104.1

Soares PMM, Cardoso RM, Miranda PMA, de Medeiros J, Belo-Pereira M, Espirito-Santo F (2012) WRF high resolution dynamical downscaling of ERA-Interim for Portugal. Clim Dyn 39:2497–2522. https://doi.org/10.1007/s00382-012-1315-2

Spinoni J, Szalai S, Szentimrey T, Lakatos M, Bihari Z, Nagy A, Németh Á, Kovács T, Mihic D, Dacic M, Petrovic P, Kržič A, Hiebl J, Auer I, Milkovic J, Štepánek P, Zahradnícek P, Kilar P, Limanowka D, Pyrc R, Cheval S, Birsan M-V, Dumitrescu A, Deak G, Matei M, Antolovic I, Nejedlík P, Štastný P, Kajaba P, Bochnícek O, Galo D, Mikulová K, Nabyvanets Y, Skrynyk O, Krakovska S, Gnatiuk N, Tolasz R, Antofie T, Vogt J (2014) Climate of the Carpathian Region in the period 1961–2010: climatologies and trends of 10 variables. Int J Climatol 35:1322–1341. https://doi.org/10.1002/joc.4059

Stadtherr L, Coumou D, Petoukhov V, Petri S, Rahmstorf S (2016) Record Balkan floods of 2014 linked to planetary wave resonance. Sci Adv 2:e1501428–e1501428. https://doi.org/10.1126/sciadv.1501428

Stagge JH, Kingston DG, Tallaksen LM, Hannah DM (2017) Observed drought indices show increasing divergence across Europe. Scientific Reports 7. https://doi.org/10.1038/s41598-017-14283-2

Tošić I, Unkašević M (2012) Extreme daily precipitation in Belgrade and their links with the prevailing directions of the air trajectories. Theoret Appl Climatol 111:97–107. https://doi.org/10.1007/s00704-012-0647-5

Trenberth K (2011) Changes in precipitation with climate change. Climate Res 47:123–138. https://doi.org/10.3354/cr00953

Uppala SM, KÅllberg PW, Simmons AJ, Andrae U, Bechtold VDC, Fiorino M, Gibson JK, Haseler J, Hernandez A, Kelly GA, Li X, Onogi K, Saarinen S, Sokka N, Allan RP, Andersson E, Arpe K, Balmaseda MA, Beljaars ACM, Berg LVD, Bidlot J, Bormann N, Caires S, Chevallier F, Dethof A, Dragosavac M, Fisher M, Fuentes M, Hagemann S, Hólm E, Hoskins BJ, Isaksen L, Janssen PAEM, Jenne R, Mcnally AP, Mahfouf J-F, Morcrette J-J, Rayner NA, Saunders RW, Simon P, Sterl A, Trenberth KE, Untch A, Vasiljevic D, Viterbo P, Woollen J (2005) The ERA-40 re-analysis. Q J R Meteorol Soc 131:2961–3012. https://doi.org/10.1256/qj.04.176

Vukovic A, Rajkovic B, Janjic Z (2010) Land ice sea surface model: short description and verification. In: 5th international congress on environmental modelling and software, 5–8 July 2010, Ottawa, ON, Canada

Zhao Q, Carr FH (1997) A prognostic cloud scheme for operational NWP models. Mon Weather Rev 125:1931–1953. https://doi.org/10.1175/1520-0493(1997)125%3c1931:apcsfo%3e2.0.co;2

Relationship Between Atmospheric Circulation and Temperature Extremes in Montenegro in the Period 1951–2010

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Abstract Previous research conducted in Montenegro suggested an increase in maximum and minimum daily temperatures in the last decades, followed by growth of extreme events frequency. This study examines the relationship between temperature and atmospheric circulation fields in Montenegro using 9 WMO-CCL/CLIVAR extreme climatic indices. The data on atmospheric circulation refers to 11 teleconnection patterns analyzed by seasonal timescales. The assessment of the impact of certain teleconnection patterns has shown a significant connection to extreme events in Montenegro. Calculated results showed the strongest impact of EA, MO, WeMO, EAWR and AO during the winter season, while the weaker impact was calculated for NAO and SCAND. The best impact is obtained for EA and AO during spring, while summer temperature variations are connected to EA, AMO, EAWR, SCAND and NAO. The autumn season showed strong connection with EA, SCAND, AMO, EAWR, MO and AO.

Keywords Temperature · Extremes · Atmospheric oscillation · Montenegro

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1 Introduction

Recent climate change has certainly caused an increase of land and ocean surface temperatures resulting in more frequent extreme weather events (Hansen et al. 2012; Rahmstorf and Coumou 2011; Cook et al. 2009; IPCC 2007, 2013; WMO 2004, 2009) such as droughts, floods, storms, heat waves, heavy showers, and wildfires, thus creating considerable damage (Klein-Tank and Können 2003; Lucie-Vincent and Mekis 2006; Zolina et al. 2008; Durao et al. 2010; El Kenawy et al. 2011; IPCC 2007, 2013).

There is no doubt that such events are a consequence of global warming. Frich et al. (2002) showed that the recent global trend in temperature indices from 1946 to 1999, is mainly caused by global warming. Similar results for Europe from Klein-Tank and Können (2003) indicate that the change in the minimum temperature is also determined by the recent temperature rise.

The role of teleconnections on temperature extremes has been studied at different spatial scales (Araghi et al. 2017; Williams et al. 2017; Polonskii et al. 2017; Deser et al. 2017; Tozer and Kiem 2017; Krzyścin 2017; Caian et al. 2018; Mpelasoka et al. 2018; Abish et al. 2018; Liu et al. 2017).

Results for Europe mainly show a significant connection with NAO (Yao and Luo 2015; Wrzesinski et al. 2015; Ciarlo and Aquilina 2016). Studies examining the impact of teleconnection patterns on the Balkan area and Montenegro mainly focus on NAO impacts on rainfall variability, with no assessment of temperature extremes. In neighboring Serbia, Unkašević and Tošić (2009, 2011) found that the warmest years were registered in 1951–1952, 1987–1998 (especially 1994) and 2000–2007. Ducić and Radovanić (2005) found that the rise of temperature in Serbia during the last decades is predominantly caused by changes in the circulation type.

The impact of teleconnections on temperature extremes so far in Montenegro has been poorly studied. The main goal of this paper is to examine the connection between atmospheric circulation and changes in temperature extremes in the area of Montenegro.

2 Research Area

The study covers the territory of Montenegro, a country with an area of 13,812 km^2 inhabited by about 620,000 inhabitants. This country is bordered by the Adriatic Sea with a coastline of about 100 km. It is important to point out that Montenegro is morphologically very heterogeneous (Fig. 1). The highest peak in this country is on the Prokletije (Zla Kolata) mountain range, with an altitude of 2534 m, while the lowest point is the Adriatic Sea (0 m).

The basic characteristic of the relief is the considerable altitude range over small areas (Burić et al. 2013). In general, three altitude belts can be distinguished. The first consists of a narrow coastal area up to 60 m high. The second altitude belt is

Fig. 1 Three-dimensional view of the relief of Montenegro

a limestone area in the southwestern part of the country, with an average height of 800–1000 m. In this area there are several limestone fields. The northern half of the land is the third belt that includes high mountains with peaks over 2000 m in hight. Between these belts are plains at 1200–1800 m and deep canyons (e.g. the Tara River Canyon is 1300 m deep—the deepest canyon in Europe).

3 Data and Methodology

Temperature data from 23 meteorological stations were used (Fig. 2) for the period 1951–2010. Data examination and correction has been done using the MASH v3.02 method, developed by the Meteorological Service of Hungary (Szentimrey 2003) and recommended by the World Meteorological Organization.

A total of 12 air temperature parameters were used to test the connection with teleconnection patterns (Table 1) of which 9 are ETCCDI temperature extreme indices (SU, TR, TD, Tn90p, Tx90p, FD, ID, Tx10p and Tn10p). All indices are defined in terms of the number of days with the maximum (Tx) and the minimum (Tn) temperature above/below the absolute or percentile threshold.

In addition to the extreme indices average temperature (Tsr), the average maximum (Txsr) and the average minimum (Tnsr) temperature are used.

The Pearson coefficient of correlation (r) was calculated, and the significance was tested using Student's test at 90 and 95% (0.10 and 0.05). The connection has been tested for each station separately and for the whole area of Montenegro. The list of variables used and the sources from which data has been taken is given in Table 2.

Luković et al. (2012) and Burić et al. (2014, 2015) calculated the trend of the mentioned air temperature parameters in Montenegro, for each station at seasonal level. The trend was calculated using the Mann-Kendall test (Mann-Kendall). The analysis

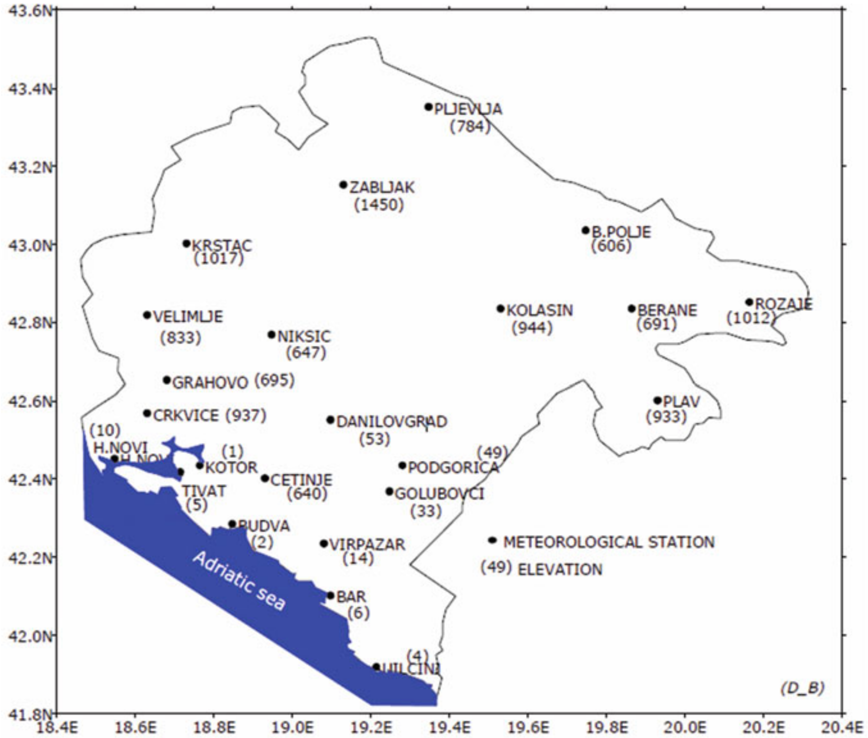

Fig. 2 Locations and altitude of meteorological stations

of trends in the ETCCDI workshop (Expert team on Climate Change Detection and Indices) is based precisely on the use of these nonparametric methods (Zhang et al. 2005).

The results achieved by the authors (Burić et al. 2015) show a significant trend, especially during the summer and spring.

4 Results and Discussion

Results indicate that all stations show the significance for the North Atlantic Oscillation (NAO) with winter hot nights (Tn90p), at 99% confidence level. In most cases, there is a significant connection with the number of frosty days (FD), while other temperature indicators show a weak correlation with the NAO-SLP index. Similar results were obtained with the NAO-500 mb index.

Table 1 List of used air temperature indicators

No.	Index	Unit	Definition
1.	FD	No. of days	Number of frosty days in unit time-daily Tn < 0 °C
2.	Tx10p	No. of days	Number of cold days in unit time—daily Tx < 10th percentile
3.	Tn10p	No. of days	Number of cold nights—daily Tn < 10th percentile
4.	ID	No. of days	Number of icy days—daily Tx < 0 °C
5.	SU	No. of days	Number of summer days in unit time—daily Tx > 25 °C
6.	TD	No. of days	Number of tropical days in unit time—daily Tx > 30 °C
7.	Tx90p	No. of days	Number of warm days—daily Tx > 90th percentile
8.	Tn90p	No. of days	Number of warm nights—daily Tn > 90th percentile
9.	TR	No. of days	Number of tropical nights—daily Tn > 20 °C
10.	Tsr	°C	Average air temperature
11.	Txsr	°C	Average maximum air temperature
12.	Tnsr	°C	Average minimum air temperature

On the other hand, at all locations, there is a significant connection between the Arctic oscillation (AO) and the winter Tn90p and FD, as well as the Tnsr at 99% probability level.

Temperature parameters showed significant correlation with the Mediterranean oscillation (MO) for the winter season. The relationship between MO index and Tn90p, Tnsr and FD is significant at 99% level, at almost all stations. Although weak, the significance of MO connection exists with the average winter temperature-Tsr (Table 3).

All the temperature parameters examined in the territory of Montenegro show significant connection with the East Atlantic oscillation (EA) at 99% confidence level. In particular, there is a good connection between the EA index with the average maximum temperature and the number of warm days (Txsr and Tx90p) for this season. A large number of stations show a significant relationship between Tnsr, Tsr, FD, Tn90p and Tn10p and the East Atlantic-West Oscillation (EAWR), but the correlation is weaker than for an EA.

The Atlantic Multi-Decadal Oscillation (AMO) and El Niño Southern Oscillation (ENSO) have no significant impact on the air temperature in Montenegro during the winter season, as relatively low correlations are obtained. The results of the calculation indicate that the Scandinavian (SCAND) and the Polar-Eurasian oscillations (POLEUR) have no effect on winter temperature parameters.

Table 2 List of used variables

Variable name	Source	Parameter	No. of el.
North Atlantic oscillation (NAO)	http://www.cru.uea.ac.uk/cru/data/nao/nao.dat	SLP	n = 60
Atlantic multirate oscillation (AMO)	http://www.esrl.noaa.gov/psd/data/COrrelation/amon.us.data	°C	n = 60
Arctic oscillation (AO)	http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/monthly.ao.index.b50.current.ascii.table	SLP	n = 60
Mediterranean oscillation (MO)	http://www.cru.uea.ac.uk/cru/data/moi/moi1.output.dat	SLP	n = 52
Western Mediterranean oscillation (WeMO)	http://www.ub.edu/gc/Documentos/cv_joan_albert/wemoi.txt http://www.ub.edu/gc/Documentos/cv_joan_albert/wemoi_update.xls	SLP	n = 59
El Ninjo Southern oscillation (ENSO)	http://www.cpc.ncep.noaa.gov/data/indices/ersst3b.nino.mth.81-10.ascii	°C	n = 60
NorthAtlantic oscillation (NAO)	https://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/NAO_index.tim	500 mb	n = 60
East Atlantic oscillation (EA)	https://ftp.cpc.ncep.NOAA.gov/wd52dg/data/indices/ea_index.tim	500 mb	n = 60
East Atlantic-West Russian oscillation (EAWR)	https://ftp.cpc.ncep.NOAA.gov/wd52dg/data/indices/eawr_index.tim	500 mb	n = 60
Scandinavian oscillation (SCAND)	https://ftp.cpc.ncep.NOAA.gov/wd52dg/data/indices/scand_index.tim	500 mb	n = 60
Polar-Eurasian oscillation (POLEUR)	https://ftp.cpc.ncep.NOAA.gov/wd52dg/data/indices/poleur_index.tim	500 mb	n = 60

In the spring season, a small number of examined teleconnections affect the air temperature parameters. The strongest influence is for the East Atlantic Oscillation (EA) whose signal is observed on almost all the considered temperature parameters. The Arctic oscillation (AO) shows the relationship with Tsr, Txsr, Tx10p and Tx90p (Table 4).

The relationship between the NAO index and temperature parameters (Tsr, Txsr, Tnsr, Tn90p, Tx90p and SU) for the summer season is statistically significant with stronger results in the north than in the south of Montenegro. The correlation coefficient calculations showed statistically significant results with the Atlantic Multidecade oscillation (AMO) and NAO. For the period from 1951 to 2010, almost all observed stations showed significant connection between the summer AMO index values and Tsr, Tnsr, Txsr, Tn90p, Tx90p, SU and Tn10p. The Arctic Oscillation (AO), the oscillations associated with the Mediterranean basin (Mediterranean oscillation—MO and the Western Mediterranean oscillation—WeMO), as well as the El Nino Southern Oscillation (ENSO), did not confirm significant impact on the summer temperature fluctuations (Table 5).

Table 3 Correlation matrix (r) between teleconnection patterns and air temperature parameters on the territory of Montenegro in general for the winter season in the period 1951–2010

Parameter	Tsr	Tnsr	Txsr	FD	Tn10p	Tn90p	Tx10p	Tx90p	SU
NAO-SLP				0.37**		−0.46**			
AMO									
AO		−0.37**		0.50**		−0.46**		0.27*	
MO	−0.37**	−0.50**		0.61**	0.28*	−0.64**			
WeMO	0.28*	0.31*		−0.35**	−0.29*				
ENSO									
NAO-500				0.30*		−0.44**			
EA	0.46**	0.42**	0.60**	−0.39**	−0.32*	0.38**	−0.46**	0.58**	
EAWR	−0.30*	−0.39**		0.47**	0.33*	−0.34*			
SCAND								−0.30*	
POLEUR			−0.28*						

Statistical significance
$*\alpha = 0.05$
$**\alpha = 0.01$

Table 4 Correlation matrix (r) between teleconnection patterns and air temperature parameters on the territory of Montenegro as a whole for the spring season in the period 1951–2010

Parameter	Tsr	Tnsr	Txsr	FD	Tn10p	Tn90p	Tx10p	Tx90p	SU
NAO-SLP									
AMO									
AO	0.40**	0.32*	0.46**		−0.29*	0.32*	−0.38**	0.40**	
MO									
WeMO				−0.32*					
ENSO									
NAO-500									
EA	0.47**	0.41**	0.51**			0.52**	−0.41**	0.46**	0.39**
EAWR									
SCAND								−0.34*	
POLEUR									

Statistical significance
*$\alpha = 0.05$
**$\alpha = 0.01$

Table 5 Correlation matrix (r) between teleconnection patterns and air temperature parameters on the territory of Montenegro in general for the summer season in the period 1951–2010

Parameter	Tsr	Tnsr	Txsr	FD	Tn10p	Tn90p	Tx10p	Tx90p	SU
NAO-SLP	−0.39**	−0.39**	−0.35**		0.29*	−0.37**		−0.35**	−0.35**
AMO	0.53**	0.52**	0.44**		−0.36**	0.55**		0.50**	0.44**
AO									
MO									
WeMO									
ENSO									
NAO-500	−0.38**		−0.39**				0.29*	−0.41**	−0.39**
EA	0.63**	0.62**	0.65**		−0.49**	0.63**	−0.60**	0.60**	0.66**
EAWR	−0.42**	−0.32*	−0.44**			−0.34*	0.30*	−0.46**	−0.41**
SCAND	−0.40**	−0.32*	−0.43**			−0.35**	0.27*	−0.41**	−0.40**
POLEUR		0.27*			−0.27*				

Statistical significance
*$\alpha = 0.05$
**$\alpha = 0.01$

In relation to the indicators of atmospheric circulation, the East Atlantic Oscillation Index (EA) has shown the best connection with the temperature parameters in the territory of Montenegro. The relationship between the summer EA values and all the temperature parameters considered is statistically significant, mainly at 99% confidence level. For this season, the absolute values of correlation coefficients range from 0.50 to 0.70, which means that in the period 1951–2010, EA had a strong impact on the annual fluctuations in the summer temperatures. The relationship with the EAWR and SCAND oscillation is weaker, but nevertheless significant with a large number of temperature parameters considered, while with the POLEUR oscillation a signal was only detected in Tnsr and Tn10p.

The NAO, WeMO and POLEUR signals do not show a signal for any temperature parameter in the autumn season. With the Atlantic Multi Decade Oscillation (AMO), a significant relationship with Tn90p and Tnsr was obtained, mainly in the north of the country and with Tsr and FD. In most places, there is a significant connection between Arctic oscillation (AO) and SU and Tx90p (Table 6).

The Mediterranean oscillation (MO) show an impact on the Tnsr fluctuations, FD and Tn90p, and the East Atlantic (EA) to Txsr, Tx10p, Tn10p and Tnsr. Although the values of the coefficient of correlation are lower than in the summer season, in most places there is a significant link between the East Atlantic-West Russian oscillation (EAWR) with the autumn values of Tnsr and Tn90p. The strongest Scandinavian oscillation signal (SCAND) is observed on the number of days of frost (FD), average (Tsr) and the average minimum (Tnsr) temperature.

Unkašević and Tošić (2013) considered the trends of six climatic indices based on maximum and minimum daily temperatures in the period 1949–2009 in Serbia. An analysis of extreme temperature indices has shown that Serbia's climate has tended to become warmer in the last 61 years. The most important trends were obtained for the summer seasons. The authors found that the East Atlantic oscillation (EA) dominates during the winter, spring and summer, while in the autumn the connection with the East Atlantic-Western (EAWR) index was obtained. A strong signal was also obtained between winter temperature extremes in Serbia and the North Atlantic Oscillations (NAO).

5 Conclusion

Previous research (Burić et al. 2015) showed that the maximum and minimum daily temperatures with "warmer" values are increasingly occurring in the territory of Montenegro. In most cases, the temperature extremes were significant, especially during the summer and spring season.

The results of this study on the relationship between the change in air temperature in the area of Montenegro and the variability of atmospheric circulation, for a period of 60 years (1951–2010) have been analyzed. The assessment on the influence of several teleconnection patterns has shown significant connection to temperature parameters over Montenegro. The strongest influence is detected during the win-

Table 6 Correlation matrix (r) between teleconctional patterns and air temperature parameters on the territory of Montenegro as a whole for the autumn season in the period 1951–2010

Parameter	Tsr	Tnsr	Txsr	FD	Tn10p	Tn90p	Tx10p	Tx90p	SU
NAO-SLP									
AMO	0.29*	0.38**		−0.32*		0.52**			
AO				0.31*				0.36**	0.33*
MO		−0.31*		0.41**		−0.28*			
WeMO									
ENSO			0.27*						
NAO-500									
EA		0.30*	0.41**		−0.37**		−0.41**	0.28*	0.30*
EAWR		−0.28*				−0.38**			
SCAND	0.30*	0.33*		−0.39**					
POLEUR									

Statistical significance
$*\alpha = 0.05$
$**\alpha = 0.01$

ter season for EA, MO, WeMO, EAWR and AO. The strongest signal in spring is obtained for EA and AO. In summer, temperature conditions largely correspond with the variations of EA, AMO, EAWR, SCAND and NAO, while in the autumn season, most of the temperature parameters considered show connection with EA, SCAND, AMO, EAWR, MO and AO.

Refernces

Abish B, Cherchi A, Ratna SB (2018) ENSO and the recent warming of the Indian Ocean. Int J Climatol 38(1):203–214. https://doi.org/10.1002/joc.5170

Araghi A, Mousavi-Baygi M, Adamowski J, Martinez C (2017) Association between three prominent climatic teleconnections and precipitation in Iran using wavelet coherence. Int J Climatol 37(6):2809–2830. https://doi.org/10.1002/joc.4881

Burić D, Ducić V, Mihajlović J (2013) The climate of Montenegro: modificators and types—part one. Glasnik Srpskog geografskog drustva 93(4):83–102

Burić D, Ducić V, Mihajlović J, Luković J, Dragojlović J (2015) Recent extreme air temperature changes in Montenegro. Glasnik Srpskog geografskog drustva 95(4):53–66. https://doi.org/10.2298/GSGD140626002B ISSN: 0350-3593

Burić D, Luković J, Ducić V, Dragojlović J, Doderović M (2014) Recent trends in daily temperature extremes over southern Montenegro (1951–2010). Nat Hazards Earth Syst Sci 14:67–72. https://doi.org/10.5194/nhess-14-67-2014

Caian M, Koenigk T, Dösche R et al (2018) An interannual link between Arctic sea-ice cover and the North Atlantic Oscillation. Climate Dyn Springer 50:423–441. https://doi.org/10.1007/s00382-017-3618-9

Ciarlo JM, Aquilina NJ (2016) An analysis of teleconnections in the Mediterranean region using RegCM4. Int J Climatol 36(2):797–808. https://doi.org/10.1002/joc.4383

Cook BI, Miller RL, Seager R (2009) Amplification of the North American “Dust Bowl” drought through human-induced land degradation. Proc Natl Acad Sci USA 106:4997–5001. https://doi.org/10.1073/pnas.0810200106

Deser C, Hurrell JW, Phillips AS (2017) The role of the North Atlantic Oscillation in European climate projections. Climate Dyn 49(9–10):3141–3157. https://doi.org/10.1007/s00382-016-3502-z

Ducić V, Radovanović M (2005) Climate of Serbia. Zavod za udžbenike i nastavna sredstva, Beograd, pp 1–212

Durao R, Pereira M, Costa MJ, Delgado AC, del Barriod J, Soares A (2010) Spatial–temporal dynamics of precipitation extremes in southern Portugal: a geostatistical assessment study. Int J Climatol 30:1526–1537

El Kenawy AM, López-Moreno JI, Vicente-Serrano SM (2011) Recent trends in daily temperature extremes over northeastern Spain (1960–2006). Nat Hazards Earth Syst Sci 11:2583–2603

Frich P, Alexander LV, Della-Marta P, Gleason B, Haylock M, Klein-Tank AMG, Peterson T (2002) Observed coherent changes in climatic extremes during second half of the twentieth century. Climate Res 19(3):193–212. https://doi.org/10.3354/cr019193

Hansen J, Sato M, Ruedy R (2012) Perception of climate change. Proc Natl Acad Sci USA 109(37):E2415–E2423. https://doi.org/10.1073/pnas.1205276109

IPCC (2007) Climate change 2007: the physical science basis. In: Solomon SD, Qin M, Manning Z, Chen M, Marquis KB, Averyt MT, Miller HL (eds) Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp

IPCC (2013) This Summary for policymakers should be cited as: IPCC, 2013: summary for policymakers. In: Climate change 2013: the physical science basis. In: Stocker, TF, Qin D, Plattner G-K,

Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA
Klein-Tank AMG, Können GP (2003) Trends in indices of daily temperature and precipitation extremes in Europe, 1946–99. J. Climate 16(22):3665–3680
Krzyścin JW (2017) El Nino-Southern Oscillation and Indian Ocean Dipole contribution to the zonal mean total ozone in the Northern Hemisphere. Int J Climatol 37(8):3517–3524. https://doi.org/10.1002/joc.4933
Liu Y, He S, Li F, Wang H, Zhu Y (2017) Interdecadal change between the Arctic Oscillation and East Asian climate during 1900–2015 winters. Int J Climatol 37(14):4791–4802. https://doi.org/10.1002/joc.5123
Luković J, Burić D, Ducić V, Doderović M, Milevski I (2012) Assessment on temperature extremes in Montenegro. In: Advances in meteorology, climatology and atmospheric physics. Springer, 577–582. https://doi.org/10.1007/978-3-642-29172-2_82. ISBN 978-3-642-29171-5; ISSN 2194-5217
Mpelasoka F, Awange JV, Zerihun A (2018) Influence of coupled ocean-atmosphere phenomena on the Greater Horn of Africa droughts and their implications. Sci Total Environ 610–611:691–702. https://doi.org/10.1016/j.scitotenv.2017.08.109
Polonskii AB, Krasheninnikova SB, Basharin DV (2017). Russ Meteorol Hydrol 42(10):653–660. https://doi.org/10.3103/S1068373917100041
Rahmstorf S, Coumou D (2011) Increase of extreme events in a warming world. Proc Natl Acad Sci USA 108:17905–17909. https://doi.org/10.1073/pnas.1101766108
Szentimrey T (2003) Multiple analysis of series for homogenization (MASH); Verification procedure for homogenized time series. In: Fourth seminar for homogenization and quality control in climatological databases. Budapest, Hungary, WMO-TD No. 1236, WCDMP No. 56: 193–201
Tozer CR, Kiem AS (2017) Large-scale ocean-atmospheric processes and seasonal rainfall variability in South Australia: accounting for non-linearity and establishing the hierarchy of influence. Int J Climatol 37:1180–1198. https://doi.org/10.1002/joc.5074
Unkašević M, Tošić I (2009) An analysis of heat waves in Serbia. Global Planetary Change 65:17–26. https://doi.org/10.1016/j.gloplacha.2008.10.009
Unkašević M, Tošić I (2011) The maximum temperatures and heat waves in Serbia during the summer of 2007. Clim Change 108:207–223. https://doi.org/10.1007/s10584-010-0006-4
Unkašević M, Tošić I (2013) Trends in temperature indices over Serbia: relationships to large-scale circulation patterns. Int J Climatol 33(15):3152–3161
Vincent Lucie A, Mekis Éva (2006) Changes in daily and extreme temperature and precipitation indices for Canada over the twentieth century. Atm. Oc. 44(2):177–193
Williams PD, Alexander MJ, Barnes EA, Butler AH, Davies C, Garfinkel CI, Zhang C (2017) A census of atmospheric variability from seconds to decades. Geophys Res Lett 44(21):11201–11211. https://doi.org/10.1002/2017GL075483
World Meteorological Organization (2004) Report of the CCI/CLIVAR expert team on climate change detection, monitoring and indices (ETCCDMI), Geneve
World Meteorological Organization (2009) Guidelines on Analysis of extremes in a changing climate in support of informed decisions for adaptation. Geneva 2, Switzerland, Climate Data and Monitoring WCDMP-No. 72
Wrzesiński D, Choiński A, Ptak M (2015) Effect of the North Atlantic Oscillation on the thermal characteristics of lakes in Poland. Acta Geophys 63(3):863883. https://doi.org/10.1515/acgeo-2015-0001
Yao Y, Luo D (2015) Do European blocking events precede North Atlantic Oscillation events? Adv Atmospheric Sci 32(8):1106–1118.https://doi.org/10.1007/s00376-015-4209-5
Zhang et al (2005) Trends in Middle East climate extreme indices from 1950 to 2003. J Geophys Res 110:D22104, https://doi.org/10.1029/2005jd006181

Zolina O, Simmer C, Kapala A, Bachner S, Gulev S, Maechel H (2008) Seasonally dependent changes of precipitation extremes over Germany since 1950 from a very dense observational network. J Geophys Res 113:D06110. https://doi.org/10.1029/2007JD008393

Analysis of the Climate Change in the Doboj Municipality and Adaptation Options

Dragana Vidić and Dragica Delić

Abstract Bosnia and Herzegovina is located in the part of the European continent, which is highly exposed to the climate change and its consequences. Climate change during the 1966–2015 periods over the Doboj area, which was chosen for case study region, was determined. Results show that the increasing trend in annual and seasonal air temperatures is present over the Doboj area. Precipitation also displayed upward trends throughout the year. Climate change in this area is manifested in a higher frequency and intensity of extreme climate events. The paper addresses the issue of the catastrophic floods, which occurred in May 2014 over the Doboj territory. Regardless the previous research on climate change, the results of which are presented in three national reports under the United Nation Framework Convention on Climate Change, public awareness is not sufficiently focused on the consequences of these changes, and local communities have not shown sufficient readiness to response to the natural disasters caused by climate change. The system of measures aimed towards the adaptation and mitigation on the observed changes is proposed in order to achieve sustainable development of this area.

Keywords Precipitation · Natural disaster · Floods · Adaptation to climate change Doboj municipality (Republic of Srpska, Bosnia and Herzegovina)

1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) report warming of the climate system is unequivocal. Many of the observed changes since the 1950s are unprecedented over decades to millennia (IPCC 2014). The atmosphere and

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oceans have warmed, the amounts of snow and ice have diminished, and sea level has risen (IPCC 2014). Each of the last three decades has been warmer than any preceding decade since 1850. The period from 1983 to 2012 was very likely the warmest 30 year period in the last 800 years in the Northern Hemisphere and likely the warmest 30 year period in the last 1400 years (IPCC 2014). During the 1880–2012 periods, the globally averaged combined land and ocean surface temperature showed a warming in the range 0.85 (0.65–1.06) °C. The total increase between the 1850–1900 and the 2003–2012 periods averages is 0.78 (0.72–0.85) °C. Since the beginning of the 20th century, almost the entire globe has experienced a warming trend (IPCC 2014).

As stated by Renwick (2015) in State of the Climate in 2014, annual precipitation was mostly close to normal, except for the Balkans region, southern Italy, and the southern Alpine region. Spring was exceptionally wet over the Balkans, and the most of the states received anomalous rainfalls up to 250% of normal.

Previous studies on trends in the extreme precipitation indices conducted in the Southeast Europe region determined mainly weak, mixed in sign and spatially incoherent trends. In Croatia, analysis showed that although the detected trends in extremes precipitation indices were mostly week, there are regions exposed to more pronounced annual and seasonal changes (Gajić-Čapka et al. 2015). Trends in mean and extreme precipitation in Serbia were statistically significant only during autumn season, in which the amount, intensity, and duration of rainfall increased (Malinović-Miličević et al. 2015). The results within the project “Modeling extreme precipitation under climate scenarios in the Republic of Srpska” suggest that a general increase in the extreme precipitation is present over the territory of Bosnia and Herzegovina. Trends that indicate increase in either the frequency or intensity of heavy precipitation are generally most prominent in Doboj area (Popov et al. 2017).

In the Third National Communication (TNC) and Second Biennial Update Report on Greenhouse Gas Emissions of Bosnia and Herzegovina under the United Nation Framework Convention on Climate Change (2016), it is stated that the mean annual temperature maintains a continuous rise over the entire territory of Bosnia and Herzegovina. Trends in annual temperatures at all analyzed stations are statistically significant. However, the changes were more pronounced in the northern continental part of the territory. During the 1961–2014 periods, the increase in annual air temperatures was in the range of 0.4–1.0 °C, whereas the increase in growing season (April–September) temperature reached 1.2 °C. According to the TNC, although significant changes in mean precipitation have not been recorded, pluviometric regime has been greatly disrupted. Due to the increased share of heavy precipitation in the total rainfall amount, there is the increased risk of flooding particularly in the north-eastern part of B&H (the most disastrous floods in history occurred precisely in this area in May 2014 (UNDP 2016).

Climate change caused increased frequency of natural disasters in many regions in the world, inflicting smaller or bigger consequences on human lives, biodiversity, landscapes, water resources, economy, property and society in general. Since the harmful effects on natural and socio-economic systems are determined, the attempts to eliminate or reduce negative consequences are necessary. It is necessary to create and implement the adequate system of adaptation and mitigation measures.

2 Study Area

The Doboj Municipality is located at the contact of the Pannonian and Dinarides Mountains macro morphological regions in Bosnia and Herzegovina. The Doboj territory is located at the confluence of three rivers—Bosna River and its tributaries Spreča River and Usora River (Fig. 1). The northern part of the municipality is characterized by hilly terrain built of Cenozoic sediments, which gradually descend to alluvial plains of river valleys. Towards the south, these hilly terrains become higher entering the Dinarides Mountains. The urban part of the municipality is located in the alluvial plain at 146 m above sea level. The geographical position of the Doboj municipality is at 44°33′20″–45°0′33″ N and 17°54′45″–18°22′30″ E.

The area of Doboj has the typical climate characteristics of Peri-Pannonian region, i.e. the moderate-continental climate, with humid characteristics. Summers are warm and winters are moderately cold. A pluviometric regime is characterized by the dominant influence of humid air masses coming from the west, i.e. from the Atlantic Ocean. Under the influence of ascendant air currents, the greatest precipitation amount occurs in summer months (June, July and August), often in the form of rain shallows.

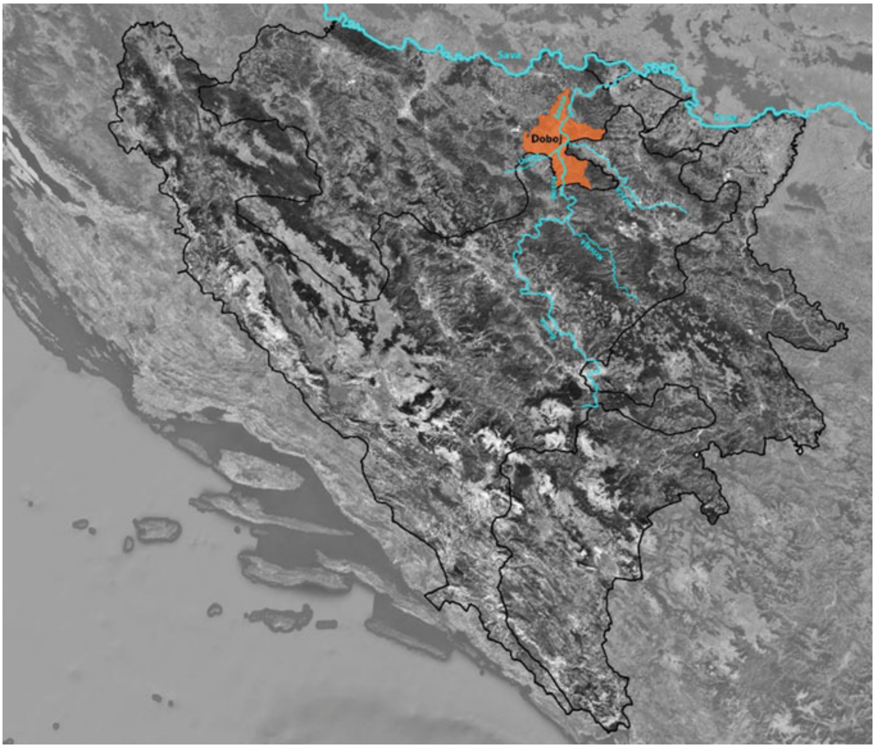

Fig. 1 Doboj Municipality location within Bosnia and Herzegovina

Total area of Doboj municipality covers 655 km^2 with 68,514 inhabitants (Statistics Institute of the Republic of Srpska 2016). The territory of Doboj is characterized by a high population density (104.6 people per km^2), which is significantly higher than the Republic of Srpska (47.5 people per km^2) and Bosnia and Herzegovina (68.95 people per km^2) average.

3 Data and Methods

The analysis of trends in precipitation and air temperatures, was carried out using data on monthly precipitation and air temperatures during the 1966–2015 period from Doboj meteorological station. Data were provided by the Republic Hydrometeorological Service of the Republic of Srpska. There were some interruptions in measurements during the war periods (1992–1996). The analysis was carried out per decades on monthly, seasonal and annual levels. Climatological seasons are defined as follows: spring—March–May (MAM), summer—June–August (JJA), autumn—September–November (SON) and winter December-February (DJF). In addition, trend analysis of annual and seasonal mean precipitation and air temperature was performed.

Data on floods in the Bosna River Basin in May 2014 and its consequences were provided by the Institute for Water Management Bijeljina and City of Doboj, respectively.

Research work on natural disaster phenomenon occurred in May 2014 and its consequences in Doboj area was realized during the second half of 2017.

4 Results and Discussion

4.1 Climate Trends in the Doboj Municipality

Decadal average values of monthly, seasonal and annual precipitation in the observed 1966–2015 periods for Doboj municipality are given in Tables 1 and 2. The differences between the last and first decade averages are also displayed.

The most significant increase in mean precipitation was recorded in May. That is directly related to the extremely large precipitation amount recorded in May 2014, which caused catastrophic floods over this area. Seasonal analysis showed that there was a decrease in precipitation in summer and autumn months, whereas on the other hand the greatest positive change was recorded in spring.

During the 1966–2016 periods, precipitation displayed positive trends throughout the year, but somewhat stronger in autumn (10.1 mm per decade) and spring (9.8 mm per decade) (Fig. 2). Annual precipitation increase was in the range of 23.3 mm per

Table 1 Decadal average values of monthly mean precipitation (mm) for the Doboj municipality with the difference between the last and first decade averages

Decade	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1966–1975	69.2	58.1	49.5	80.0	75.1	103.1	98.5	96.0	70.1	65.4	81.9	70.2
1976–1985	51.4	57.6	64.3	64.2	76.3	102.0	79.6	70.6	68.4	55.0	71.5	75.2
1986–1995	57.8	47.9	70.1	59.7	94.4	125.7	93.8	72.6	72.8	82.5	84.3	63.1
1996–2005	71.4	62.7	50.5	87.0	94.6	106.5	109.1	71.6	112.6	79.2	92.8	84.1
2006–2015	66.4	65.7	75.3	75.0	124.2	105.4	71.5	79.6	73.8	77.7	65.6	72.7
Average	63.2	58.4	61.9	73.2	92.9	108.5	90.5	78.1	79.5	71.9	79.2	73.1
Difference 2006–2015/1966–1975	−2.8	7.6	25.8	−5.0	49.1	2.3	−27.0	−16.4	3.7	12.3	−16.3	2.5

Table 2 Decadal average values of annual and seasonal mean precipitations (mm) for the Doboj municipality with the difference between the last and first decade averages

Decade	Winter	Spring	Summer	Autumn	Growing season	Year
1966–1975	197.5	204.6	297.6	217.4	522.8	917.1
1976–1985	184.2	204.8	252.2	194.9	461.1	836.1
1986–1995	168.7	224.2	292.1	239.6	519.0	924.6
1996–2005	218.1	232.0	287.2	284.5	581.4	1021.9
2006–2015	204.8	274.5	256.5	217.1	529.5	952.8
Average	194.7	228.0	277.1	230.7	522.7	930.5
Difference 2006–2015/1966–1975	7.3	69.9	−41.1	−0.3	6.7	35.7

decade, whereas precipitation in growing season increased by 16.3 mm per decade (Fig. 2).

Decadal average values of monthly, seasonal and annual air temperatures for the Doboj municipality in the 1996–2015 periods are given in Tables 3 and 4.

In the Doboj Municipality, increase in air temperature throughout the year is unambiguous. The only negative trend in monthly air temperatures was recorded for February. Although air temperature displayed an upward tendency in all seasons, the most prominent changes were recorded in summer season. For instance, the last decade (2006–2015) was 2.1 °C warmer than the first decade (1966–1975) in the observed period.

Trend analysis showed that warming tendency over Doboj area was present in all seasons (Fig. 3). However, most prominent increase in seasonal mean air temperatures was determined in summer season (0.47 °C per decade), and then in winter (0.40 °C per decade).

4.2 Floods Occured in 2014 in Doboj Area

Precipitation, as one of the most important climatic elements is highly variable. Long-term or high intensity rainfall over a certain area cause high water levels which may lead to flood occurrence.

Directive 2007/60/EC on the assessment and management of flood risks enter into force in November 2007. Under this Directive the maps of the Bosna River Basin including the river basin boundaries, sub-basins, waterway and main basin areas with topography and possibilities of land utilization have been provided by Institute for Water Management Bijeljina. The Bosna River is the right tributary of the Sava River. Its basin covers the central part of Bosnia and Herzegovina and the central part of the Dinaric Mountain range. It is located between the Sava River basin in the north, the Neretva River basin in the south, the Drina River basin in the east and the Vrbas River basin in the west. The entire area of the Bosna River basin is located within the

Table 3 Decadal average values of monthly air temperatures (°C) for the Doboj municipality with difference between the last and first decade averages

Decade	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1966–1975	−0.7	3.5	6.3	11.2	16.1	18.9	20.3	19.8	16.2	10.5	6.0	0.7
1976–1985	−0.4	1.3	6.8	10.1	15.4	18.6	20.0	19.3	15.9	11.5	5.1	2.1
1986–1995	0.5	2.5	6.5	11.2	15.6	18.7	21.3	20.8	16.7	11.1	5.5	1.3
1996–2005	0.3	2.6	6.5	11.3	16.7	20.2	21.2	21.1	15.7	11.9	6.8	1.1
2006–2015	1.9	2.7	7.4	12.5	16.6	20.5	22.7	22.0	16.9	11.7	7.1	2.7
Average	0.3	2.5	6.7	11.3	16.1	19.4	21.1	20.6	16.3	11.3	6.1	1.6
Difference 2006–2015/1966–1975	2.6	−0.8	1.1	1.3	0.5	1.6	2.4	2.2	0.7	1.2	1.1	2.0

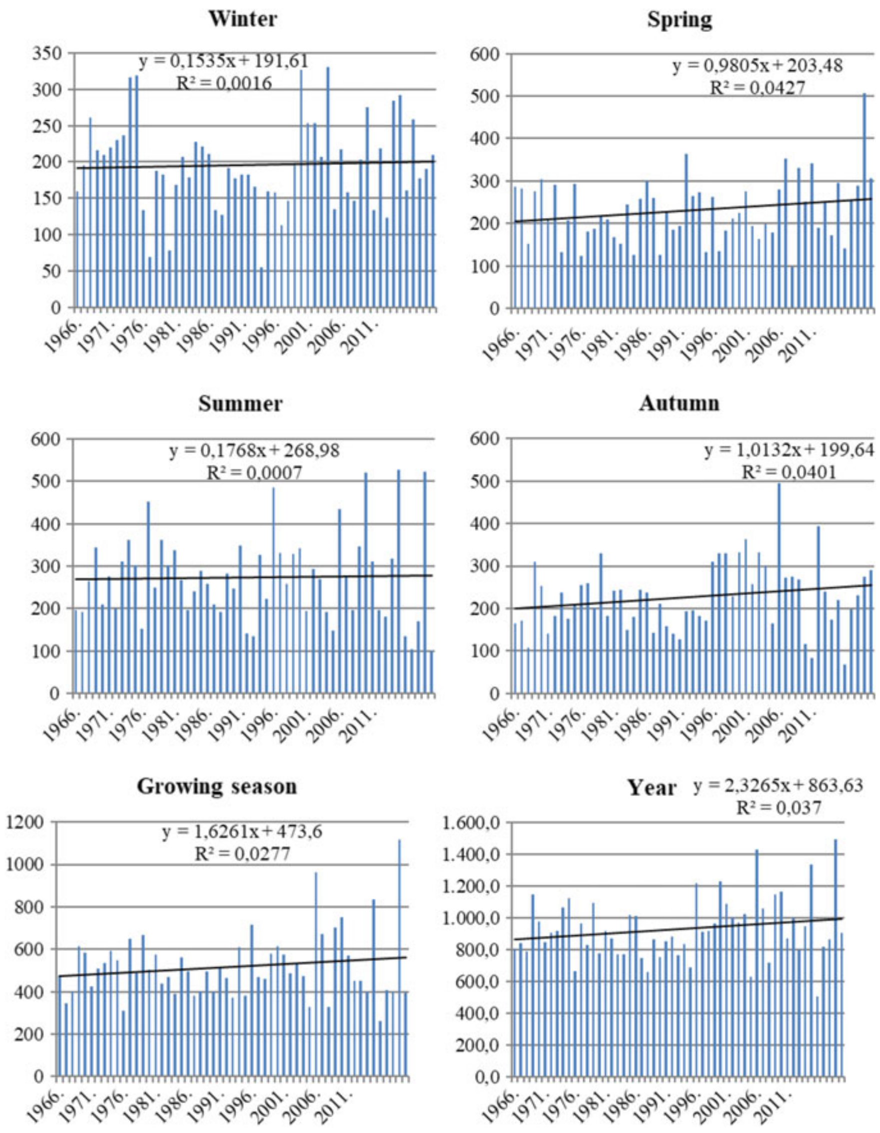

Fig. 2 Linear trend in seasonal mean precipitation in Doboj in 1966–2015

borders of Bosnia and Herzegovina. The basin area covers an area of 10.663 km^2, i.e. 20% of the total area of Bosnia and Herzegovina. Out of that, 2.983 km^2 (27.97%) belongs to the Republic of Srpska (Table 5). The river Bosna is formed from several springs below the Igman Mountain, at 492 m above sea level and flows towards north, where it flows into the Sava River near Šamac municipality. The average altitude of the basin is 640 m (Institute for Water Management Bijeljina 2014).

Table 4 Decadal average values of annual and seasonal mean air temperature (°C) for the Doboj municipality with difference between the last and first decade averages

Decade	Winter	Spring	Summer	Autumn	Growing season	Year
1966–1975	1.2	11.2	19.7	10.9	17.1	10.7
1976–1985	1.0	10.8	19.3	10.8	16.6	10.5
1986–1995	1.4	11.1	20.3	11.1	17.4	11.0
1996–2005	1.3	11.5	20.8	11.5	17.7	11.3
2006–2015	2.4	12.1	21.7	11.9	18.5	12.1
Average	1.5	11.3	20.4	11.2	17.4	11.1
Difference 2006–2015/1966–1975	1.3	0.9	2.1	1.0	1.4	1.4

Table 5 Basic characteristics of the River Bosna

Square area (km^2)	10.663
Square area in the Republic of Srpska (km^2)	2.983
Square area in the Federation of Bosnia and Herzegovina (km^2)	7.680
The length of the watercourse (km)	271
The total decline in watercourse (km)	420

Source Institute for Water Management Bijeljina (2014)

Important mining and industrial centers of Bosnia and Herzegovina are located in the Bosna River Basin. Due to the complexity of the terrain and its geomorphologic characteristics, all economic capacities, settlements and roads are located in the valleys of Bosna River and its tributaries (Fojnica, Lašva and Usora on the left side, and Krivaja and Spreča on the right side). The basin area also represents a zone of high population concentration. The basin area is covered with dense forests however many erosion processes and torrential waters are present. Climate and terrain configuration (high mountains with steep slopes) condition a very uneven water regime. The tributaries of the Bosna River are even more torrential, not only in the ratio of the minimum to maximum flows, but also due to the large decline of the riverbed in upper stream of the basin and the large amount of deposits in the flows in the lower streams of the basin and in the mouth (Institute for Water Management Bijeljina 2014).

The area of Central and South-East Europe was affected by cyclone on May 13, 2014, which spread over a large horizontal surface. The path of the cyclone was from the Genoese Bay over the Apennines, southern Adriatic, southern Serbia, Bulgaria and Romania, with an elliptical loop over the southeastern part of the Pannonian Plain. That low-pressure system remained steady for more than three days and generated extremely high precipitation, particularly over the Sava River Basin. The highest cyclone activity was on May 15, 2014. The precipitation recorded between 14th and 18th May were higher than average sum for that month: in Croatia 1.5–1.8-fold, in

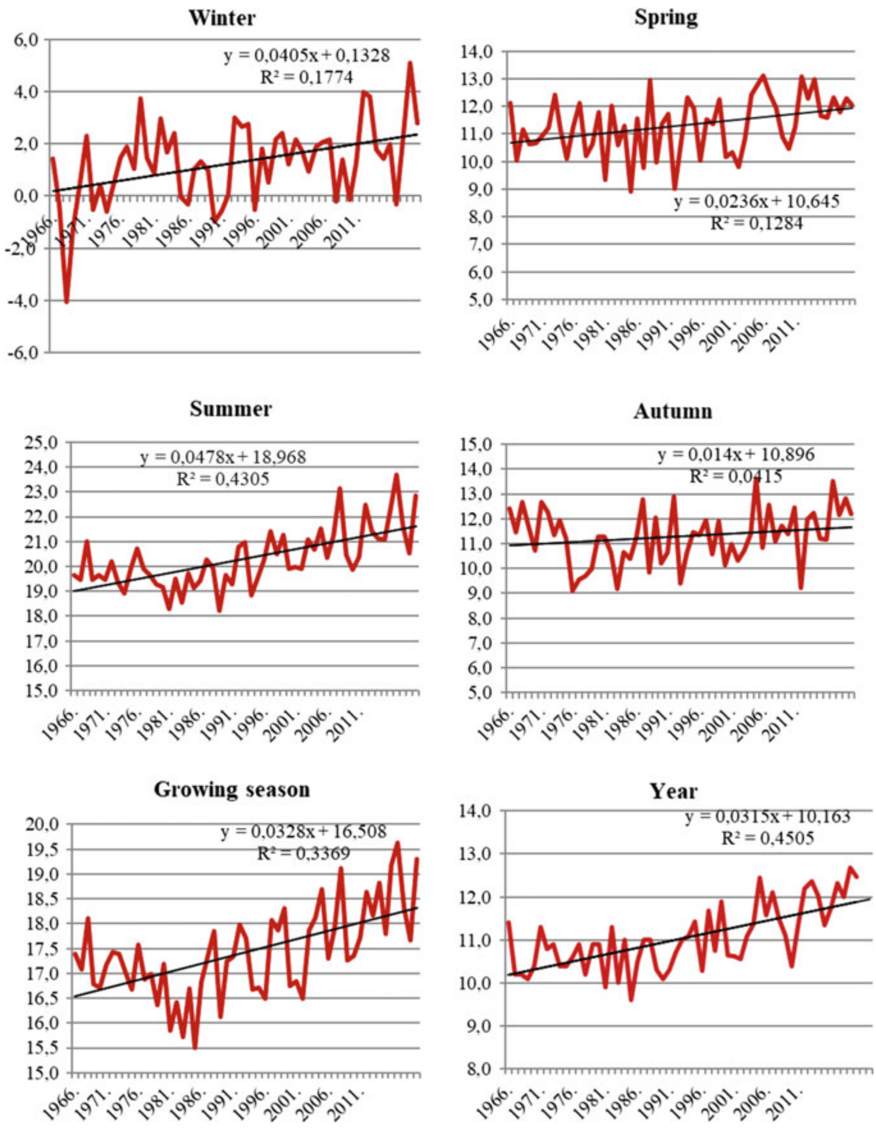

Fig. 3 Linear trend in seasonal mean air temperatures in Doboj in 1966–2015

the Republic of Srpska (B&H) more than 2-fold, and in Serbia more than 3-fold. Historical maxima were recorded in the middle and lower parts of the basin on May 15, on both the Bosna River main course and on its tributaries (Krivaja, Usora and Spreča). The return period of the flood peak on the Bosna River was 500 years, and 100 years on tributaries. Sudden rise of water level (more than 6 m in less than 24 h) was recorded on Doboj hydrological station. As a result, floods with disastrous

Table 6 The consequences of the flood in May 2014 in the Doboj Municipality

Flooded area	4676 ha
Number of victims	11
Number of hospitalized persons	73
Number of flooded residential buildings	4500
Evacuated people	11,000
The total estimated damage	560,000,000 BAM

Source Institute for Water Management Bijeljina (2014), City of Doboj (2014)

consequences occurred in cities Zavidovići, Maglaj and Doboj (ICPDR and ISRBC 2015).

Soil saturation with large amounts of water triggered a large number of landslides, which caused damage to individual facilities and infrastructure.

The flood affected the urban centre and suburban settlements of Doboj and 33 settlements in the immediate vicinity (City of Doboj 2014). The flood in the Doboj area caused damage to assets and property owned by natural and legal persons. The damage is also reflected in interruption of social and commercial activities—all economic activities were suspended, as well as classes in schools, whereas electricity and drinking water supply, transport, postal and telephone communications were interrupted (City of Doboj 2014).

Consequences of the floods in May 2014 in the area of Doboj are summarized in Table 6. The 11,000 persons have been evacuated. Moreover, 11 people died as a direct consequence of floods, whereas 73 were hospitalized. According to the Institute for Water Management estimate, the total damage (direct and indirect) caused by the floods in May 2014 in the city of Doboj was close to 300 million Euros.

5 Adaptation and Mitigation to Consequences of Climate Change

According to the Global Climate Risk Index for 2014, Bosna and Herzegovina ranked third in the world hit by the heaviest rainfalls, which caused the most disastrous flooding since instrumental measurements began 120 years ago (Germanwatch e.V. 2015).

According to the Global Adaptation Index (ND-GAIN Country Index) for 2016, Bosnia and Herzegovina ranks 87th in the world regarding vulnerability and preparedness to response to climate change (Web page of ND-GAIN).

Natural disaster as a phenomenon, expressed through flooding of the city of Doboj and its surroundings in 2014, as one of the consequences of global climate change in the region, was taken as a case study example for this paper preparation. If we observe flood as a natural disaster through the relationship between two elements as follows:

$$\frac{\text{the amount of precipitation realized during a certain time interval and}}{\text{the existing watercourse (culverts, canals)}},$$

it is evident that all relevant institutions must and should have an impact on the second element, as the cause of flooding.

There are three main watercourses in Doboj area (Bosna River, Usora River and Spreča River). In addition to watercourses, there is a certain infrastructure of permeable and drainage canals. The total watercourse (presented in m^3/sec) is enough to neutralize a certain amount of precipitation. In conditions with increased or extremely increased precipitation, the existing watercourse is inadequate to neutralize the excess precipitation, and that in turn floods occur, which have as a direct consequence endangering human lives and damages on facilities, property and infrastructure. Society preparation for adaptation to such drastic natural phenomena is reviewed through two elements:

1. Elimination of causes and revitalization of existing watercourses and drainage canals, and
2. Improvement of the watercourses, i.e. enabling the excess precipitation to be neutralized without consequences for the lives and property.

Causes that have been recognized as factors that have devastated to a certain extent the existing watercourses and which reduce their optimal flows are:

- Inadequate urban plans or lack thereof.
- Unauthorized construction of objects not in compliance with urban planning terms, and in places that do not meet the safety requirements against possible flooding.
- Use of land contrary to plans, exploitation of gravel from offshore areas, unplanned deforestation (which results in increase of erosion), landslides and changes of terrain configuration.
- Insufficient maintenance (cleaning) of existing watercourses and drainage canals, thus reducing their flow.

Technical investment projects, which would improve and minimize consequences of floods, are:

- Hydrological and potamological study of the existing watercourses and terrain in the region.
- "Recognition" of critical pointes, i.e. areas that are the most vulnerable to consequences from increased precipitation (deteriorating embankments, narrowing of watercourses, lower embankments compared to the designed water level, lack of or insufficient number of drainage canals, etc.).
- Construction or upgrade of existing protective embankments along riverbanks, for uninterrupted flow of increased precipitation.
- Construction or expansion of existing drainage canals, i.e. construction of a canals network along settlements, which are defined as the ones in danger of flooding.
- Forestation of terrains subjected to the erosion, especially in areas where deposits can reduce or prevent optimal watercourse.

System of measures for adaptation to climate change:
In order to adapt and efficiently response to the consequences of evident climate change, a system of measures should be undertaken. The above-mentioned activities represent one segment of the overall system of measures that must be undertaken in order to responsibly and efficiently approach the great issue of natural disasters consequences on natural and socio-economic systems. Like every other system, the system of necessary measures must be clearly defined, organized, implemented and controlled.

Necessary steps in establishing system of measures can be defined as follows:

A. Adoption of strategic documents, plans and procedures;

It represents the activity of defining the strategic documents necessary for setting up and implementing a system of measures. The strategic plan is prepared by the competent authority, and, in line with a regular procedure, it is adopted by a Legislative authority. Plans and procedures must contain detailed activities for all relevant institutions and authorities at all levels of executive power.

B. Establishment of authorized bodies and authorities from the sectors of the competent ministries, which would be in charge of implementation of the procedures and the tasks defined in the plan;

The necessity of an independent regulatory body, solely responsible for the activities aimed at establishing of a defined system, is justified by extremely dire consequences that can be caused by natural disasters. The tasks of such a body are not only limited to monitoring of implementation of the adopted measures. Identification of weak links, insufficiently or incompletely defined parts of the system and introduction of adequate corrective measures in order to optimize the system are of utmost importance.

C. Continuous development based on new scientific findings which implies cooperation with scientific institution;

Developments in science and technology is of exceptional importance in practical applicability. The moment when scientifically proven laws, phenomena and extremes find their application in local, regional and global protection plans, justifies their missions, roles and goals.

D. Interactive relationship between authorized bodies and institutions at local, regional and global levels;

Once adopted strategic, regional and global plans must be subjected to constant monitoring, verification and control, which is achieved by the absolute interaction of all stakeholders in charge of plans implementation. Implementation of the measures is only feasible and effective through full interactivity of all stakeholders included in this extremely important task.

The system of measures should include the following activities:

– Activities undertaken on daily basis, which are focused on preparation and strengthening of all factors included in implementation of measures in order to ensure optimal response in case of natural disasters:

(a) Setting up plans,
(b) Education of all necessary factors, i.e. stakeholders in the planned activities,
(c) Development of local procedures, documents and operating procedures of local authorities, derived from strategic plans,
(d) Full and permanent monitoring of areas, landscapes, and all factors (soil, air, waterways, discharge canals, drainage systems, erosion protections, and all other circumstances that may affect implementation of the system of measures);

– Activities that are undertaken immediately before and during manifestation of natural disasters:

(a) Timely monitoring of phenomena.
(b) Provision of adequate information.
(c) Undertaking measures to protect the people lives, animals, facilities and property.
(d) Ensuring the functioning of main infrastructure.
(e) Provision of alternative ways for vital societal functions in natural disaster conditions.
(f) Establishment of full cooperation of all competent services (Ministries, Fire departments, Civil protection bodies, Army authorities, local self-government bodies, etc.);

– Activities that are undertaken after natural disasters, aimed at eliminating their consequences and revitalizing endangered functions of the society:

(a) Setting up teams for quick rehabilitation and provision of conditions for maintaining vital societal functions at optimum level,
(b) Fast and adequate assessment of potential damage,
(c) Measures and ways for reconstruction of endangered infrastructure facilities,
(d) Measures and ways for reconstruction and elimination of inflicted damage,
(e) Analysis of undertaken activities, identification of weaknesses and introduction of corrective measures.

The measures are based on institutional frameworks and result in actual interventions in the field. It is important to implement them at all levels, from local to national. Between the Republic of Srpska and the Federation of Bosnia and Herzegovina, there are no joint plans for flood protection measures, as well as between B&H and the countries in the region. Since the Bosna River flows mostly through the Federation of B&H, it is necessary that the entities act together in order to provide efficient regulation and protection of its basin. Cross-border cooperation with the Republic of Croatia and Republic of Serbia should also be a priority given the fact that Bosna River is the tributary of the Sava River, which forms the northern border with the Republic of Croatia and continues its course through the Republic of Serbia. Partial and unplanned works in the basin may have a negative impact on downstream areas. Therefore, participation of Bosnia and Herzegovina in all cross-border projects is a necessary measure in order to diminish possible negative consequences of natural disasters.

6 Conclusion

According to the Third National Communication of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change (2016), significant climate change can be expected over the territory of Bosnia and Herzegovina in the future, especially in the case of climate scenarios that do not foresee implementation of appropriate mitigation measures. Climate trends in the Doboj area are consequence of global climatic conditions in interaction with morpho-physiognomic changes. An intensive process of urbanization during the last two decades led to the changes in physical properties of the soil (construction materials, asphalt and concrete, changing the thermal properties of the soil and preventing water from plunging), changes in the hydrological characteristics of the substrate (draining of the soil and water surfaces, increase of outflow), changes in vegetation. Anthropogenic activity has also influenced heat production (artificial heat production due to household heating, heat from transport and industry).

According to the Third National Communication (2016), Bosnia and Herzegovina is a European country that is significantly threatened by climate change and it is relatively under-developed in terms of international cooperation in climate change. There are insufficient resources in the country to solve the problems related to global climate change, and therefore international cooperation in this region needs to be established. It is necessary to define a sustainable development policy, which takes into account measures for adaptation and mitigation to climate change.

Taking into account the current state of infrastructure in the Bosna River Basin and its functionality, not excluding the negative consequences of climate and hydrological events in the recent past, it can be concluded that the scenario from 2014 can be repeated. Consequently, the city of Doboj should consider adaptation to climatic scenarios in the future and mitigation of their negative effects as one of its long-term strategic goals. Increasing public awareness on need for implementation of adaptation and mitigation measures is of utmost importance, so that projects for mitigation of climate change consequences could be implemented through mutual cooperation with the local population.

The authors of this paper have faced the challenges of exploring a very sensitive topic of climate change effects and consequences for this region. Applicability of further research, scientific findings and production of high-quality hydrological and potamological studies of the region would bring the consequences of global climate change to the lowest possible extent.

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References

City of Doboj (2014) Commission for the assessment of damage from natural disasters. The report on the estimated damages in the area of the city of Doboj caused by natural disasters—floods. Doboj (in Serbian)

Gajić-Čapka M, Cindrić K, Pasarić Z (2015) Trends in precipitation indices in Croatia, 1961–2010. Theoret Appl Climatol 121(1):167–177. https://doi.org/10.1007/s00704-014-1217-9

Germanwatch e.V. (2015) Global climate risk index 2016, Bonn, Germany. https://germanwatch.org/en/cri. Last Accessed 15 Mar 2018

ICPDR—International Commission for the Protection of the Danube River and ISRBC—International Sava River Basin Commission (2015) Floods in May 2014 in the Sava River Basin (Brief overview of key events and lessons learned). ICPDR Secretariat & ISRBC Secretariat, Vienna/Austria & Zagreb/Croatia

Institute for Water Management Bijeljina (2014) Preliminary assessment of the flood risk in the Republic of Srpska, Book 4—the Bosna River Basin. Bijeljina (in Serbian)

IPCC (2014) Climate change 2014: synthesis report. In: Pachauri PK, Meyer LA (eds) Contribution of working groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team]. IPCC, Geneva, Switzerland, p 151

Malinović-Miličević S, Radovanović MM, Stanojević G, Milovanović B. (2015) Recent changes in Serbian climate extreme indices from 1961 to 2010. Theoret Appl Climatol 124(3):1089–1098. https://doi.org/10.1007/s00704-015-1491-1

ND-GAIN (Notre Dame Global Adaptation Initiative) web page. https://gain.nd.edu/our-work/country-index/rankings/. Last Accessed 15 Mar 2018

Popov T, Gnjato S, Trbić G, Ivanišević M. (2017) Trends in extreme daily precipitation indices in Bosnia and Herzegovina. Collection of papers. Faculty of Geography at the University of Belgrade, 65:5–24. https://doi.org/10.5937/zrgfub1765005p

Renwick JA (2015) Europe and Middle East [in "State of the Climate in 2014"]. Bull Amer Meteor Soc 96(7):191–200

Statistics Institute of the Republic of Srpska (2016) 2013 Census of Population, Households and Dwellings in the Republic of Srpska, Banja Luka

UNDP (2016) Third National Communication and Second Biennial Update Report on Greenhouse Gas Emissions of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change. UNDP in Bosnia and Herzegovina, Sarajevo, B&H

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An Analysis of Problems Related to Climate Change in Serbian Planning Documents

Dejan Filipovic and Ljubica Duskov

Abstract Tackling the climate change represents one of the top priorities in the politics of the international community nowadays. The expected effects of climate change are complex and far-reaching; it is therefore not surprising that various global initiatives are focusing on these issues. In addition to the activities aimed at mitigating the effects of climate change, the need for urgent development of systems for the adaptation to these changes has become imminent. Numerous authors emphasise the role of spatial planning in the process of adaptation to climate changes due to its integrativity and sector policies. The correlation between the adaptation to climate changes and other development issues and the necessity for a comprehensive solution are particularly challenging to spatial planning. Consequently, there is a need to change the traditional methodology of planning and develop a new one which is capable of dealing with the dynamics of climate change and which will use certain climate indicators when making decisions related to space. To determine the extent to which spatial plans consider the climate change issues, this paper uses the 3A model (Moser and Luers 2008) and analyses the Regional Spatial Plan of the Republic of Serbia and the Regional Spatial Plan of the Republic of Srpska based on 30 criteria sorted into 3 categories—Awareness, Analysis, Action. The results have shown that the role of spatial planning in the adaptation to climate changes is still limited, the awareness of the importance of this phenomenon is still low and that the analysed plans put forward a limited number of actions as responses to climate changes. The goal of the paper is to point out certain flaws in the current planning policies as well as to emphasise the importance of considering climate change issues in the process of spatial plan development.

Keywords Spatial planning · Climate change · Adaptation · Republic of Serbia Republic of Srpska

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1 Introduction

Climate changes represent one of the key topics in international relations in the XXI century. It is no longer only a matter of environmental protection and ecologic awareness, but the term itself encompasses the main topics of this century: sustainability, economic growth and energy security. For the aim of planning of sustainable development in the regions sensitive to climate changes, it is necessary to create and apply new strategies and measures in environmental protection and preservation, while at the same time respecting the adopted international conventions, declarations, strategies and national legislative regulations.

Parallel to confrontation with problems and consequences of the climate changes, new activities related to adaptation have also been appearing worldwide. The term adaptation is used to denote adjustment of the natural and human systems as their answer to the observed or expected climate changes and their effects (Smit et al. 1999). There are different types of adaptation, including anticipative, autonomous and planned adaptation (de Bruin et al. 2009). In case when the term adaptation is used in spatial planning, it denotes the planned adaptation, i.e. the one that comes as a result of a politically decided process. Climate change adaptation is a critical task for contemporary planning. Planning is expected to play a significant role in preparing human settlements for the impacts of climate change (Bulkeley 2006). According to Campbell (2006), spatial planning can be the strategic framework where both mitigation and adaptation measures are positioned in the broader perspective of sustainable development. For certain countries, establishing adaptation to climate changes presents a priority for modern manner of planning, and its measures may often be focused on individual sectors, such as water management and exploitation (Rosenzweig et al. 2007) and the health sector (Ebi and Burton 2008). Canada, Finland and Great Britain have conducted national adaptation assessments or they have developed national strategies for climate change adaptation. According to Knieling and Klindworth (2016) adapting to climate change and its impacts will continue to be necessary even if we are able to reach the most optimistic climate mitigation goals and scenarios. A first step toward adaptation implies mainstreaming or integrating into planning and ongoing sectoral decision-making policies and initiatives expected to enhance adaptive capacity and to reduce the vulnerability and sensitivity of natural and human systems to the effects of actual or anticipated climate change (Anisuzzaman and Jennings 2012; Klein et al. 2007).

The basic aim of this paper is to point out the significance of including the issue of climate changes into spatial plans as a current problem, as well as to show the possibility of utilization of the aforementioned model with the objective of improving the planning methodology in the Republic of Serbia and the Republic of Srpska.

2 Method

Several authors have been trying to solve the problem of integrating the climate-changes-issue into different policies by suggesting different models (Brooks et al. 2011; Lim et al. 2005; Urwin and Jordan 2008) which are being used by different international and national research organisations. Most of them are used in order to establish the disadvantages and questions concerning climate change policies throughout the planned processes (Preston et al. 2011; Urwin and Jordan 2008; Wilson 2006). Experience with several different models was used as a reference for creating a model that has been used in this study.

According to Moser and Luers (2008) it is necessary for the local authorities to improve their adaptation capacities in order to prepare the cities for the negative climate change impacts. The three main components for creating successful adaptation capacity against climate change are identified and called Awareness, Analyses and Action (AAA Model). In order to analyse the Spatial Plan Policy of the Republic of Serbia and the Republic of Srpska, the AAA Model (Moser and Luers (2008)) has been used as to establish the climate change policy degree presence in its content. The Model has been defined based on 32 criteria categorised within 3 components, where each component reflects some of the activities that may be expected within the spatial plan policy. The objective of the "Awareness" component is to assess a degree to which the plan "recognises" the causes of climate change (gas emission with the greenhouse effect and its consequences, global warming concept etc.); the "Analyses" component represents the capacity of the spatial plans to analyse, quantify and synthesise the data on climate change within its plan procedure, and the "Action" component assesses whether and in which way the spatial plan consists of practical measures for adaptation and the climate change problem-solving policy (Biesbroek et al. 2010; Füssel 2007). The criteria within the model have been selected in a manner that can be applicable on domestic spatial planning methodology, which would integrate in itself the climate change policy in the forthcoming period.

Spatial plan assessments were based on the presence of a certain criterion in the planned document, where the value of 0 is assigned if the criterion was not mentioned and was not recognised within the document; the value of 1 is assigned, in case the criterion was recognised but it lacks a more detailed explanation and the value of 2 is assigned, in case the criterion was recognised with a more detailed, more accurate information and analyses, in the planned document. For instance, when taking into consideration the criterion "Assessment of gas emission with the greenhouse effect on yearly basis"—value 0—the plan does not mention any information on a yearly based emissions; value 1—in case the plan showed the picture or the chart on emission, without further information and value 2—a detailed representation of a yearly-based emission, gas sources data, their spatial dispersal etc. (Moser and Luers (2008)). The planned solutions which were assessed in the paper, were adopted for the period from 2010–2020 for the Spatial Plan of the Republic of Serbia, and for the period from 2007–2025 for the Spatial Plan of the Republic of Srpska (with amendments of the Spatial Plan).

3 Climate Changes and Spatial Development

Climate change adaptation will represent one of the main tasks of modern spatial planning. There are numerous authors who point out the significance of spatial planning policies in the preparation of both housing-estates and living population to the negative effects of the climate change. Crane and Landis (2010) not only identify that planning can make an active contribution to climate change adaptation, but regard it to be a moral and professional imperative, stating that it would be irresponsible for planning not to consider predicted future conditions. However, some scepticism regarding the role of spatial planning in the climate change debate remains. In this respect, Bulkeley (2006) concludes that given the complexity, uncertainties and scale of the climate change issue, spatial planning might play a key role in facilitating the development of both adaptation and mitigation strategies with a spatial component, but at the same time has little to offer in terms of comprehensive or pragmatic solutions. It will prove to be both an opportunity as well as a requirement to 'change the policy footing of climate change within spatial strategy (Bulkeley 2006). The discussion on the role of spatial planning in the climate change debate has only recently started to take place in the planning community.

International treaties on climate change have constituted the principles, institutional mechanisms and rules for solving the causes and effects of climate change. The UN framework convention on climate change and the Kyoto Protocol, among other things, oblige the member countries, together with Republic of Serbia and B&H, thus including Republic of Srpska, to develop strategies for mitigation of climate change and strategies on adaptation to the altered climate changes, to conduct measures that would bring about mitigation and to adjustment to climate changes, to cooperate in climate observations, researches and the technology transfers, and to advance the programs of education and strengthening the public awareness on this topic. In relation to the above mentioned, each European country in transition that had a status of a candidate for joining the European Union, or is still waiting for the admittance, has taken over obligation according to the Framework Convention on climate changes and the Kyoto Protocol. Having in mind the actual and possible consequences of climate change on long-term developmental goals of Spatial Development of Republic of Serbia and Republic of Srpska, and the aforementioned ratified documents which oblige their signing countries, it is necessary to define developmental strategies with the elements of action plans.

4 Planned-Documents Analysis

Spatial Plan Policies of Republic of Srpska and of Republic of Serbia have been defined as strategic-developmental documents which give basic directives and suggestions for the latter creation of the special purpose area spatial plans, regional spatial plans, local municipality spatial plans, and further for creation of urban planning. Hence, proportionally they give basic outlines and they offer concrete solutions, to the extent that their actual feasibility is being assessed through the republic sectors, organs and organisations, and with cooperation on the municipality level. Methodology stems from the necessary integration of the three key spatial development elements: (a) nature and environment, (b) population and social issues, (c) economy and technical systems (infrastructure of republic significance).

The climate change issue is being differently discussed in the adopted spatial plans of Republic of Serbia. Republic of Serbia Spatial Plan Policy from 2010–2020 represents the first planned document treating this problem in a special chapter, but commitments, conditions and directives from this plan were not taken over in the lower-rank planned documents, except for the Regional Spatial Plan of the City of Belgrade. The concept of spatial development in the context of climate change effect on the specific regions of Republic of Serbia in this spatial plan policy may be realised through two complementary approaches: as a general development concept based on the information of the observed and the anticipated climate changes and the impacts of climate changes on the natural resources accessibility (the first phase); and as a sectoral development concept which will take climate change effects into detailed consideration, both negative and positive, with the aim of adequate planning of spatial development within the framework of the given sector (the second phase).

Republic of Serbia Spatial Plan Policy defined the concept of spatial development in the context of climate change effects that comprise:

- Establishing changes of climate zones for different scenarios of global climate changes and different time periods relevant for strategic planning and long-term measures of protection and sustainable natural resources utilisation;
- Establishing the effects of climate changes on natural resources accessibility, especially water resources, cultivable soil, forests and other ecosystems and biodiversities with the aim of the planned sustainable development and ecologically acceptable activities in the areas sensitive to climate changes;
- Development of spatial database and data on local and regional climate change, including information on extreme climate phenomena and natural disasters, vulnerability of specific areas, with the purpose of their utilisation in spatial and urban planning;
- Establishing and application of new measures in preservation and protection of water resources, agricultural land and woodland and the utilisation of renewable energy resources in the context of climate change effects assessment and adjustment to the altered climate conditions;
- Application of conventions, standards and good practice, and the experience of EU and other countries in including factors of climate change into the process of spatial development planning;
- Levelling of sector strategies, instruments, measures and policies together with harmonisation of its inter-sectoral coordination and participation of supervising institutions and local communities, as well as raising awareness of the need for including climate change policy into sectoral strategies;

– Multi-disciplinary development programme of researching climate change impacts on spatial development.

With the aim of climate protection and establishment of operating risks-free climate change systems, some of the priorities of Spatial Plans of Republic of Serbia represent conducting multi-disciplinary research programmes of local climate changes and the climate change impacts on agriculture, forestry, water supplies, energetic supplies, biodiversity and ecosystems, infrastructure and population's health; creating sectoral plans and adaptation programme policies and climate changes mitigation plans; conducting a strategy of introducing ecologically acceptable technologies in production, energetics, traffic etc., including greater utilisation of available renewable energy resources; development of climate monitoring system and spatial database and information on local and regional climate change, including information on extreme climate phenomena and natural disasters, vulnerability of specific regions, with the purpose of its utilisation in strategic planning and planning of spatial development.

The existing legislative framework in Bosnia and Herzegovina does not provide an adequate basis that would appropriately treat the influence of climate changes, which creates an additional problem to the process of adaptation to changed climate conditions (Trbić et al. 2018). The concept of spatial development model with a reduced impact on climate changes, which are defined by Spatial Plan of Republic of Srpska, defines as its primary goal introduction of climate change issue into all the policies and strategies that refer to spaces or activities on whom these changes depend upon, together with an institutional organisation that is going to monitor it. Its operational goals are:

– Application of different measures in planning, construction and all economic, traffic and other activities that may contribute to reduction of climate changes according to the valid conventions;
– Coordinating legislative framework and completing it with measures and instruments that may contribute to reduction of their impact on climate changes;
– By means of spatial and urban plans, prescribing measures and solutions for the reduction of climate changes;
– Implementing measures for mitigating the consequences on climate changes, such as preventing further reduction of green areas, reforestation etc.;
– Implementing special plans and programmes for climate change adaptation and its sectoral and strategic harmonisation;
– Introducing special system of monitoring and forecasting existence of the more significant phenomena of climate changes.

Amendments to the Spatial plan of the Republic of Srpska (2013) gave the initial results of the research connected to the climate variability assessment. Based on analyses of historical and meteorological information from the Hydro-Meteorological Agency of the Republic of Srpska and the information gathered from the Hydro-Meteorological Agency of B&H Federation, and with the aim of assessing the observed tendencies of climate changes and the calibration of the regional climate model, the gathered data were used for the latest climate standards according to the World Meteorological Organisation (1961–1990), and for the latest thirty-year period from 1981–2010. Based upon meteorological information from the stations, the thematic climate charts have been created in GIS for two periods, 1961–1990 and 1981–2010. In addition, average temperature values of the air and average precipitation amounts, were calculated for the total observed regional area.

Furthermore, the climate scenarios up to 2030 (A1B Scenario 2001–2030) are presented within the same chapter of the Spatial Plan of Republic of Srpska, where the temperature fluctuation and the precipitation amounts were projected for the 2001–2030 period, compared to basic period of 1961–1990 (Djurdjevic et al. 2013). On the yearly basis the expected temperature change is within the 0.8–1 °C limit, with greater values in the north. The precipitation change on a yearly level is negative on the whole of the territory from 0 to −10%, except in the northeast where the change is positive i.e. up to +5%.

5 Results of AAA Model Assessment

As it has been previously stated, the Spatial Plan Policy of Republic of Srpska and Spatial Plan Policy of Republic of Serbia have been assessed based on the AAA Model, i.e. the value scale regarding the presence of the criteria in the Plans. Both plans were created based on similar methodologies and there are no big differences regarding the treatment of the climate change policies. The Spatial Plan of Republic of Srpska is more comprehensive regarding cartographic display of the projected temperature changes, the amount of precipitation changes and the scenarios analysis (A1B Scenario 2001–2030), while the Spatial Plan Policy of Republic of Serbia paid more attention to the concept of climate changes and the impact it might have on this area. Both plans have defined the concept of spatial development in the context of climate changes effect. The criteria used to evaluate the content of the plans were taken based on the work of Kumar and Geneletti (2015). The representation of criteria and the manner of assessment of the content of both plans have been shown in the Table 1.

The assessment results have pointed out to the insufficient presence of the policies on the climate changes in the Plans. Out of 64 points (32 criteria with maximum 2 points by criterion), the SPP of the Republic of Srpska has 7 points, and the SPP of the Republic of Serbia has 10 points. The “Analyses” component has been the least represented in the documents—there are no information on gas emission, future gas emission tendencies, no GHG emission scenario, nor any planned solution analyses regarding climate changes (in SPP of the Republic of Serbia, only the criterion “Assessment of the physical development” has been assessed with 1 point). The reason for this is the fact that not enough attention has been paid to defining planned solutions regarding sensitivity of specific systems to climate changes. Low degree of awareness concerning planned climate changes shows the assessment of the “Awareness” criterion. The climate changes concept and global warming are referred to in general terms in the documents, as well as long-term operational goals for spatial

Table 1 Criteria and assessment of content for SPP of the Republic of Srpska and SPP of the Republic of Serbia

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Awareness				
Concept of climate change or global warming	The broad concept of climate change or global warming has been stated and minor discussion of specific concept with some consideration of policy response	There is clear vision about the concept of climate change and how it has an impact at various spatial scales and locality. Goals and objectives to be recognized and response priorities have been identified with explanation or justification	1	1
Prediction of the impacts of climate change on the biophysical/social/economic contextof the planning area	Basic evidence or acknowledgement of climate change impacts and climate change issues on biophysical/social/economic context of the planning area	Climate change vulnerability at various scale and sector wise has been assessed	0	1
Long term goals and targets for changing climate variability and its impacts	The broad climate change strategies have been stated, as well as some discussion of specific objectives, with some consideration of adaptation priorities on various climate related issues but has not been explained on how to implement it onground	There is a clear vision about the goals of the action response for climate change and how it supports wider goals or targets in spatial plan, objectives that allow progress towards the goals to be recognized and adaptation priorities have been identified with some explanation or justification	1	1
Guidance and standards for the implementation of adaptation and mitigation measures in planning area	A range of policies and action plans to acknowledged the need of guidelines and standards on issues like GHG emission, energy,water, etc.	Spatial plan included guidelines and standards for climate changes concerns like energy, water,pollution and environmental protection, etc.	0	0

(continued)

Table 1 (continued)

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Analyses				
Base year assessment of GHG emission	Spatial plan provides base year assessment of GHG emission at various spatial scales and location	GHG emission have been assessed in term of historical trends, current variability and projected future changes	0	0
Future emission trends forecast	Based upon historical and current GHG emission, development policy goal for future emission have been predicted or are planned to be assessed.	Based upon historical and current GHG emission,development policy goals for future emission are forecasted and have been predicted	0	0
GHG emission scenario development	GHG emission scenario is identified or are planned to be developed in the spatial plan development process	Goals for GHG emission scenarios are made during the spatial plan development process	0	0
Assessment of the physical development	The current nature or status of physical asset and resource stocks that are sensitive to climate risks or integral in their management have been acknowledged, or are planned to be assessed	The current nature or status of physical asset and resource stocks as well as associated institutions, organizations and businesses responsible for designing, delivering and implementing adaptation measures, which are sensitive to climate risks or integral in their management have been assessed	0	1

(continued)

Table 1 (continued)

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Assessment of the transportation system in relation to climate change issues	The current nature or status of traffic and transporting system and infrastructure that are sensitive to climate risks or integral in their management have been acknowledged, or are planned to be assessed	The current nature or status of traffic and transporting system and infrastructure and associated institutions, organizations and businesses responsible for designing, delivering and implementing action response under transport policies, which are sensitive to climate risks or integral in their management have been assessed	0	0
Assessment of water and sanitation situation in relation to climate condition issues	The current nature or status of water and sanitation system and infrastructure that are sensitive to climate risks or integral in their management have been acknowledged, or are planned to be assessed	The current nature or status of water and sanitation system and infrastructure and associated institutions, organizations and businesses responsible for designing, delivering and implementing action response under water and sanitation, which are sensitive to climate risks or integral in their management have been assessed	0	0
Assessment of energy demand and supply	The current nature of demand and supply of energy in various form, which is sensitive to climate risks or integral in their management have been acknowledged, or are planned to be assessed	The current nature demand and supply of energy in various form and associated institutions, organizations and businesses responsible for designing, delivering and implementing action response under clean energy, which are sensitive to climate risks or integral in their management, have been assessed	0	0

(continued)

Table 1 (continued)

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Assessment of land use change in relation to climate change	The current nature or status of land use which are sensitive to climate risks or integral in their management have been acknowledged, or are planned to be assessed	The current nature or statuses of land use which are sensitive to climate risks or integral in their management have been assessed	0	0
Assessment of the consequence of the changing climate on natural and protected area	The current nature or status of natural resource stocks and environmental services that are sensitive to climate risks or integral in their management have been acknowledged, or are planned to be assessed	The existing nature or status of natural resource stocks and environmental services and associated institutions, organizations and businesses responsible for designing, delivering and implementing adaptation measures on natural and protected area, which are sensitive to climate risks or integral in their management have been assessed	0	0
Cost estimation of the physical asset disaster	The cost estimation climate sensitive physical assets or damaged during the disaster have been identified or are planned to assessed	Method of cost estimation of climate sensitive physical assets or damaged physical assets has been assessed in terms of historical trends, current variability and projected future changes	0	0
Cost estimation for GHG emission reduction	The relevant cost estimation for GHG emission reduction has been identified, or are planned to be assessed	Method of cost estimation for GHG emission has been assessed in terms of historical trends, current variability and projected future changes	0	0

(continued)

Table 1 (continued)

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Assessment of the organization and political support to have the capacity to act on climate change issues	Addressed the issues by local body and political support but not explained further	Identified various stakeholder and respective roles and there involvements while preparing various policies	0	0
Engagement of relevant stakeholders	There has been interaction with stakeholders during the production of the adaptation strategy, or will be during the adaptation process	Stakeholder engagement is central to the adaptation process	0	0
Definition of roles and responsibilities	Roles and responsibilities for different adaptation measures have been acknowledged or will be considered	Roles and responsibilities for different adaptation measures have been assigned	0	0
Exploitation of synergies with other climate change policies	Synergies with other policies and programs have been or will be recognized	Integration with other policies and programs has been or will be achieved	0	0
Action				
Disaster-resistant land use and building code	Existing spatial plan and development institution are planning to encourage disaster-resistant land use and building code	Existing spatial plan and development institution have adapted disaster-resistant land use and building code	0	0

(continued)

Table 1 (continued)

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Conservation of parks, forest, natural and protected area	Existing spatial plan and development institution are planning to encourage and integrating conservation of eco-region within the space that is sensitive to climate change	Existing spatial plan and development institution are adapting and integrating conservation of eco-region areas within the space that is sensitive to climate change	0	0
Infill development and reuse of remediated brown field sites	Existing spatial plan and development institution are planning to encourage Infill development and reuse of remediated brown field sites	Existing spatial plan and various development institutions are adapting and using brown field sites for new development	1	1
Green building and green infrastructure standards	Existing spatial plan and various development institutions are planning to encourage policies or guidelines to integrate green building and green infrastructure	Existing spatial plan and development institution are adapting policies and guidelines to integrate green building and green infrastructure	0	0
Pedestrian and bicycle-friendly, transit-oriented community design	A range of policies and action plans to include and encourage public transport and pedestrian facilities to the region	A range of policies and action plans to include like public transport and pedestrian facilities to the region have been implemented	0	0
Multimodal transportation strategies	A current status of transport system and range of policies like multimode transport system and transport oriented development have been planned to be considered or identified	A current status of transport system and range of policies like multimode transport system and transport oriented development have been developed or planned to developed	1	0

(continued)

Table 1 (continued)

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Climate proofing of transport infrastructure	Polices like climate proofing or sensitivity to transport infrastructure have been acknowledged or are planned to be assessed	Policies like climate proofing or sensitivity to transport infrastructure have been assessed	0	0
Renewable energy and solar energy	Alternative options to conventional energy like renewal or solar energy are planned to be considered or to identify in the spatial plan	Alternative options to conventional energy like renewal or solar energy have been planned or identified in the spatial plan	2	2
Energy efficiency and energy stars	A range of policies and technological instruments are planned, considered or acknowledged to increase the energy efficiency	A range of policies and technological instruments are considered and acknowledged to increase the energy efficiency	1	1
Waste management and GHG mitigation technologies	Existing infrastructure for waste management and GHG mitigation technologies that are sensitive to climate risks or integral in their management have been acknowledged or are planned to be assessed	Existing infrastructure for waste management and GHG mitigation technologies that are sensitive to climate risks or integral in their management have been assessed	1	1
Waste water control and treatment	Existing infrastructures for water control and treatment which are sensitive to climate risks or integral in their management have been acknowledged or have been planned to be assessed	Existing infrastructure for water control and treatment which are sensitive to climate risks or integral in their management have been assessed	1	1

(continued)

Table 1 (continued)

Criteria	Score 1	Score 2	SPP of Republic of Srpska	SPP of Republic of Serbia
Financial/budget commitment	Existing stocks and flows of financial resources and associated institutions, organizations and businesses responsible for designing, delivering and implementing spatial plan and climate change response have been acknowledged, or are planned to be assessed	Existing stocks and flows of financial resources and associated institutions, organizations and businesses responsible for designing, delivering and implementing spatial plan and climate change response, which are sensitive to climate risks or which can be used to manage climate risks have been assessed	0	0
Identify role and responsibility among sectors and stakeholders	Roles and responsibilities among various sectors and stakeholders for spatial plans have been acknowledged or will be considered	Roles and responsibilities among various sectors and stakeholders for spatial plans have been assigned	0	0
Public awareness and education about the climate change issues	The climate change issues, impacts and responses under spatial plan have been or will be communicated clearly to the concerned community	A communication strategy has been established, placing the strategy within broader dissemination and outreach activities (e.g., websites, workshops)	0	0

development without paying attention to detailed explanations and the ways of their adaptation. And lastly, by limiting the level of the activities as answers to the existing climate changes, the result is insufficient representation of the previous two criteria, as well as systematic approach toward the issue through a procedure of plan creation. Within the "Action" component, the mentioned plans contain only the criteria that refer to directives for spatial development through revitalisation and reutilisation of the brownfield locations, renewable energy resources and solar energy, energetic efficiency, waste management and technologies of GHG emission reduction etc. The aforementioned directives are indirectly related to climate changes, while those that are directly connected, such as an identification of responsibility and jurisdiction of the specific sectors and stakeholders, planning of financial resources and institutions for realisation and implementation of the spatial plan and their response to climate changes, have been absent from the Plans.

6 Conclusion

This paper covers an analysis of the adopted nationally planned documents of the Republic of Srpska and the Republic of Serbia. In the course of creating its analytical-documentational basis, the research and the thematic bulletin on the climate changes have also been created; however, a more detailed representation of this topic was lacking in its very synthesis. The authors of this paper point out that, in the course of the plan preparation, it is necessary to do more detailed research and analyses on this issue, as well as to display a more comprehensive representation in the planned document itself.

A recent practice of making spatial plans in the Republic of Srpska and the Republic of Serbia has not paid sufficient attention to the climate change issue in their documents. The issues related to climate changes, in the process of creating the spatial planning, demand significant changes. It is necessary to perform a more detailed insight into the climate change issues and the global warming, with clearly stressed consequences to biophysical, social and economic concept of spatial planning. Furthermore, it is necessary to complete the information concerning gas emission with the greenhouse effect, to complete the information concerning their future tendencies for the planned period, and to identify the spaces especially sensitive to climate changes (or extreme climate conditions) etc. as well.

This paper represents the first step toward identification of disadvantages of the previous planning policies, where it lacked the issue of climate changes, to a great degree, and what is more important, the issue of changes that may be caused by spatial climate changes. Considering the aforementioned scenarios of the climate changes in this century, during the following decades, even less favourable effects may be expected on food and energy production, water supplies, biodiversity and human health (in the whole region of Southeast Europe). Inherently, the justification as well as applicability of specific planned solutions will be questioned, if the climate change issue is not integrated into the spatial planning procedure.

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Bibliography

Amendments to the Spatial Plan of the Republic of Srpska by 2025 (2013) PI "New planning office of Republic of Srpska". Ministry of Physical Planning, Construction and Ecology of the Republic of Srpska

Anisuzzaman M, Jennings P (2012) A framework for mainstreaming climate change adaptation within local government operations. Int J Clim Change: Impacts & Responses 3(3):31–46

Biesbroek GR, Swart RJ, Carter TR, Cowan C, Henrichs T, Mela H, Morecroft MD, Rey D (2010) Europe adapts to climate change: comparing adaptation strategies. Glob Environ Change 20:440–450

Brooks N, Anderson S, Ayers J, Burton I, Tellam I (2011) Tracking adaptation and measuring development. In: IIED Climate Change Working Paper Series. IIED, London

Bulkeley H (2006) A changing climate for spatial planning. Plann Theor Pract 7(2):203–214

Campbell H (2006) Is the issue of climate change too big for spatial planning? Plann Theor Pract 7(2):201–203

Crane R, Landis J (2010) Introduction to the special issue: planning for climate change: assessing progress and challenges. J Am Plann Assoc 76(4):389–401

de Bruin K, Dellink RB, Ruijs A, Bolwidt L, van Buuren A, Graveland J, Groot RS, Kuikman PJ, Reinhard S, Roetter RP, Tassone VC, Verhagen A, Ierland EC (2009) Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. Clim Change 95:23–45

Djurdjevic V, Trbić G, Vujadinovic M (2013) Development of climate models in Bosnia and Herzegovina, Second National Report on Climate Change of Bosnia and Herzegovina under the UN Framework Convention on Climate Change-UNFCCC

Ebi KL, Burton I (2008) Identifying practical adaptation options: an approach to address climate change-related health risks. Environ Sci Policy 11:359–369

Füssel HM (2007) Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustain Sci 2:265–275

Klein RJ, Eriksen SE, Næss LO, Hammill A, Tanner TM, Robledo C et al (2007) Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance. Clim Change 84(1):23–44

Kumar P, Geneletti D (2015) How are climate change concerns addressed by spatial plans? An evaluation framework and an application to Indian cities. Land use Policy 42:210–226

Knieling J, Klindworth K (2016) Climate adaptation governance in cities and regions: framework conditions, theoretical concepts and research questions. In Climate adaptation governance in cities and regions—theoretical fundamentals and practical evidence, pp 1–19

Lim B, Spanger-Siegfried E, Burton I, Malone E, Huq S (2005) Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge University Press, Cambridge

Moser SC, Luers AL (2008) Managing climate risks in California: the need to engage resource managers for successful adaptation to change. Clim Change 87:309–322

Preston BL, Westaway RM, Yuen EJ (2011) Climate adaptation planning in practice: an evaluation of adaptation plans from three developed nations. Mitig Adapt Strat Glob Change 16:407–438

Rosenzweig C, Major DC, Demong K, Stanton C, Horton R, Stults M (2007) Managing climate change risks in New York city's water system: assessment and adaptation planning. Mitig Adapt Strat Glob Change 12:1391–1409

Smit B, Burton I, Klein RJT, Street R (1999) The science of adaptation: a framework for assessment. Mitig Adapt Strat Glob Change 4:199–213

Spatial Plan of the Republic of Serbia from 2010 to 2020 (Official Gazette of RS, no. 88/10)

Trbić G, Bajic D, Djurdjevic V, Ducic V, Cupac R, Markez Đ, Vukmir G, Dekic R, Popov T (2018) Limits to adaptation on climate change in Bosnia and Hercegovina: insights and experiences. In Filho WL, Nalau J (eds) Climate change management—limits to climate change adaptation. Hamburg, Germany. Springer, pp 245–259. https://doi.org/10.1007/978-3-319-64599-5 ISBN 978-3-319-64598-8

Urwin K, Jordan A (2008) Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance. Glob Environ Change 18:180–191

Wilson E (2006) Adapting to climate change at the local level: the spatial planning response. Local Environ 11:609–625

Climate Change Impact on River Discharges in Bosnia and Herzegovina: A Case Study of the Lower Vrbas River Basin

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Abstract The paper analyses the impact of recent climate change on river discharges in Bosnia and Herzegovina. Data on mean monthly precipitation, temperature and discharges from the Banjaluka meteorological station and from the Delibašino Selo (Banjaluka) hydrological station during the 1961–2016 periods were used for calculations of annual and seasonal trends in the Lower Vrbas River basin (which was chosen for the case study). The nonparametric Mann-Kendall test and the Sen's method were used to assess the trend magnitude and its statistical significance, whereas the Pearson correlation index was chosen to detect the connections between climatic and river discharge data series. Given the results, a significant warming tendency was present throughout the year. Annual temperature increased 0.46 °C per decade. Unlike temperature, trends in annual and seasonal precipitation were mixed in sign, but were all insignificant. During the observed period, river discharges displayed a significant negative correlation with temperatures throughout the year (insignificant only in winter), whereas links with precipitation were significant and positive. As a result of the determined climate variability, annual river discharges showed a significant downward trend in the range of -8.74 m^3/s per decade. Negative discharge trends were detected in all seasons, but were most prominent in winter and spring. The observed changes in river discharges were strongly related to the large-scale atmospheric circulation patterns over the Northern Hemisphere: the Artic Oscillation pattern, the East-Atlantic pattern, the North Atlantic Oscillation and the East Atlantic-West Russia pattern. A significant warming of the climate system, combined

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with the downward discharge trends throughout the year and precipitation decrease in summer, will lead to decreased water availability over the Lower Vrbas River basin in the future. Given the stated, adaptation towards the observed and projected climate change will be necessary in all key sectors in Bosnia and Herzegovina such as agriculture, energetics (hydropower) and tourism. The adaptation and mitigation options aimed to increase their resilience were considered.

Keywords River discharges · Temperature · Precipitation · Trend
Climate change · Northern hemisphere teleconnection patterns
Adaptation options · Vrbas river basin (Bosnia and Herzegovina)

1 Introduction

Over the past several decades, numerous studies all over the world have analyzed river discharge variability and its relations to the recent climate change (Bai et al. 2014; Castino et al. 2017; Li et al. 2016; Thodsen 2007; Szolgayova et al. 2014; Xu and Luo 2015). Climate change and human activities are two major drivers of hydrological regime modifications. The hydrological regime is very vulnerable to climatic variations, particularly precipitation and temperature. Recent climate change has already affected the global hydrological cycle. These effects have manifested in changing the seasonal river flows and increasing the frequency of occurrence of floods and droughts (but also in their severity) in some regions (EEA 2017). The combined effects of increasing water temperatures in rivers and lakes (caused by a global warming) and changes in river flow regimes would have a great consequence on freshwater ecosystems (EEA 2017).

Global scale studies on stream flows found a significant upward trend in discharges (along with an increase in precipitation) in many parts of the USA, southeastern South America, eastern Russia, Canada and northern Europe (Dai et al. 2009; Stahl et al. 2010). A decreasing discharge trend was detected over Southern and Eastern Europe, South and East Asia, eastern Australia, northern South America and western Canada and the USA (IPCC 2014). In Europe, river discharges decreased over the southern and eastern parts of the continent, whereas a positive trend was found for some rivers discharging into the North Sea and Eastern Atlantic (Stahl et al. 2010). In general, river discharges in Europe have increased in winter season since the 1960s, whereas a downward tendency was found in summer (EEA 2017). Previous studies carried out in the Southeast Europe region have already determined that significant changes in river discharges occurred in some areas. A significant negative trend in annual and seasonal discharges was detected over Serbia (in all seasons except autumn) (Kovačević-Majkić and Urošev 2014). A prominent decrease in mean daily discharges was found at majority of rivers in Slovenia (Ulaga et al. 2008). In Croatia, an upward tendency was present in autumn and winter seasons, whereas discharges decreased in summer (Čanjevac and Orešić 2015).

A long-term stream flow analysis at basin scale is necessary for an efficient water resource management (Croitoru and Minea 2014). Given that changes in climate strongly reflect the river discharges variability, this kind of analysis should be preceded by the analysis of changes in precipitation and temperatures.

The global scale analysis of land and ocean temperatures showed a consistent warming trend present all over the world in the last quarter of the 20th century and at the beginning of the 21st century (Foster and Rahmstorf 2011). On the other hand, the global scale studies found less spatially and temporally coherent patterns of change in mean and extreme precipitation (Donat et al. 2013). In most regions of the world, the small-scale and mixed in sign trends that have lower level of statistical significance were detected (Donat et al. 2013). During this period, temperature increased significantly in most parts of Europe, including the part of the continent where Bosnia and Herzegovina is located (Kovats et al. 2014). The positive trends in annual temperatures over Bosnia and Herzegovina were in the range of 0.2–0.5 °C per decade (Trbić et al. 2017). It should be noted that the Vrbas River basin is one of Bosnia and Herzegovina regions with most pronounced warming tendency—for instance, in the Banjaluka and Bugojno areas annual temperature increased 0.47 and 0.40 °C per decade, respectively (Trbić et al. 2017). Although warming is apparent in all seasons, it was most prominent in summer season, and then in winter and spring (Trbić et al. 2017). Similar warming patterns were detected in other regions of Southeast Europe (Bajat et al. 2015; Branković et al. 2013; de Luis et al. 2014; Dumitrescu et al. 2015; Burić et al. 2014). In contrast to the temperature, annual and seasonal precipitation in Bosnia and Herzegovina and in other parts of Southeast Europe region displayed spatially and temporally (seasonally) very heterogeneous patterns of change—i.e. the occurrence of trends mixed in sign (Popov et al. 2017; Luković et al. 2014; Gajić-Čapka et al. 2015; de Luis et al. 2014; Dumitrescu et al. 2015; Burić et al. 2015). For instance, in Serbia and Montenegro precipitation decreased in winter and spring, whereas the increasing tendency was detected in autumn (Luković et al. 2014; Burić et al. 2015). The upward trend in autumn was also found in Croatia, whereas precipitation decreased over this area in summer season (Gajić-Čapka et al. 2015). However, the majority of determined trends in both mean and extreme precipitation were weak and mostly insignificant over the entire Southeast Europe region. The observed trends in temperature and precipitation had a great impact on river discharges.

Although some earlier studies (Trbić et al. 2017; Popov et al. 2017) had already addressed the issues of climate change in Bosnia and Herzegovina, the effects of the observed trends on river discharges were poorly documented. In order to overcome the existing gaps in knowledge, the main goal of this study is to analyze the changes in river discharges over the Lower Vrbas River basin (Bosnia and Herzegovina) in the 1961–2016 periods. The aim was to investigate the impact of changes in climate (primarily in temperatures and precipitation) on river discharges over this area. In order to evaluate the observed trends, seasonal and annual climatic and hydrological data were correlated with dominant large-scale atmospheric circulation patterns over the Northern Hemisphere.

2 Data and Methods

2.1 Study Area

The Lower Vrbas River basin was set as the study area for the assessment of changes in river discharges in Bosnia and Herzegovina conditioned by the changing climate.

The Vrbas River basin is located at 43° 49′–45° 6′N and 16° 48′–17° 50′E. It covers an area of approximately 6288 km^2 or 12.3% of Bosnia and Herzegovina territory (Fig. 1). It is ranked as the fourth largest catchment in the country. The Vrbas River originates in the Dinaric Mountains at 1715 m a.s.l. (the southeastern part of the basin) and flows northwards to the mouth of the Sava River at 86 m. The mean basin elevation is 761 m, whereas the average slope value is approximately 14°. The Vrbas River flow is characterized by the pluvio-nival regime. The climate varies from an alpine climate in the upper part of the basin to a humid continental climate in the lower part. The climate of the Lower Vrbas River basin is characterized by cold winters and warm summers. Maximum and minimum precipitation occurs in summer and winter seasons, respectively.

The Vrbas River basin encompasses 28 municipalities with approximately 460.000 inhabitants (COWI 2012). It is the main water resource and a significant developing factor for the key economic sectors in the largest cities located in the basin—Banjaluka, Bugojno, Jajce, Laktaši, etc.

2.2 Data and Methods

The Delibašino Selo hydrological station located in lower part of the Vrbas River basin is selected as the case study area given that it is the only station within the basin with the continuous long-term measurements. The analysis of seasonal and annual trends in temperatures, precipitation and discharges was carried out for the 1961–2016 periods. Climatological and hydrological datasets containing mean monthly temperatures, precipitation and discharges collected at the Banjaluka meteorological station and the Delibašino Selo hydrological station were used for the analysis. Data were provided by the Republic Hydrometeorological Service of the Republic of Srpska. During the observed period, stations did not change their locations and there were no interruptions in measurements. The time series of annual and seasonal values of variables were subjected to the nonparametric Mann-Kendall test and the nonparametric Sen's estimator of slope. The Mann-Kendall trend test is a widely used nonparametric instrument to detect a trend in a data series, whereas the Sen's nonparametric estimator is used to determine trend magnitude (Salmi et al. 2002). The statistical significance of the observed trends was defined at the 99.9% (p value ≤ 0.001), 99% ($0.001 < p$ value ≤ 0.01) and 95% ($0.01 < p$ value ≤ 0.05) level.

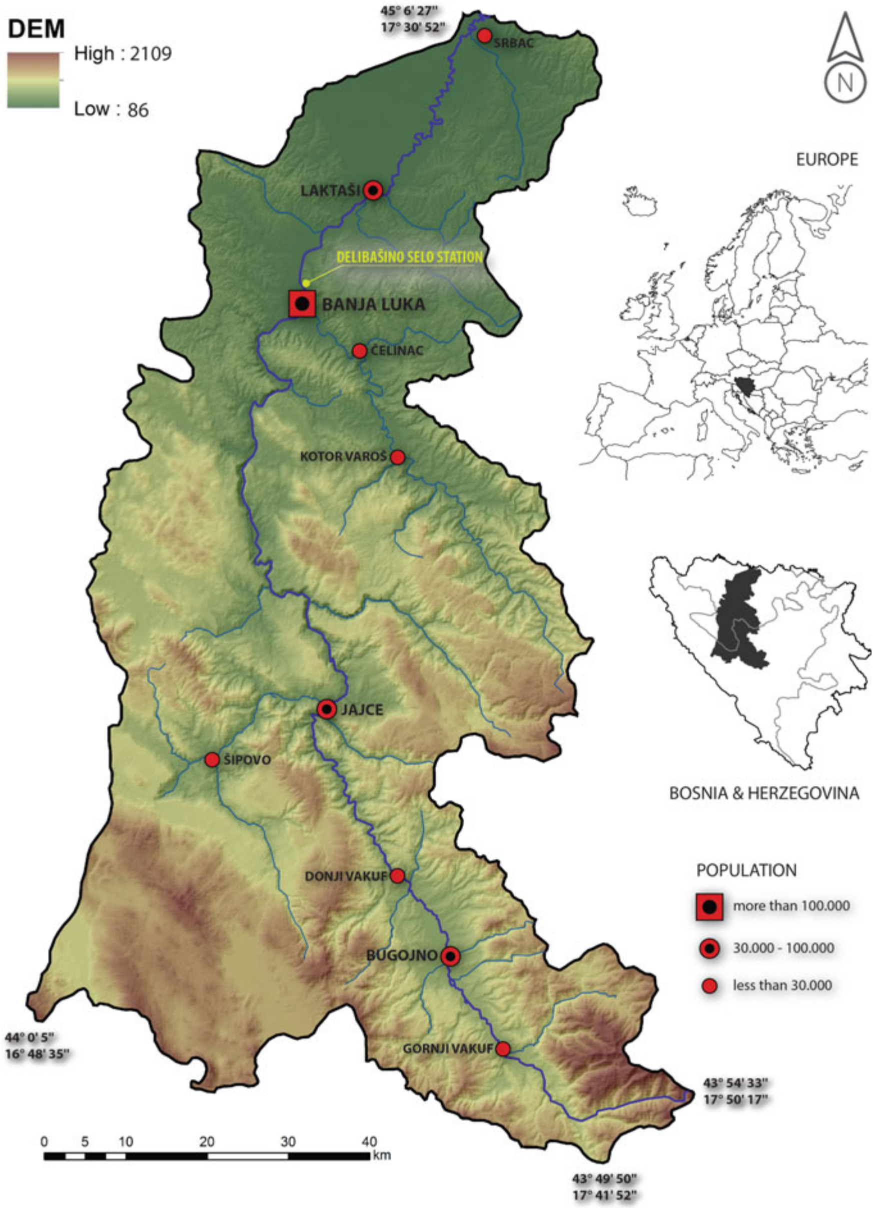

Fig. 1 The geographical location of the study area

In order to evaluate the observed changes in river discharges, the relations with the climatic variability (i.e. changes in temperature and precipitation) and the dominant Northern Hemisphere teleconnection patterns were investigated. The three primary modes of atmospheric circulation variability over the North Atlantic—the North Atlantic Oscillation (NAO), the East-Atlantic (EA) pattern and the East Atlantic/West Russia (EAWR) pattern—and the Arctic Oscillation (AO) were analyzed. Data on these large-scale atmospheric circulation indices were collected from the NOAA National Weather Service Climate Prediction Center (NOAA NWS CPC 2017). The Pearson correlation coefficients were calculated for quantification of the relationships between annual and seasonal river discharges, climate variability and the large-scale circulation patterns. The statistical significance of the determined correlations was defined at the 99% (p value ≤ 0.01) and 95% ($0.01 < p$ value ≤ 0.05) levels. All calculations were made in XLSTAT Version 2014.5.03.

3 Results and Discussion

3.1 Climate Change

The average values of annual and seasonal temperatures and precipitation for Banjaluka are given in Table 1. The trend analysis results are shown in Table 1 and Fig. 2. Given the results, the warming of the climate system was present over the Lower Vrbas River basin during the observed 1961–2016 periods. The significant positive trends in mean temperatures were detected at the Banjaluka meteorological station throughout the year. The most prominent upward tendency was detected in summer and winter seasons, during which time temperature increased 0.6 and 0.5 °C per decade, respectively. The annual temperature also increased significantly (0.46 °C per decade). In contrast to the significant changes in temperature, the incoherent patterns of change (i.e. occurrence of trends mixed in sign) were found for mean precipitation. The weak and insignificant positive trends were found in all seasons (ranging from 0.48 mm per decade in spring season to 7.00 mm per decade in autumn) except in summer, when a much more prominent negative trend was detected (−14.00 mm per decade). A pronounced decrease in summer precipitation caused the overall negative trend in annual precipitation (−7.80 mm per decade). However, all of the estimated precipitation trends during the past 56 years were statistically insignificant.

The observed changes in mean temperatures and precipitation have a strong impact on changes in river discharges that are discussed in the following section.

3.2 Changes in River Discharges

The trend analysis of the Vrbas River discharges at the Delibašino Selo hydrological station revealed that a decreasing tendency was present throughout the year (Table 2 and Fig. 3). The estimated negative trend values were significant in all seasons, except in autumn. A most prominent reduction in river discharges was recorded in

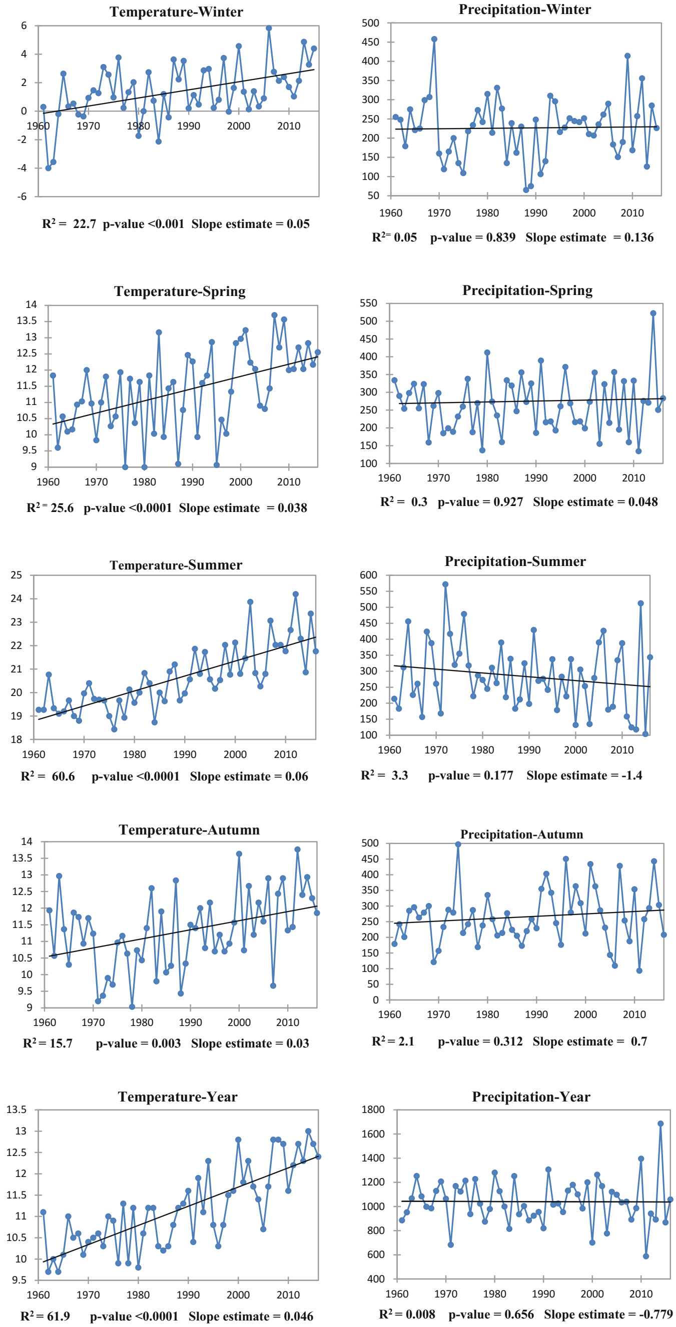

Fig. 2 Linear trend in annual and seasonal temperatures and precipitation in Banjaluka in 1961–2016

Table 1 Annual and seasonal mean temperatures (°C) and precipitation (mm) in Banjaluka and their decadal trends in the 1961–2016 periods

Season	Temperature		Precipitation	
	Average value	Trend slope	Average value	Trend slope
Winter	1.38	0.50[b]	226.5	1.36
Spring	11.37	0.38[a]	266.1	0.48
Summer	20.61	0.60[a]	284.5	−14.00
Autumn	11.30	0.30[c]	266.0	7.00
Year	11.17	0.46[a]	1040.4	−7.80

Note Statistical significance at the 99.9% (a), 99% (b) and 95% (c) level

Table 2 Annual and seasonal mean river discharges (m^3/s) at the Delibašino Selo hydrological station and their decadal trends in the 1961–2016 periods

Season	Average discharge	Trend slope
Winter	112.90	−13.67[b]
Spring	146.79	−11.38[b]
Summer	70.83	−5.69[b]
Autumn	67.88	−3.94
Year	99.46	−8.74[a]

Note Statistical significance at the 99.9% (a), 99% (b) and 95% (c) level

winter and spring seasons—in the range of −13.67 and −11.38 m^3/s per decade, respectively. Somewhat lower and insignificant decrease was observed in autumn season (−3.94 m^3/s per decade). Annually, river discharges decreased significantly by −8.74 m^3/s per decade.

3.3 Relationship Between the Observed Trends in River Discharges and Climate Change

Given that river discharges are strongly dictated by precipitation and temperatures, climate change significantly affects their regime. The annual discharges displayed a significant positive correlation with precipitation (+0.556, $p < 0.01$), whereas relationship with temperature was also significant, but negative (−0.643, $p < 0.01$). A statistically significant ($p < 0.01$) positive correlation between river discharges and precipitation is present throughout the year—the determined correlation coefficients were in the range of 0.544–0.619 (Table 3). The relationship was somewhat stronger in summer and winter seasons. The increasing temperatures were reflected in a downward tendency of the river discharges, as verified by the Pearson correlations for annual, summer, spring and autumn series. A significant ($p < 0.01$) negative

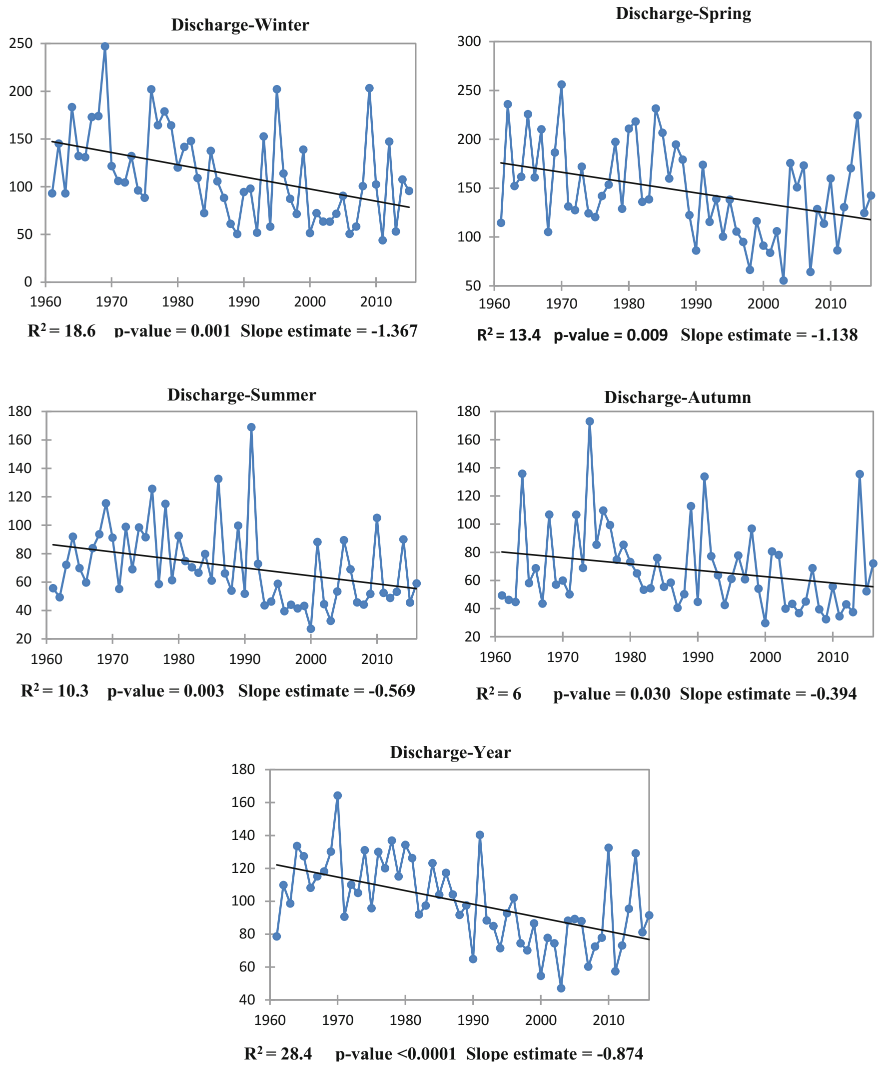

Fig. 3 Linear trend in annual and seasonal river discharges at the Delibašino Selo hydrological station in 1961–2016

correlation was found for temperatures in all seasons (except in winter, when determined links were insignificant). As expected, the temperature had a stronger impact on river discharges in the warmer part of the year. The highest correlation coefficients were calculated for summer and spring seasons (−0.529 and −0.515, respectively).

Table 3 Pearson correlation coefficients between annual and seasonal discharges and temperatures and precipitation in the Lower Vrbas River basin in the 1961–2016 periods

	Winter	Spring	Summer	Autumn	Year
Temperature	−0.216	**−0.515**	**−0.529**	*−0.321*	**−0.643**
Precipitation	**0.572**	**0.544**	**0.619**	**0.565**	**0.556**

Note Statistically significant at $p < 0.01$ (bold) and $p < 0.05$ (italic)

3.4 Relationship Between the Observed Trends in River Discharges and the Dominant Northern Hemisphere Teleconnection Patterns

The positive phases of the NAO, the EAWR pattern and the EA pattern are associated with drier conditions and below-average precipitation across the southern and central parts of Europe (NOAA CPC 2017). Given the stated, relationships between these teleconnection patterns and river discharges over the study area are negative (a negative correlation was also found with precipitation, whereas the links with temperature were positive). Climate variability in Europe is strongly dictated by the NAO, especially during winter season (Hurrell et al. 2003). In this part of the year, during the positive NAO phase, warmer maritime air masses are advected to Europe by stronger-than-average westerlies over the middle latitudes associated with low pressure anomalies over the region of the Icelandic low and anomalously high pressures across the subtropical Atlantic (Rust et al. 2015; Hurrell et al. 2003). This leads to warmer and wetter weather conditions over the northwestern Europe and drier conditions in the Mediterranean region (Ionita 2014; Krichak and Alpert 2005). During winter season, the NAO and EAWR patterns have a significant impact on river discharges over the Lower Vrbas River basin (correlation coefficients in the range of −0.536 and −0.304, respectively) (Table 4). Previous studies found a significant positive correlation between the EA pattern and temperatures throughout the year over the Bosnia and Herzegovina territory and a mainly insignificant negative correlation between the EA pattern and precipitation (Trbić et al. 2017; Popov et al. 2017). A strong and significant negative correlation between the EA pattern and river discharges in the Lower Vrbas River basin was determined in summer and autumn seasons (correlation coefficients in the range of −0.369 and −0.293, respectively).

The Arctic Oscillation (AO) has a major influence on climate in Europe, especially during its negative phase when cool and dry air masses from polar and sub-polar northern regions move towards the Southern and Southeastern Europe, conditioning the temperature cooling and decrease in river discharges and runoff (Mihăilă and Briciu 2015). A significant negative correlation between the AO and river discharges in the Lower Vrbas River basin was detected throughout the year, except in summer season. The strongest relationship was found for winter season (correlation coefficient in the range of −0.649).

Table 4 Pearson correlation coefficients between the dominant Northern Hemisphere teleconnection patterns indices and river discharges in the Lower Vrbas River basin in the 1961–2016 periods

	Winter	Spring	Summer	Autumn	Year
EA	−0.221	−0.204	−0.369[b]	−0.293[c]	−0.424[b]
NAO	−0.536[a]	−0.212	0.176	0.061	−0.199
EAWR	−0.304[c]	−0.186	0.211	0.116	0.026
AO	−0.649[a]	−0.363[b]	0.126	−0.367[b]	−0.449[b]

Note Statistical significance at the 99.9% (a), 99% (b) and 95% (c) level

4 Conclusion

The river discharge regime in the Lower Vrbas River basin is strongly dictated by the climate variability. Results of the correlation analysis showed that changes in climatic variables (primarily temperature and precipitation) had a strong impact on river discharges. During the observed 1961–2016 periods, the Lower Vrbas River basin was characterized by significant positive trends in annual and seasonal temperatures, whereas precipitation trends were mixed in sign and insignificant. These changes in climate have strongly affected the river discharges over this area. The warming trend over the study area and the decreasing summer precipitation conditioned a prominent decrease in river discharges at the Delibašino Selo hydrological station. Although a downward trend was present throughout the year, the most prominent decrease was detected in winter and spring seasons. The observed changes in river discharges were also related to the Northern Hemisphere teleconnection patterns. A significant correlation between the AO and river discharges was detected in all seasons (except in summer). Moreover, winter and summer discharges displayed a significant negative correlation with the NAO and the EA patterns, respectively.

Water shortages will have wide socioeconomic and natural impacts. The observed downward tendency of river discharges will certainly have numerous and diverse negative effects on key economic sectors such as agriculture, hydropower and tourism. Given that, the implementation of adaptation strategy for the Lower Vrbas River basin will be of great relevance.

Higher temperatures and increased precipitation variability would lead to the increasing demand for irrigations in the Lower Vrbas River basin. Therefore, improvement in the irrigation system efficiency is crucial because the agriculture sector is one of the most important economic activities over this area. The construction of complex hydro melioration systems will certainly be one of the key adaptation mechanisms in this sector. In addition, the watershed-based planning approach should be set as a key strategic management issue. Moreover, farmers will need to acquire new knowledge and to implement new scientific and technological solutions in order to adapt their production to the altered climate conditions (Radusin et al. 2016).

Hydropower production is also highly dependent on the changing climate. Climate change led to the downward trends in annual and seasonal river discharges and increased stream flow variability (i.e. higher frequency of occurrence of floods and droughts). Changes in these hydrological features could affect hydropower production (potentially leading to a significant decrease). The establishment of run-of-river power plants, which are more susceptible to the increased flow variability than plants at dams, could be one of the adaptation measures in this sector (IPCC 2014). On the other hand, creation of new artificial accumulations would also help to increase energy production.

The tourism industry is also strongly affected by climate change and adaptations will be necessary in order to alleviate the negative impacts. Water shortages, heat waves, droughts, reduction in snow cover and other consequences of climate change will have negative effects on tourism activities in the Lower Vrbas River basin such as river tourism, ecotourism, adventure tourism, fishing tourism, winter tourism, etc.

Given that river discharges are projected to decrease in the future over the Southern and Southeastern Europe (EEA 2017), further research should focus on study of river discharges projections for the Lower Vrbas River basin by the end of the 21st century. Future research should also focus on more detailed impact assessment studies, i.e. the analysis of climate change effects on sectors such as energetics, water management, agriculture and tourism and adaptation and mitigation options.

References

Bai P, Liu W, Guo M (2014) Impacts of climate variability and human activities on decrease in streamflow in the Qinhe River, China. Theor Appl Climatol 117(1–2):293–301

Bajat B, Blagojević D, Kilibarda M, Luković J, Tošić I (2015) Spatial analysis of the temperature trends in Serbia during the period 1961–2010. Theor Appl Climatol 121(1):289–301

Branković Č, Cindrić K, Gajić-Čapka M, Güttler I, Pandžić K, Patarčić M, Srnec L, Tomašević I, Vučetić V, Zaninović K (2013) Sixth national communication of the republic of croatia under the united nation framework convention on the climate change (UNFCCC) Selected Sections in Chapters: 7. Climate change impacts and adaptation measures 8. Resarch, systematic observation and monitoring. Meteorological and hydrological service of Croatia, Zagreb

Burić D, Luković J, Bajat B, Kilibarda M, Živković N (2015) Recent trends in daily rainfall extremes over Montenegro (1951–2010). Nat Hazards Earth Syst Sci 15(9):2069–2077

Burić D, Luković J, Ducić V, Dragojlović J, Doderović M (2014) Recent trends in daily temperature extremes over southern Montenegro (1951–2010). Nat Hazards Earth Syst Sci 14:67–72

Čanjevac I, Orešić D (2015) Contemporary changes of mean annual and seasonal river discharges in Croatia. Hrvatski geografski glasnik 77(1):7–27

Castino F, Bookhagen B, Strecker MR (2017) Oscillations and trends of river discharge in the southern Central Andes and linkages with climate variability. J Hydrol 555:108–124

COWI (2012) Update of the water resources management basis for the Vrbas River Basin, project report for the World Bank. COWI, Norway

Croitoru AE, Minea I (2014) The impact of climate changes on rivers discharge in Eastern Romania. Theor Appl Climatol 120(3–4):563–573

Dai A, Qian T, Trenberth KE (2009) Changes in continental freshwater discharge from 1948 to 2004. J Clim 22(10):2773–2792 de Luis M, Čufar K, Saz MA, Longares LA, Ceglar A, Kajfež-Bogataj L (2014) Trends in seasonal precipitation and temperature in Slovenia during 1951–2007. Reg Environ Change 14(5):1801–1810

Donat MG, Alexander LV, Yang H, Durre I, Vose R, Dunn RJH, Willett KM, Aguilar E, Brunet M, Caesar J, Hewitson B, Jack C, Klein Tank AMG, Kruger AC, Marengo J, Peterson TC, Renom M, Oria Rojas C, Rusticucci M, Salinger J, Elrayah AS, Sekele SS, Srivastava AK, Trewin B, Villarroel C, Vincent LA, Zhai P, Zhang X, Kitching S (2013) Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The Hadex2 dataset. Geophys Res Atmos 118(5):2098–2118

Dumitrescu A, Bojariu R, Birsan MV, Marin L, Manea A (2015) Recent climatic changes in Romania from observational data (1961–2013). Theor Appl Climatol 122(1–2):111–119

EEA (2017) Climate change, impacts and vulnerability in Europe 2016: An indicator-based report. European Enivronment Agency, Copenhagen

Foster G, Rahmstorf S (2011) Global temperature evolution 1979–2010. Environ. Res. Lett. 6044022

Gajić-Čapka M, Cindrić K, Pasarić Z (2015) Trends in precipitation indices in Croatia, 1961–2010. Theor Appl Climatol 121(1–2):167–177

Hurrell JW, Kushnir Y, Ottersen G, Visbeck M (2003) An overview of the North Atlantic oscillation. In: Hurrell JW, Kushnir Y, Ottersen G, Visbeck M (eds) The North Atlantic oscillation: climatic significance and environmental impact. American Geophysical Union, Washington, DC

Ionita M (2014) The impact of the East Atlantic/Western Russia pattern on the hydroclimatology of Europe from mid-winter to late spring. Climate 2(4):296–309

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Kovats RS, Valentini R, Bouwer LM, Georgopoulou E, Jacob D, Martin E, Rounsevell M, Soussana JF (2014) Europe. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (1267–1326). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Krichak SO, Alpert P (2005) Decadal trends in the East Atlantic-West Russia pattern and mediterranean precipitation. Int J Climatol 25(2):183–192

Li Z, Huang G, Wang X, Han J, FanY (2016) Impacts of future climate change on river discharge based on hydrological inference: a case study of the Grand River Watershed in Ontario. Canada. Sci Total Environ 548–549:198–210

Luković J, Bajat B, Blagojević D, Kilibarda M (2014) Spatial pattern of rainfall trend in Serbia. Reg Environ Change 14(5):1789–1799

Majkić JK, Urošev M (2014) Trends of mean annual and seasonal discharges of rivers in Serbia. J Geogr Inst Cvijic 64(2):143–160

Mihăilă D, Briciu AE (2015) Climatic teleconnections with influence on some rivers from South-Eastern Europe. Bol Asoc Geogr Esp 69:37–62

NOAA NWS CPC (2017) Northern hemisphere teleconnection patterns. Retrieved on 15 Oct 2017 from: http://www.cpc.ncep.noaa.gov/data/teledoc/telecontents.shtml

Popov T, Gnjato S, Trbić G, Ivanišević M (2017) Trends in extreme daily precipitation indices in Bosnia and Herzegovina. Collection of Papers—Faculty of Geography at the University of Belgrade, vol 65, pp 5–24

Radusin S, Medić V, Cero M, Abdurahmanović I, Avdić S et al (2016) Third national communication and second biennial update report on greenhouse gas emissions of Bosnia and Herzegovina under the United Nations framework convention on climate change. UNDP, Sarajevo

Rust HW, Richling A, Bissolli P, Ulbrich U (2015) Linking teleconnection patterns to European temperature—a multiple linear regression model. Meteorol Z 24(4):411–423

Salmi T, Maatta A, Anttila P, Ruoho-Airola T, Amnell T (2002) Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's Slope estimates—the excel template application MAKESENS. Publications on air quality, No. 31, Finnish Meteorological Institute, Helsinki

Stahl K, Hisdal H, Hannaford J, Tallaksen L, Van Lanen H, Sauquet E, Demuth S, Fendekova M, Jordar J (2010) Streamflow trends in Europe: evidence from a dataset of near-natural catchments. Hydrol Earth Syst Sci 14(12):2367–2382

Szolgayova E, Parajka J, Bloschl G, Bucher C (2014) Long term variability of the Danube River flow and its relation to precipitation and air temperature. J Hydrol 519(Part A):871–880

Thodsen H (2007) The influence of climate change on stream flow in Danish rivers. J Hydrol 333(2–4):226–238

Trbić G, Popov T, Gnjato S (2017) Analysis of air temperature trends in Bosnia and Herzegovina. Geographica Pannonica 21(2):68–84

Ulaga F, Kobold M, Frantar P (2008) Trends of river discharges in Slovenia. IOP Conf Ser: Earth Environ Sci 4(1):012030

Xu H, Luo Y (2015) Climate change and its impacts on river discharge in two climate regions in China. Hydrol Earth Syst Sci 19(11):4609–4618

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Water Body Extraction and Flood Risk Assessment Using Lidar and Open Data

Gordana Jakovljević and Miro Govedarica

Abstract Floods are one of the most serious, common and expensive natural disasters that cause fatalities and considerable economic losses worldwide every year. Climate change has dramatically increased the frequency and the severity of the flood events. In May 2014, 2/3 of Serbia were affected by the floods, more than 400 homes were destroyed while the total economic damage exceeded 1.7 billion euros. This fact causes concern and identifies an urgent need for designing and improving flood mitigation measurements. An important aspect of the flood risk studies deals with the topography of river and floodplain. Digital Elevation Model (DEM) is widely used in order to estimate the flood inundation and associated damages to properties and livelihoods. The resolution and accuracy of a DEM are critical in a flood risk assessment, especially in lowlands area, where the offset of few decimeters in the elevation data has a significant impact on the accuracy of the risk assessment. The accuracy of the publicly available DEMs is relatively low in the level of accuracy required for flood risk assessment. Throughout this paper, the Light Detection and Ranging (LiDAR) was used for water body delineation. Water body extraction from LiDAR data was compared to a publicly available Sentinel-2 satellite image. Also, DEM data were used for flood risk estimations in Vojvodina Province, Republic of Serbia. Flood risk assessment by using the publicly available ASTER SRTM DEM was compared to a flood risk assessment using LiDAR DEM.

Keywords LiDAR · Water body's extraction · Sentinel-2 · DEM

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1 Introduction

Flood is an indudation of the land that is usually dry. Floods are one of the most serious, common and expensive natural disasters that caused fatalities and considerable economic losses worldwide every year. Observed climate trends and future climate projection show increase in high temperature extreme, meteorological drought and heavy precipitation events with variations across Europe, and small or no changes in wind speed extreme (Kovats et al. 2014). Data suggests that extreme wet and dry episodes have increased in recent years in Serbia in both frequency and amplitude (Serbian Floods 2014). Extreme rainfall during April and May 2014 caused extreme floods in part of Serbia. The assessment revealed that the total effects of the disaster in the 24 affected municipalities amounts to EUR 1525 million (Serbian Floods 2014). In September 18, 2007 The European Flood Directive (EFD) endorsed the aims to reduce the adverse consequences on human health, the environment, cultural heritage and economic activity associated with floods in the Community.[1] The EFD required from the Member States to develop: a preliminary flood risk assessment, flood mapping comprising of flood hazard maps and flood risk maps and flood risk management plans. Flood management covers the holistic and continuous assessment, evaluation and reduction of flood hazard and flood risks (European Exchange Circle on Flood Mapping 2007).

Remote sensing, covering a large geographical area at different spatial, spectral and temporal resolution, provides a large amount of data that have been extensively used for flood management.

Optical satellite images are widely used for water body extraction and monitoring changes. Different image classification techniques can be used for water body delineation. For example, Verpoorter et al. (2012) used unsupervised classification for automatic water body delineation from Landsat 7 images, whilst Yang et al. (2017) used water indices for inland water body delineation and obtained an average Overall Accuracy (OA) of 97.2% and an average kappa coefficient of 0.73. Topaloglu et al. (2016) used supervised Supported Vector Machine (OA 82% and Kappa coefficient 0.81) and Maximum Likelihood Classifier (OA 73%; kappa coefficient 0.69) from Sentinel 2 images, while Kaplan and Avdan (2017) proposed combination of water index and object-based classification for river delineation from Sentinel 2 images achieving perfect agreement between extracted water bodies and reference data. However, there are some limitations, temporal resolution and revised time depends on the satellite program, high-resolution images can be very expensive, the area of interest can be covered by clouds and haze.

Beside optical images, Synthetic-Aperture Radar (SAR) images can be employed for water delineation and monitoring changes. A combination of a threshold-based algorithm and texture indicators have been applied in Bolanos et al. (2016) an automated water body extraction from Radarsat-2. Due to its all-weather capabilities, and its image acquisition capacity during day or night or in cloudy conditions, SAR

[1]European Flood directive, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=EN.

imagery offers better alternatives for water mapping than optical imagery (Polat et al. 2015).

Most of the flood risk mapping is based on a conceptual risk approach where Digital Elevation Model (DEM) is used in order to estimate the flood hazard according to the projected water levels (van de Sande et al. 2012) and associated damages to properties and livelihoods. DEM is one of the most important input parameters. DEM resolution and accuracy highly influence on inundation extent, flow velocity, flow depth, and flow patterns (Wedajo 2017) hence, the accuracy and the reliability of flood inundation maps (National Research Council of the National Academies 2009; Smeeckaert et al. 2013a; Brzank et al. 2008; Bodoque et al. 2016; Hofle et al. 2009) especially in lowlands area, where the offset of few decimeters in the elevation data have a significant impact, and urban areas are highly correlated with DEM.

A limitation of an existing topographical dataset is often availability, coverage spatial resolution, and accuracy. Although, publicly available DEMs like ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and SRTM DEM (Shuttle Radar Topography Mission) with 30 and 90 m horizontal resolution can be used for flood risk assessment (Yan et al. 2015) their overestimate land elevation and therefore, underestimate the flood hazard and associated risk (van de Sande et al. 2012).

Airborne light detection and ranging (LiDAR) remote sensing has become a widely-used method that provides high-resolution topographical datasets. LiDAR is an active remote sensing system which operates by emitting laser pulses of light at high frequencies towards the Earth's surface. Every emitted pulse propagates through the atmosphere before hitting a target, where parts of the pulse are reflected, absorbed, and transmitted depending on the characteristics of the illuminated object. A receiver collects the photons which are reflected. The range is computed by the travel time between pulse and return of a signal. LiDAR system is generally mounted on an aircraft and integrated with Global Navigation Satellite System (GNSS) and Inertial Navigation System (INS) systems to determine the location and account for trajectory variability that occurs during the collection process (Turner et al. 2013). The LiDAR data are frequently used for flood modeling (Yan et al. 2015), flood risk mapping (Bodoque et al. 2016; Webster 2010) and surface water body extraction (Smeeckaert et al. 2013a; Brzank et al. 2008; Hofle et al. 2009) but all these subjects are built around the generation of digital terrain models using raw LiDAR point clouds. Flood inundation studies are based on mapping and defining an area covered by water during a flood event (Turner et al. 2013). This is typically done by comparing digital water surface elevation with Digital Terrain Model (DTM) of the bare earth elevation indicating where the water surface elevation is above the land surface (Merwade et al. 2008). Raw LiDAR point clouds include ground and non-ground points. DTM refers to a bare earth surface created through interpolation of ground points while Digital Surface Model (DSM) refers to a model that corresponds to the elevation of the man-made or natural object. DSM is created by interpolation of the entire point cloud. Although a large body of algorithms has been proposed, DTM generation is still challenging especially in urban areas and wooded mountain area. Polat et al. (2015) generated DEM using TIN filtering process in order to obtain only ground points and different interpolation methods. Chen et al. (2012) used the upward-fusion method to generate qualified DTMs in urban areas using airborne Lidar data with the bias in the experimental DTMs were, on average less than 15 cm; while Guan et al. (2014) used cross-section-plane analysis to automatically separate terrain from non-terrain points. For flood hazard modeling important step is the discrimination of land and water areas within the developed point clouds. Some studies have been reported for extracting water areas from LiDAR data. The LiDAR system mostly operates in the near infrared spectrum. The reflection properties of water surfaces for NIR beams are categorized by strong absorption, hence, LiDAR intensity returns are usually lower than the intensity of the land. The point cloud returns for water surface are usually associated with low signal intensity, dropouts and a high relative variation of intensity (Smeeckaert et al. 2013a; Hofle et al. 2009) of course that this depends on the velocity turbulence and depth of the water (Antonarakis et al. 2008). To date, most of the land-cover classification methods work on rasterized digital elevation and intensity models derive from the original point cloud. Schmidt et al. (2012) classified LiDAR data into three classes; water, mudflat and mussel bed by Conditional Random Field (CRF) method. Hofle et al. (2009) used geometrical and intensity information of the airborne LiDAR data for extracting water surfaces by a seeded region-growing segmentation algorithm. The Smeeckaert et al. (2013a) adopted 2D-raster mode supervised classifier for water body extraction. They selected Support vector machine and have focused on three families of features: the height, the local point density and the local shape of 3D point neighborhood. Recent studies showed that object-based analysis offers more robust laser point classification methodology with higher success for classification of land cover and water bodies than pixel based methods. Johansen et al. (2011) used threshold based method for extraction of the wet channel network extraction by integrating LiDAR intensity and elevation data. Antonarakis et al. (2008) proposed supervised object-based land cover classification of elevation and intensity airborne LiDAR data in order to classify land cover and five types of riparian forest. Accuracy indices for water class between 95 and 99%.

Johansen et al. (2010) used object-based image analysis of airborne LiDAR data for mapping riparian condition indicators. Results showed that object-based approach could be used to accurately map the riparian condition indicators ($R^2 = 0.99$ for streambed width, $R^2 = 0.82$ for riparian zone width, $R^2 = 0.89$ for PPC, $R^2 = 0.40$ for bank stability). Zhou (2013) implemented object-based classification of LiDAR height and intensity data for land cover classification. The overall accuracy was 90.7% and overall Kappa statistics equaled 0.87. Used parameters for water extraction are shown in Table 1.

The aims of this study are: (1) to research the utility of a high resolution airborne LiDAR dataset and object-based classification for water surface extraction (2) to compare classification LiDAR results with those from Sentinel 2 multispectral satellite images, (3) to evaluate the accuracy and usability of ASTER GDEM in flood risk assessment in low lying areas.

Table 1 Parameters used for water extraction from LiDAR data

Authors	Method	Used parameters		
Brzank et al. (2008)	Fuzzy logic concept (pixel based)	Height		
		Intensity		
		2D point density		
Johansen et al. (2011)	(Object based)	DTM		
		Terrain slop		
		Fractional cover count to PPC		
Johansen et al. (2010)	Treshold (object based)	DTM		
		Terrain slop		
		Fractional cover count		
		Canopy height model		
Teo and Huang (2016)	Supervised NN classifier	Lidar	Terrain	nDSM
				Roughness
			Lidar feature	Intensity
				Echo ratio
			Texture	Entropy
				Homogeneity
		Spectral image	Spectral feature	MNF
			Spectral feature	NDVI
			Texture	Entropy, Homogeneity
		Object	Spectral feature	Area
			Spectral feature	Length-to-width ratio
Antonarakis et al. (2008)	Threshold (object-based)	Canopy surface		
		Terrain model		
		Vegetation height model		
		Intensity model		
		Identity difference model		

(continued)

Table 1 (continued)

Authors	Method	Used parameters
		Skewness model
		Kurtosis model
		Percentage canopy model
Smeeckaert et al. (2013a)	SVM (pixel based)	Height
		Local point density
		Local shape of the 3D point neighborhood
Hooshyar et al. (2015)	Thresholds (pixel based)	Intensity
		Elevation

2 Materials

2.1 Study Area

The study area is located at the confluence of the river Bosut and Sava, Municipality of Sremska Mitrovica, Republic of Serbia. The study area is part of Pannonian basin with a dominant flat topography, mostly covered by agricultural fields and built up areas. River Bosut is a "flatland river" with the height difference between the source and confluence of only 15 m. Such a small slope causes great river meandering and frequent natural pollution (transparency, mud) (Wikipedia 2018). Bosut pumping station is located at the confluence of Bosut and Sava. When the water level of Sava is higher than Bosut, water needs to be pumped back to the Sava, therefore Bosut pumping station has an influence on Sava water level and, during the floods in May 2014 it had a significant role in the flood protection of Sremska Mitrovica and its surroundings (Fig. 1).

2.2 Dataset

2.2.1 Free Data

Sentinel-2 Image

Sentinel-2 is a European wide-swath, high-resolution, multi-spectral optical satellite system which provides observations over global terrestrial surfaces with a revisit frequency of approximately 10 days using one satellite i.e. 5 days using two satellites (Sentinel 2B satellite was launched on March 07, 2017, data are still not available). Sentinel-2 carries a Multispectral Instrument (MSI) with 13 spectral bands from the

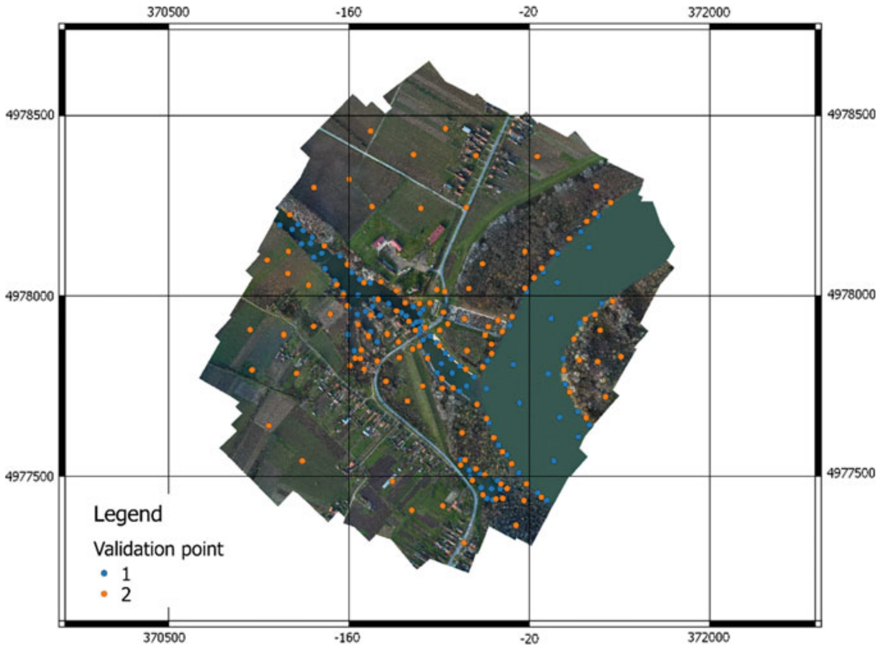

Fig. 1 Study area (*Validation points* 1 water, 2 non-water)

Visible Spectrum (VIS) and NIR to SWIR at different spatial resolutions on the ground, ranging from 10 to 60 m with a 290 km field of view[2] (Table 2). The atmospheric and terrain corrections of Bottom-of-atmosphere BoA (surface) reflectance Sentinel-2 Level 2A T34TCQ image used in classification were gathered in November 1, 2017 and provided by Copernicus Open Access Hub.[3] The level-2A output image products were resampled and generated to make all the bands have an eq0 dual spatial resolution, based on the requested resolution (10, 20 or 60 m) (Sentinel-2 User Guides 2018).

ASTER GDEM2

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) was jointly developed by the U.S. National Aeronautics and Space Administration (NASA) and Japan's Ministry of Economy, Trade and Industry (METI). The ASTER GDEM covers land surfaces between 83° N and 83° S and is comprised of 22,702 tiles. Tiles that contain at least 0.01% land area are included. The ASTER GDEM is distributed as Geographic Tagged Image

[2]https://sentinel.esa.int/web/sentinel/missions/sentinel-2/overview (accessed 16.01.2018).
[3]https://scihub.copernicus.eu/dhus/ (accessed 16.01.2018).

Table 2 Instruments mapping list

Type	Description
LiDAR	LMS-Q680i-Full Waveform Analysis with settable frequency up to 400,000 Hz, with Field of View of 60° and a divergence of 0.5 mrad beam; Class 3R
Navigation system	– IGI CCNS5 + Aerocontrol (positioning and navigation unit data storage) – IMU IIf (Inertial Unit—400 Hz) – GPS a 2 Hz (Novatel Antenna 12-channel L1/L2)
Camera	n.1 Metric Camera Digicam-H39 (39 Mpixels) with frame capture rate of up to 1.9 s and the ability to record in the frame Visible Color (VIS) or color-infrared (CIR), using filters
Thermal camera	Variocam thermal sensor system with a detector of 1024 × 768 pixels and the spectral range from 7.5 to 14 μm
Environmental temperature sensor	Temp.-logger RC-30B with the sampling interval programmed

File Format (GeoTIFF) files with geographic coordinates (latitude, longitude). The data are posted on a 1 arc-second (approximately 30-m at the equator) grid and referenced to the 1984 World Geodetic System (WGS84)/1996 Earth Gravitational Model (EGM96) geoid (LP DAAC 2018). The GDEM version 2 N44E019 was gathered on October 17, 2011 and was obtained from EarthExplorer (2017).

2.2.2 Commercial Data

LiDAR

The airborne LiDAR data and digital aerial photographs used in this study were captured using Litemapper 6800 on December 01, 2017. Instrument mapping list is provided in Table 2.

The LiDAR data were captured with an average point spacing of 5.4 cm. The LiDAR returns were classified into eight classes: unassigned, ground, low vegetation, medium vegetation, high vegetation, buildings, noise and model key by the data provider using proprietary software. The flying height when capturing the LiDAR data was approximately 200 m above ground level. The aircraft speed was 45 in. Maximum scan angle was set to 60°.

Orthophoto

Digital orthophotos were captured by a digital aerial photogrammetric camera and GPS/INS systems on board (in the plane). The assessment of XY coordinates was conducted by using control points. The location of these control points was three times more accurate than the defined accuracy of digital orthophoto coordinates. Additional GNSS data were obtained from the GNSS station of AGROS (Active Geodetic Network of Serbia) network. Also, data were gathered by using the signal from at least 5 GNSS satellites properly distributed (PDOP $\leq$ 4).

3 Methods

3.1 Water Bodies Extraction

The approach followed in this paper consists of three main parts: preprocessing, classification and validation.

3.1.1 Preprocessing

Sentinel-2 The feature space for the Sentinel-2A image comprised of four 10 m Sentinel-2A Level 2A bands (R, G, B, NIR) and two bands 20 m bands (SWIR 1, SWIR 2) pan-sharpened to 10 m resolution. According to Du et al. (2016) 10 m NIR band had the greatest correlation with SWIR band, therefore, it is used as a pan like band-since Sentinel-2 mission doesn't have a pan band.

ASTER GDEM data were reported from WGS84 geographic coordinates (EPSG 4326) to WGS84/UTM zone 34 (EPSG 32634). Consequently, TIN was created.

LiDAR the LiDAR point cloud was processed into five separate raster datasets: DTM, DSM, Slope, Intensity and point density (Fig. 2). Digital terrain model was produced at a pixel size of 10 cm using an inverse distance weighted interpolation of returns classified as ground hits. From this DTM, the rate of change in horizontal and vertical direction terrain slope layer measured in degrees was calculated. Digital Surface Model was produced from the first return points, which samples' elevation of the first object encountered by the laser beam on its path to the ground, by using the maximal height. Normalized DSM was produced by subtracting DTM from DSM. nDSM represents vegetation height above ground. According to Hooshyar et al. (2015) in order to classify water body, it is essential to use the return of the intensity from the ground surface. Therefore, intensity layer used in this study was created as the minimum intensity of ground returns. Point density was created as a ratio of a number of registered points and number of pixels.

Digital orthophotos were captured by a digital aerial photogrammetric camera and GPS/INS systems on board (in the plane). The assessment of XY coordinates was conducted by using control points. The location of these control points was three times more accurate than the defined accuracy of digital orthophoto coordinates. Additional GNSS data were obtained from the GNSS station of AGROS (Active Geodetic Network of Serbia) network. Also, data were gathered by using the signal from at least 5 GNSS satellites properly distributed (PDOP $\leq$ 4).

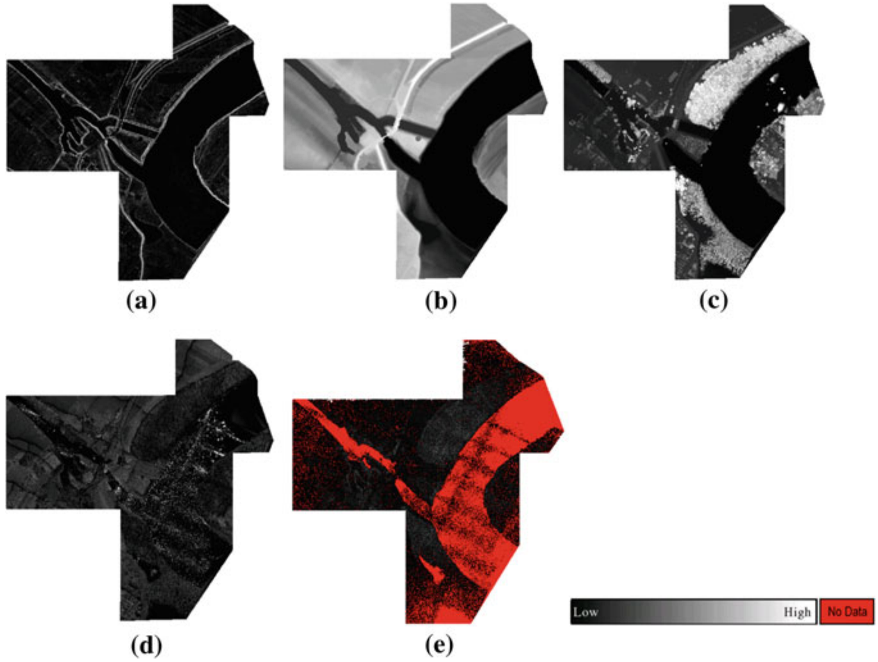

Fig. 2 LiDAR-derived raster data set **a** slope, **b** DTM, **c** nDSM, **d** intensity, **e** point density

3.1.2 Classification

Object-based image analysis was carried out in order to identify two classes (water and non-water), using a threshold based method. According to Smeeckaert et al. (2013b) surface water body is defined as a discrete and significant element of surface water such as a lake, a reservoir, a stream, a river or a canal, part of a stream, river or canal, a transitional water or a stretch of coastal water.

LiDAR-derived data: Streambed is continuous flat low-lying areas surrounded by steep stream banks. First, lowest-lying areas, that represent potential water bodies, were identified based on low absolute height. However, mapping the water body cannot be simply done by setting an elevation threshold from a DTM, as upstream areas will have different elevations to downstream areas, therefore, additional information is used. Water surfaces are assumed to be very horizontal (Smeeckaert et al. 2013a, b; Hofle et al. 2009) therefore slope layer was generated based on DTM in order to identify flat surfaces. Intensity information from near-infrared topographical LiDAR system, that is a relative strength measurement of the return pulse by the LiDAR sensor, is lower from water surface compared with land cover since water highly absorb NIR range of spectra (Brzank et al. 2008; Hooshyar et al. 2015). Since water is low albedo surface part of the emitted radiation returning significantly varies and may not be distinguished from the background noise (Smeeckaert et al. 2013a). Also,

Table 3 Water indices used for water body extraction from Sentinel-2

Index	Equation	Remark	Reference
Normalized Difference Water Index	$NDWI = (B_{green} - B_{NIR})/(B_{green} + B_{NIR})$	Water has a positive value	McFeeters (1996)
Modified Normalized Difference Water Index	$MNDWI = (B_{green} - B_{SWIR})/(B_{green} + B_{SWIR})$	Water has a positive value	Xu (2006)

the intensity of LiDAR return can be too small to be detected therefore, dropouts are frequent and the point density is typically lower on the surface water body, therefore, the point density is much lower in the water bodies comparing to inland areas (Smeeckaert et al. 2013b). DSM was used to mask vegetation which is frequent in the riparian zone. In reality, the ground surface objects are composed of a number of pixels. Segmentation algorithm aggregates the pixels into an object according to the one or more criteria of homogeneity and provides building blocks of object-based image analysis. Object-based classification considers the properties of the object i.e. additional spectral information compared to pixels (mean band value, median values, minimum and maximum values, mean ratios, variance) but spatial dimension like shape, size, distance, neighborhood, topologies etc. are crucial to OBIA method (Ke et al. 2010; Teo and Huang 2016; Du et al. 2016). The OBIA was based on LiDAR-derived raster products (DTM, DSM, Slope, Intensity and point density). The OBIA was performed in recognition 8.7 where Cognition Network Language was used for the development of a rule set which provides a time-efficient mapping of water bodies. The multi-resolution segmentation was used. Weights for each layer were determined based on their ability to delineate the water body. The higher weights were established for DTM, Slope, and DSM. Threshold values are determined in eCognition using update range function.

Sentinel 2 In order to detect and extract water bodies from satellite image due to simplicity, low cost, and superior performance based on specific noises, water indices are widely used for identification of water bodies (Yang and Chen 2017; Li et al. 2013; Rokni et al. 2014). In doing so, the performances of NDWI and MNWI (Table 3) were examined. A land-water threshold was manually applied to classify the image into two classes, land and water. The suitable land-water threshold for each index was determined through trial and error and visual comparison to reference map using recognition update range tool.

3.1.3 Accuracy Assessment

In order to estimate the accuracy of the classification pixel-by-pixel approach based on the analysis of the entries in confusion matrix was used. The confusion matrix is a simple cross-tabulation of the predicted class label(s) against the reference data for a sample of the cases at the specific locations, it provides a simple summary of

Table 4 Kappa coefficient interpretation (Landis and Koch 1977)

Kappa coefficient value	Interpretation
$0.81 \leq \hat{K} \leq 1$	Perfect agreement
$0.61 \leq \hat{K} \leq 0.8$	Substantial agreement
$0.41 \leq \hat{K} \leq 0.6$	Moderate agreement
$0.21 \leq \hat{K} \leq 0.4$	Fair agreement
$0.0 \leq \hat{K} \leq 0.2$	Poor agreement

classification accuracy and highlights the two types of error that may occur, omission (OE) and commission (CE) (Foody 2008). Omission and commission errors describe the errors related to individual classes. CE represents pixels that belong to another class but are labeled as belonging to the target class (i.e. the percentage of pixels classified as water but which do actually not belong to that class). OE represents the pixels that belong a class but fails to be classified into that class (i.e. the percentage of pixels which are water but which were not classified as such). Overall accuracy (OA) describes the proportion of the total number of correctly classified for all class and a total number of pixel in confusion matrix (sum of diagonal members of matrix divided by the total sum of pixels). KHAT statistics is used as a measure of classification accuracy reduced for accidentally correct class agreement (Cohen 1960). In this paper KHAT, an estimation of KHAT was used and its interpretation is shown in Congalton and Mead (1986). Registered value reflects the overall classification accuracy and consistency between the image and the reference grid with a random distribution of pixels in the classes. Interpretation of Kappa coefficient proposed by Landis and Koch (1977) is shown in Table 4.

The validation points were verified using a digital RGB orthophoto (spatial resolution of 5 cm) and their spatial distribution is displayed in Fig. 1.

3.2 *Flood Risk Assessment and DEM Comparison*

In this paper, inundation was simulated by selecting the grid cell of DEM that is lower than the projected water level and that is connected to an adjacent flooded grid cell or open water indicate inundation (van de Sande et al. 2012; Poulter and Halpin 2008). Flood risk assessments were performed at different vertical scale level.

The difference in estimated flood extents is supported by error measurement in order to quantify the elevation accuracy of a DEM. The LiDAR points were adopted as ground truth. The errors are calculated for every control points by taking the difference of elevation of the ASTER GDM and the true elevation of the points. The error statistics of the publicly available DEM dataset are assessed by the root mean square error (Eq. 1), the mean error of elevation measurements (Eq. 2) and the standard deviation (Eq. 3).

$$RMSE = \sqrt{\frac{\sum (Z_t - Z_{aster})^2}{n}} \quad (1)$$

$$ME = \frac{\sum (Z_t - Z_{aster})}{n} \quad (2)$$

$$SD = \sqrt{\frac{((Z_t - Z_{aster}) - ME)^2}{n - 1}} \quad (3)$$

where Z_t is elevation of LiDAR points, Z_{aster}—is elevation of ASTER GDEM and n is number of control points.

4 Results and Discussion

The experiments in this study analyzed three different aspects: accuracy assessment of water body extraction, comparison of results obtained from LiDAR-derived data and Sentinel 2 images and assessment of usability and accuracy of ASTER GDEM.

4.1 Water Body Extraction

The visual comparison of the delineation of water bodies is shown in Fig. 3. Visual inspection of Fig. 3 indicated that the proposed method successfully extracted water bodies with complete shapes, while the extracted results for Sentinel-2 were incomplete. Results of the river Bosut extraction were incomplete and part of the shallow river body was completely omitted producing large omission errors.

The results of the accuracy assessment for surface water body mapping using the LiDAR-derived data and Sentinel-2 are shown in Table 5.

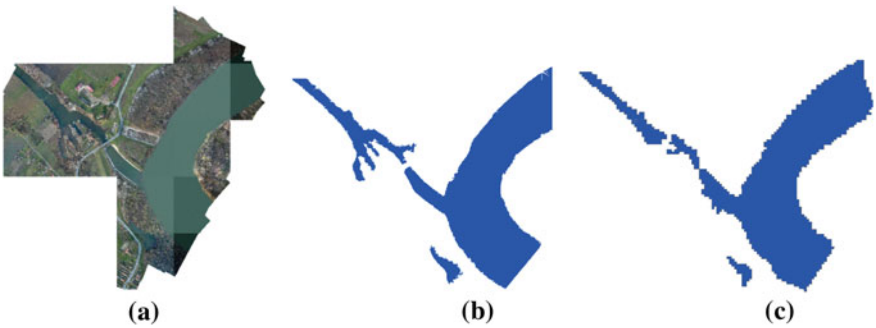

Fig. 3 **a** Digital orthophoto, **b** water bodies extracted from LiDAR-derived data, **c** water bodies extracted from Sentinel 2

Table 5 Accuracy assessment for a surface water body

	Kappa	OA	Commission		Omission	
			Water	Else	Water	Else
LiDAR	0.82 (0.75–0.90)	91.19	12.26	5.79	7	10.24
Sentinel-2	0.43 (0.31–0.55)	73.69	26.25	27.89	41	16.54

As a measure of agreement or accuracy, KHAT is considered to show strong agreement when it is greater than 0.75 (Jones and Vaughan 2010), while values lower than 0.40 indicate poor agreement (Chen et al. 2004). Therefore waterbody extraction from LiDAR-derived **data shows a perfect**, while Sentinel 2 provide moderate agreement with reality. The classification using LiDAR-derived data had a significantly higher according to all parameters (OA, Kappa. CE, OE) than Sentinel 2 which is expected to the significantly higher resolution.

Although the classification of LiDAR data uses the additional features intensity, point density, the height, and the slope represent the most important feature because the additional features are often noisier due to the unstable emitted pulse, changing surface reflectance etc. Also, waves within water cause often larger height variations and in case of white crests inhomogeneous reflectance behavior (Brzank et al. 2008). Based on accuracy assessment and visual validation proposed algorithm tends to overestimate water bodies. Trees over water bodies which were classified as water produce higher commission error and overestimation in LiDAR dataset. One of the advantages of LiDAR as an active remote sensing technology over passive optical images is that LiDAR-derived data are not affected by shadows that significantly affect the accuracy of water body extraction.

The algorithm used for Sentinel 2 images strongly underestimated water area and produced high omission error. The main reasons for high omission error of Sentinel-2 are low spatial resolution and mixing pixels that produce confusion between water and other features. Haze, shadow, seasonal and the daily difference in the sun angle, the change in water quality parameter can produce lower accuracy. Considering, there is one month gap between the acquisition of Sentinel 2 and digital orthophoto used for determining the location of validation points, the change of water level can produce a significant error.

4.2 Flood Risk Assessment

The visual comparison of flood inundation areas derived from LiDAR and ASTER GDEM were shown in Fig. 4. The publicly available flood inundation map is incomplete and provides large inundation deviations especially in the area of the Sava river where even riverbed wasn't marked as flooded. The mean error was −3.18 meaning

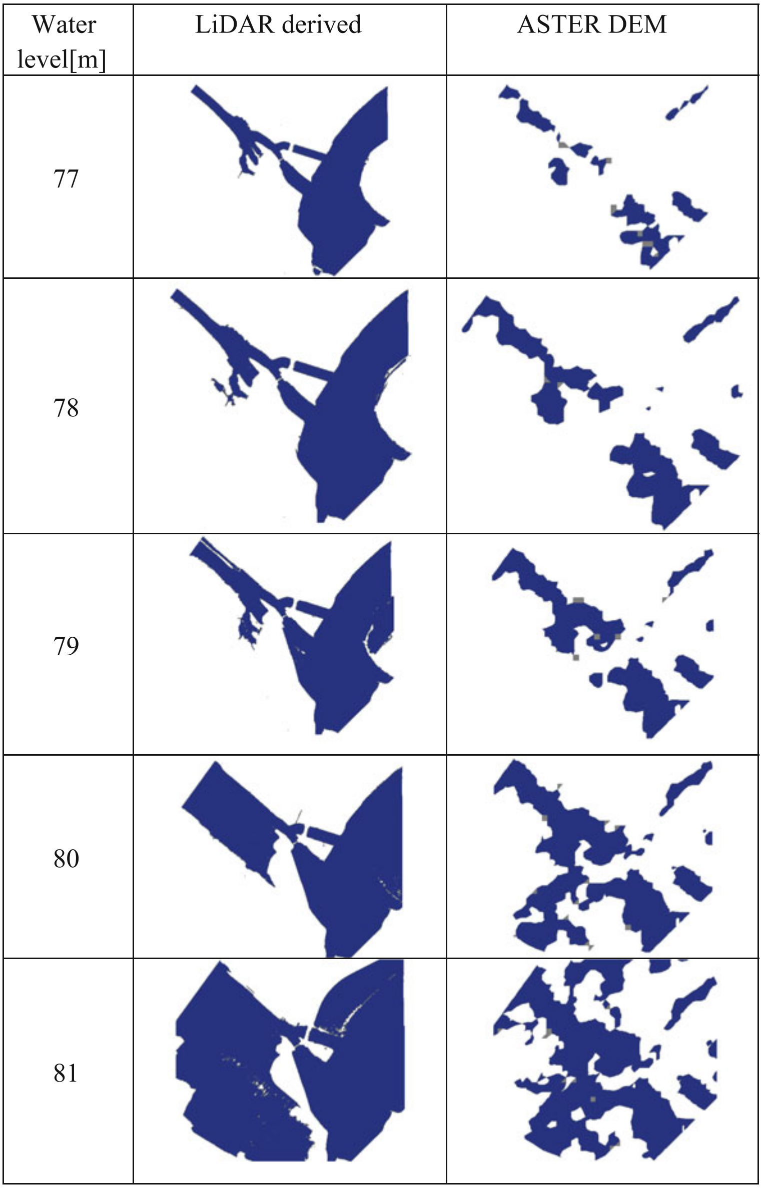

Fig. 4 Flooded area according to water level

that publicly available DEM overestimated the elevation and consequently underestimated the risk of flooding. ASTER GDEM shows a high RSME of 5.74 m and SD of 4.79 m that indicates to what extent there is a variety in the magnitude of the errors

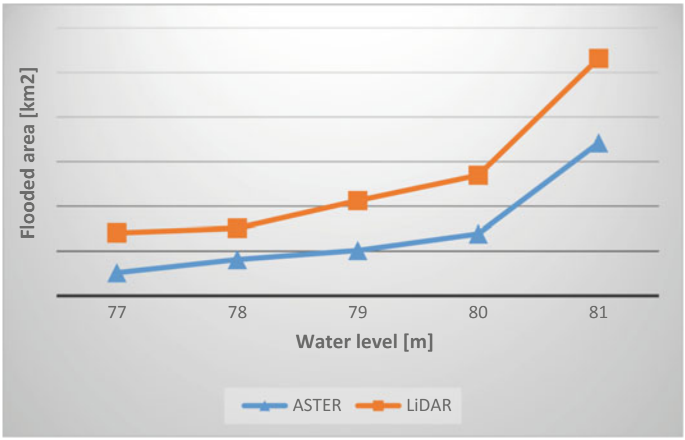

Fig. 5 Comparison of flood inundation area between LiDAR and ASTER

in the dataset. van de Sande et al. (2012) obtained similar results (ME −5.25 m and RMSE of 5.3 m).

There was a large difference in the extent of inundation between LiDAR and ASTER DEM. ASTER GDEM significantly decreased a flooded area (Figs. 4 and 5) The flood inundation maps using ASTER shows inundation is twice smaller.

5 Conclusion

In this study, we evaluated the performance of LiDAR data and Sentinel 2 image for surface water body mapping as well as a comparison between the publicly available and LiDAR DEM for flood risk assessment. Also, accuracy assessment of ASTER GDEM was performed.

The major contributions of this study are to (1) establish an object based water body delineation scheme using LiDAR data and automatic water body classification using Sentinel 2 multispectral images, (2) compare classification LiDAR results with those from Sentinel 2, (3) compare the public available ASTTER DEM and very accurate LiDAR DEM for flood risk assessment and (4) evaluate the accuracy of ASTER DEM. The proposed workflow apply object-based analysis for water body delineation from LiDAR-derived data and Sentinel-2 satellite images. The LiDAR data was converted to raster layer (DTM, nDSM, slope, intensity and point density) in order to provide efficient land/water discrimination in terms of both accuracy and computing time. For Sentinel-2 water indices (NDWI, MNDWI) and spatial features are used for automatic water bodies extraction. The presented results shows the following (1) water bodies extracted from LiDAR derived data shows perfect agreement with reality (2) LiDAR data provide significantly higher accuracy, compared with Sentinel 2, which was expected due to higher resolution. (3) The ASTER DEM overestimates the land elevation (ME = −3.18) and significantly underestimates the flood inundation and associated risk. The flood inundation maps using Aster DEM shows an inundation area two times smaller then a LiDAR based inundation map. (4) Although ASTER GDEM datasets are used in risk assessment, underestimation of flood inundation area can have serious consequences during investment decision and policy adaptation therefore Aster DEM do not meet accuracy requirementd for flood risk assessment applied on low laying area of Sremska Mitrovica. (5) The accurate LiDAR data and generate DTM have great potential in term of water body extraction and flood risk assessment. However the availabilty and high cost limits their applicationThe possible limitations of paper are: presented methods are based on the segmentation parameter and classification rule sets whichmay need to be modified for another area of reasearch and ground truth points used for classification accuracy assessment were determined by visual inspection of digital orthophoto images.

In future work, LiDAR data should be integrated with different spectral images in order to provide a automatic water body mapping with higher accuracy. Also, evaluation of publicly available DEMs for flood risk assessment in mountains areas should be preformed.

References

Antonarakis AS, Richards KS, Brasington J (2008) Object-based land cover classification using airborne LiDAR. Remote Sens Environ 112:2988–2998. https://doi.org/10.1016/j.rse.2008.02.004

Bodoque JM, Guardiola-Albert C, Aroca-Jimenez E, Angel Eguibar M, Martinez-Chenoll ML (2016) Flood damage analysis: first floor elevation uncertainty resulting from LiDAR-derived digital surface models. Remote Sens 8:604. https://doi.org/10.3390/rs8070604

Bolanos S, Stiff D, Brisco B, Pietroniro A (2016) Operational surface water detection and monitoring using Radarsat 2. Remote Sens 8:285. https://doi.org/10.3390/rs8040285

Brzank A, Heipke C, Goepfert J, Soergael U (2008) Aspects of generating precise digital terrain models in Wadde Sea from lidar—water classification and structure line extraction. ISPRS J Photogramm Remote Sens 63:510–528. https://doi.org/10.1016/j.isprsjprs.2008.02.002

Chen D, Stow D, Gong P (2004) Examining the effect of spatial resolution and texture window size on classification accuracy: an urban environment case. Int J Remote Sens 25(11):2177–2192. https://doi.org/10.1080/01431160310001618464

Chen Z, Devereux B, Gao B, Amable G (2012) Upward-fusion urban DTM generating method using airborne Lidar data. ISPRS J Photogramm Remote Sens 72:121–130. https://doi.org/10.1016/j.isprsjprs.2012.07.001

Cohen J (1960) A coefficient of agreement for nominal scales. Educ Psychol Meas 20(1):37–46. https://doi.org/10.1177/001316446002000104

Congalton RG, Mead RA (1986) A review of three discrete multivariate analysis techniques used in assessing the accuracy of remotely sensed data from error matrices. IEEE Trans Geosci Remote Sens 24(1):169–174

Du Y, Zhang Y, Ling F, Wang F, Li W, Li X (2016) Water bodies' mapping from Sentinel-2 imagery with modified normalized difference water index at 10-m spatial resolution produced by sharpening the SWIR Band. Remote Sens 8(4):354. https://doi.org/10.3390/rs8040354

EarthExplorer (2017) https://earthexplorer.usgs.gov/ Accessed 25 Dec 2017

European Exchange Circle on Flood Mapping (2007) Handbook on good practices for flood mapping in Europe. http://ec.europa.eu/environment/water/flood_risk/flood_atlas/pdf/handbook_goodpractice.pdf
Foody G (2008) Harshness in image classification accuracy assessment. Int J Remote Sens 29(11):3137–3158. https://doi.org/10.1080/01431160701442120
Guan H, Li J, Yu Y, Zhong L, Ji Z (2014) DEM generation from lidar data in wooded mountain areas by cross-section-plane analysis. Int J Remote Sens 35(3):927–948. http://dx.doi.org/10.1080/01431161.2013.873833
Hofle B, Vetter M, Pfeifer N, Mandlburger G, Stotter J (2009) Water surface mapping from airbone laser scanning using signal intensity and elevation data. Earth Surf Process Landforms 34(12):1635–1649
Hooshyar M, Kim S, Wang D, Medeiros S (2015) Wet channel network extraction by integrating LiDAR intensity and elevation data. Water Resour Res 51:10029–10046. https://doi.org/10.1002/2015WR018021
Johansen K, Arroyo L, Armston J, Phinn S, Witte C (2010) Mapping riparian condition indicators in a sub-tropical savanna environment from discrete return LiDAR data using object-based image analysis. Ecol Ind 10:796–807. https://doi.org/10.1016/j.ecolind.2010.01.001
Johansen K, Tiede D, Blaschke T, Arroyo L, Phinn S (2011) Automatic geographic object based mapping of streambed and riparian zone extent from LiDAR data in a temperate rural urban environment, Australia. Remote Sens 3:1139–1156. https://doi.org/10.3390/rs3061139
Jones HG, Vaughan RA (2010) Remote sensing of vegetation: principles, techniques, and applications. Oxford University Press, Oxford
Kaplan G, Avdan U (2017) Object-based water body extraction model using Sentinel-2 satellite imagery. Eur J Remote Sens 50(1):137–143. https://doi.org/10.1080/22797254.2017.1297540
Ke Y, Quackenbush LJ, Im J (2010) Synergistic use of QuickBird multispectral imagery and LIDAR data for object-based forest species classification. Remote Sens Environ 114:1141–1154
Kovats RS, Valentini R, Bouwer LM, Georgopoulou E, Jacob D, Martin E, Rounsevell M, Soussana J-F (2014) Europe. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York, pp 1267–1326
Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. Biometrics 33:159–174
Li W, Du Z, Ling F, Zhou D, Wang H, Gui Y, Sun B, Zhang X (2013) A comparison of land surface water mapping using the normalized difference water index from TM, ETM+ and ALI. Remote Sens 5:5530–5549. https://doi.org/10.3390/rs5115530
LP DAAC (2018) https://lpdaac.usgs.gov/dataset_discovery/aster/aster_products_table/astgtm. Accessed 22 Feb 2018
McFeeters SK (1996) The use of the normalized difference water index (NDWI) in the delineation of open water features. Int J Remote Sens 17:1425–1432
Merwade V, Olivera F, Arabi M, Edleman S (2008) Uncertainty in flood inundation mapping: current issues and future directions. J Hydrol Eng 13:608–620
National Research Council of the National Academies (2009) Mapping the zone, improving flood map accuracy. The National Academies Press, Washington, DC
Polat N, Uysal M, Toprak AS (2015) An investigation of DEM generation process based on LiDAR data filtering, decimation, and interpolation methods for an urban area. Measurement 75:50–56. http://dx.doi.org/10.1016/j.measurement.2015.08.00
Poulter B, Halpin PN (2008) Raster modelling of coastal flooding from sea-level rise. Int J Geogr Inf Sci 22(2):167–182. https://doi.org/10.1080/13658810701371858
Rokni K, Ahmad A, Selamat A, Hazini S (2014) Water feature extraction and change detection using multitemporal landsat imagery. Remote Sens 6:4173–4189. https://doi.org/10.3390/rs6054173

Schmidt A, Rottensteiner F, Sörgel U (2012) Classification of airborne laser scanning data in Wadden sea areas using conditional random fields. In: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol XXXIX-B3, XXII ISPRS Congress, 25 August–1 September 2012, Melbourne, Australia

Sentinel-2 User Guides (2018) https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/processing-levels/level-2. Accessed 16 Jan 2018

Serbian Floods 2014, Belgrade (2014). http://www.sepa.gov.rs/download/SerbiaRNAreport_2014.pdf. Accessed 14 Mar 2018

Smeeckaert J, Mallet C, David N, Chehata N, Ferraz A (2013a) Large-scale water classification of coastal areas using airborne topographic LiDAR data. In: IEEE International Geoscience and Remote Sensing Symposium, Melbourne, VIC, Australia, 21–26 July 2013. https://doi.org/10.1109/igarss.2013.6721092

Smeeckaert J, Mallet C, David N, Chehata N, Ferraz A (2013b) Large-scale classification of water areas using airborne topographic lidar data. Remote Sens Environ 138:134–148

Teo TA, Huang CH (2016) Object-based land cover classification using airborne lidar and different spectral images. Terr Atmos Ocean Sci 4:491–504. https://doi.org/10.3319/TAO.2016.01.29.01(ISRS)

Topaloglu RH, Sertel E, Musaoglu N (2016) Assessment of classification accuracies of Sentinel-2 and Landsat-8 data for land cover/use mapping. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol XLI-B8, XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic. https://doi.org/10.5194/isprsarchives-xli-b8-1055-2016

Turner A, Colby J, Csontos R, Batten M (2013) Flood modeling using a synthesis of multi-platform LiDAR data. Water 5:1533–1560. https://doi.org/10.3390/w5041533

van de Sande B, Lansen J, Hoyng C (2012) Sensitivity of coastal flood risk assessments to digital elevation models. Water 4:568–579. https://doi.org/10.3390/w4030568

Verpoorter C, Kutser T, Tranvik L (2012) Automated mapping of water bodies using Landsat multispectral data. Limnol Oceanogr Methods 10:1037–1050. https://doi.org/10.4319/lom.2012.10.103

Webster T (2010) Flood risk mapping using LiDAR for Annapolis Royal, Nova Scotia, Canada. Remote Sens 2:2060–2082. https://doi.org/10.3390/rs2092060

Wedajo GK (2017) LiDAR DEM data for flood mapping and assessment; opportunities and challenges: a review. J Remote Sens GIS 6:4. https://doi.org/10.4172/2469-4134.1000211

Wikipedia (2018) https://sr.wikipedia.org/sr-el/%D0%91%D0%BE%D1%81%D1%83%D1%82_(%D1%80%D0%B5%D0%BA%D0%B0). Accessed 22 Jan 2018

Xu H (2006) Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. Int J Remote Sens 27:3025–3033

Yan K, Di Baldassarre G, Solomatine D, Schuman G (2015) A review of low-cost space-borne data for flood modelling: topography, flood extent and water level. Hydrol Process 29(15):3368–3387

Yang X, Chen L (2017) Evaluation of automated urban surface water extraction from Sentinel-2A imagery using different water indices. J Appl Remote Sens 11(2):026016. https://doi.org/10.1117/1.JRS.11.026016

Yang X, Zhao S, Qin X, Thao N, Liang L (2017) Mapping of urban surface water bodies from Sentinel-2 MSI imagery at 10 m resolution via NDWI-based image sharpening. Remote Sens 9(6):596. https://doi.org/10.3390/rs9060596

Zhou W (2013) An object-based approach for urban land cover classification: integrating LiDAR height and intensity data. IEEE Geosci Remote Sens Lett 10(4). https://doi.org/10.1109/lgrs.2013.2251453

Resilient Functional Urban Regions: Spatial Planning in the Light of Climate Change

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Abstract In European documents, practice and policies of regional and spatial development, functional urban regions (FURs) are recognized as the regions with one or more urban settlements and their in (direct) impact zone(s). The historical connection of the city and its surroundings, as well as the contemporary trends in networking of cities and their hinterland, imply the issues of better modalities for the establishment of such FURs that would be economically more productive, socially inclusive and more environmentally sustainable. The concept of urban governance, along with supporting segments, is proposed as the model for future planning of resistant FURs. It was considered what cities and their functional areas should take in order to prospectively enable an establishing the sustainable spatial and regional development of the Republic of Serbia. The paper tries to answer how much are FURs adjustable, what is their "threshold" of vulnerability, to which they can face the side effects of climate change.

Keywords Climate change · Functional urban region · Resilient city
Urban governance · Sustainable infrastructure
Sustainable spatial and regional development

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1 Introduction

Modern Functional Urban Regions (FURs) represent the driving forces and encourage development but they also take new risks such as environmental urban degradation, overburdened traffic systems, inefficient public utility services, the spread of informal settlements, *etc.* (UNISDR 2017). Therefore the issue of the right measure or the "threshold" of sensitivity, above which a FUR cannot face the adverse effects of climate change, calls for a thorough scientific examination and a wide-ranging academic discussion.

Through the concepts of urban management, sustainable mobility, etc., the authors tend to identify resilient FURs that could be potential instruments of the regional development of Serbia and have a more decisive role and wider significance in understanding the concept of resilience in planning. Namely, as the networking of cities and their functional areas is today one of the main directions of EU regional development policy, the management of modern metropolitan regions requires greater awareness of the need to introduce approaches that would reduce the sensitivity of FURs to the potential negative impacts of climate change and at the same time build their resilience.

Environmental hazards of modern times put the planning practice in an awkward position as they undermine the concepts that used to form the basis of management and planning. Therefore, the authors' intention was to improve the understanding of "ecological uncertainty", which has an enormous impact on the urban vulnerability in the planning of cities and their surroundings, through the recognition of the challenges posed by climate change and insufficient knowledge of individuals or groups about possible environmental threats to settlements or communities. This would raise awareness of the phenomenon of resilience not only among the general population, but also among the professionals who prepare plans at different territorial levels, design development strategies, draft legal documents and adopt legislative frameworks. The authors tend to point to the opportunities to create such FURs that would be more resilient and sustainable and as such contribute to the establishment of a coherent, spatially-functional system in the country.

2 The Concept of Resilience

Although the concept of resilience is a relatively new way of thinking in the modern theoretical approaches of studying cities and their surroundings, its origins date back to the 1930s and the very beginnings of **the systems approach** to researching phenomena and processes in nature. The first theoretical frameworks of the concept were given by Ludwig von Bertalanffy, who studied the system in relation to nature and the environment. Having ecosystems as models, Bertalanffy defined the system as an organized entity made up of interrelated and interdependent parts (Tošić 2012).

In the early 1960s, ecologists started the research into the concept of resilience from the aspect of the adaptability, i.e. the “ability of the system to resist disturbances and maintain its functions and controls” (Gunderson and Holling 2001). One of the early researchers to present the elasticity/resilience of ecological systems and the processes within them through the concept of “resilient thinking” was Holling (1973), who thought that the resilience was “the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between the elements of the system”.

Another concept of resilience was developed in natural and technical sciences. It was an engineering category developed to explain the stability and resistance of objects and materials to external forces in order to reduce potential defects and failures in manufacturing or technological processes. The ecological and engineering-technical concepts are close to the up-to-date **system approach in functional regionalization**, which views the region as a coherent whole that exists in the space thanks to its homeostatic structure.

The systems approach was applied in spatial planning and social sciences in the early ’60s and ’70s of the 20th century, with certain attempts of social scientists to reject it later. However, the systems approach is again being used both in the theory and methodology and in the practice of planning. It is somehow most suitable for the research of urban, functional and functional urban systems. In this context, functional regionalization refers to resilience as the ability of the (urban and functional) system, as a whole (with its sub-wholes), to adapt and absorb external shocks while retaining the same functions and the same intensity of the functions.

Functional regionalization views the **region as a whole** composed of interrelated components (sub-wholes) between which there are various functional feedbacks of different intensities and which function in the space thanks to homeostasis. If the functional links between the components in the system are not strong enough, if their intensity or frequency decreases, the system becomes vulnerable, susceptible and cannot function as a coherent whole.

Resilience is an emergent property of a system and cannot be understood or predicted by explaining the parts (Berkes and Turner 2006). Resilience is the degree to which cities are able to tolerate alteration before reorganizing around a new set of structures and processes (Alberti and Marzluff 2004).

The concept of resilience has been elaborated and today it is interpreted in many ways by numerous scientific disciplines: humanistic and social sciences recognize resilient **human-social systems** (Adger 2000; Pelling 2003), **environmental systems** (Walker et al. 2004; Folke et al. 2005), **urban systems** (Porter and Davoudi 2012; Collier et al. 2013). Economy and political sciences deal with the system resilience in terms of economic recovery (Rose and Krausmann 2013; Hallegatte 2014), *etc*.

On the other hand, the modern theoretical research and the planning practice still find it quite unclear what the concept of resilience really implies and what kind of resilience the academic community has in mind. If we focus on spatial and regional planning, which are always in correlation with the planning, social and political system of the country, it is possible to assume that the systems that are economically, socially and politically stable have greater resilience than the unstable ones (Davoudi 2013).

An interesting thesis by Davoudi et al. implies thinking about the so-called "developmental resilience" which is particularly important for the planning in today's political and economic circumstances, as it opens up the possibilities of turning a crisis into an opportunity. This thesis is related to the paradigm of the "evolutionary resilience" which is based on the assumption that as systems mature they are faced with reduced resilience, i.e. they are susceptible to disturbances (Davoudi et al. 2013).

In the context of the Republic of Serbia (RS), this would mean that the current adverse political and social circumstances pose a challenge to the society. However, these unfavorable circumstances can bring about innovative planning policies and new institutional and governance arrangements. Although resilience can be quite high in uncertain times, it has significant potential for change.

Correlating the concept of resilience with spatial planning, it must be emphasized that planning interventions in space are, through local and regional spatial plans, affected by systemic factors (management and market) and shaped by political institutions. Starting from the dilemma of the extent to which the public interest is preserved in planning, the issue of the link between the planning, city resilience and functional regionalization arises? If planners are recognized as the actors of public interest and socially justified activities (Perić 2016; Šećerov and Filipović 2017), how can they, in coordination with institutions, increase the resilience of cities and their surrounding areas? Starting from the premise that effective resilience views planners as actors who use institutions to anticipate and resolve uncertainty, what is the link between planning resilient functional regions and governance mechanisms at the level of the entire functional region? What is the role of the concept of resilience in functional regionalization?

3 Characteristics of Functional-Urban Resilience

The degree to which FURs, as urban systems, are adaptable to possible ecological threats and what makes them vulnerable can be seen from the aspect of several key **characteristics of functional-urban resilience**: demographic, social, spatial and economic.

Bearing in mind that the demographic and socio-economic indicators on the population (age, gender, income, education, physical and mental capacity, language proficiency, territorial capital, *etc.*) affect the vulnerability of a functionally coherent system, it can be noticed that each urban system has **groups or individuals** with a lower capacity to face, take or adapt to environmental risks. Therefore, the idea of functional urban resilience implies social integration and inclusion of vulnerable categories of population and informal settlements into the entire FUR.

The spatial aspect of the system resilience is reflected in the uneven distribution of environmental risks and hazards in the area so that some local communities are more sensitive to the effects of climate change than others (e.g. floodplains and rural settlements near river courses, *etc.*).

Economic aspects of urban resilience include the engagement of the green economy and the development of such economic instruments which would help cities and their surrounding areas to reduce environmental risks. A clean, efficient and renewable use of energy is the key to achieving greater resilience in cities. The energy should be based on new low-carbon technologies in order to reduce the emission of harmful gases.

The revised cohesion policy of the EU, with an estimated total of €356.5 billion, has assigned a large portion of investment funds to clean/green energy, including smart grids, energy efficient buildings, renewable energy and energy efficiency efforts, energy storage research and development (European Commission (EC) 2013).

All these characteristics are the basis of an **integrated approach to resilient FUR planning**. In a wider context of observation, the integrated planning of cities and their surrounding areas plays a key role in the shaping of all segments of the environment, including land use planning and environmental socio-spatial policies. At the local level, cities tend to attain an integrated approach to the planning of urban zones because it recognizes the modes of urban renewal and urban design which are preconditions for city resilience. This is essentially a complex reconstruction of cities which is not based only on the ecologically desirable form of the city, but also on the economic and social urban renewal.

Cities can adapt to climate change and the adverse effects of climate change can be addressed and mitigated through the compact city design, sustainable mobility, high-density housing planning, specific project planning of buildings, green corridors, compatible land use, different urban features, *etc*. (Jabareen 2013).

Compact city design can reduce the need of cities for the transport of energy, people, goods and materials (Dempsey 2010). Through the improvement of previously undeveloped urban zones, the transformation of existing buildings or sites and conversion of land, the central city areas are getting denser and eventually become compact and thus help conserve the good-quality agricultural land in the city surroundings.

FUR adaptation to climate change also requires **sustainable mobility** which can be achieved through: traffic reduction, increased use of electric vehicles and other non-motorized forms of traffic, traffic safety, introduction of ecological taxes, legal equality, reduced emissions of exhaust gases, the use of renewable energy sources, *etc* (Banister 2008).

The resilience of FURs further depends on the **urban density** because it affects climate change through the differences in the consumption of energy, materials and housing land, traffic, and urban infrastructure. The concept of large-scale housing density can save significant amounts of energy (ESMAP 2014).

Sustainable Building through **Specific Project Planning** is based on the optimal use of solar energy, the application of specific design measures in the selection of the location, orientation and layout of buildings, spatial design, the use of specific building materials, *etc*. The aim is to reduce the use of the conventional energy sources for heating and cooling and thus achieve efficient energy consumption adapted to the given microclimate.

Generally, the desirable form of a resilient FUR can be achieved through the **restoration of the whole functional system**, especially of the central city parts. This restoration implies the following: revitalization of good-quality architecture, public spaces, buildings and structures of cultural and religious significance, activation of abandoned industrial zones and buildings, improve access to urban services, urban safety improvement and raising awareness of the urban life with the aim of improving the quality of life in degraded areas and achieving social cohesion (Jeftić 2017).

4 The Method

Starting from the premise that the city resilience is a complex phenomenon, insufficiently defined, but dynamic and uncertain in its nature, this study used the methodology of **qualitative analysis** (Jabareen 2009) as a tool to establish a conceptual framework.

The conceptual framework of the study of the resilience of cities and their surroundings, as a key part of the problem-solving process, is based on a system of concepts, assumptions, expectations, and theories that support this type of research (Mahoney 2010).

The evolution of the methodological approach should be presented as a synopsis of the specific direction of the envisaged conceptual framework of the research: finding the source of relevant data, reviewing the literature of the previous research, sorting data according to the synopsis, identification and categorization of concepts, integration of concepts, synthesis and the verification of the conceptual framework.

5 The Impact of Urbanization on FUR Resilience

Throughout history, the city and its immediate surroundings have been organically and functionally linked. The symbiosis of the village and the city has been reflected in the supply of cities with food, goods, raw materials, *etc*. produced in the villages. With the intensification of **industrialization**, immediate rural environments have become parts of the sphere of influence of cities, thus strengthening their centrality through the assimilation of different functions. Namely, the 1950s have seen the intensification of the **process of urbanization** which was based on intensive industrialization. These processes affected the positioning of economic activities and consequently the concentration of population in cities.

Table 1 Degree of urbanization, RS

Settlements	1981	1991	2002	2011
Urban	9,313,686	7,822,795	7,498,001	7,186,862
Other	4,390,358	4,214,698	4,218,479	4,271,872
	4,923,328	3,608,097	3,279,522	2,914,990
Urban %	47.1	53.9	56.3	59.4
Other %	52.9	46.1	43.7	40.6

Source Comparative overview of the number of population in 1981, 1991, 2002, 2011 (Census book 20), Statistical Office of the RS, 2011

According to the 1953 Population Census, about one-fifth of the total population lived in urban settlements in the territory of the RS (22.1%), while about two-thirds of the active population (67%) were agricultural (Tošić and Nevenić 2010). Although the degree of urbanization in the territory of the RS increased to around 59.4% (in Central Serbia to 55.2%, and in Vojvodina to 56.4%) by 2011, the urban population was not increasing evenly in the same period (Table 1).

The constant increase in the urbanization of Serbia had clear **implications**. The gradual development of city centers caused planned, and partly, spontaneous dislocation of industrial plants from urban settlements to suburban areas in which new industrial and service enterprises developed over time. Urban concentration of population and functions in urban settlements and centers of FURs as well as the demographic emptying of rural areas, caused either by emigration or by reducing birth rates, and most often by the combination of these two factors, brought about demographic, social and economic changes in the settlements on the territory of RS. The concentration of population, industry and activities of the tertiary and quaternary sector in the FUR cores caused the demographic emptying and decline of villages, especially in the isolated mountain areas. Simultaneously FURs became overcrowded causing numerous **problems** in the sectors vital for the normal functioning of cities and their surrounding areas (water, energy, transport, environment, urban planning and management).

The trends of urbanization in Serbia have been similar to the trends of other European countries, especially the countries of Southeastern Europe. They have all experienced the effects of polarization resulting from extremely centralized urban systems (Petrakos 2012). Some authors believe that the centralized urban systems of the countries of Southeastern Europe have resulted from the socialist orientation of their socio-economic systems (Tsenkova 2011). However, the imbalance between the capital city and other smaller centers of national urban systems have also been experienced by some capitalist states. Therefore urbanization should be studied as a historical, geographical and social phenomenon.

6 Relation Between the Degree of Urbanization and GDP Per Capita in the Republic of Serbia

The urbanization increase is also in correlation with GDP per capita (Fig. 1). The symbiosis of the city and the village, embodied in the FUR concept, still affects the dynamics of the economy in Serbia. According to Sachs (2014), cities, on the one hand, provide scientific and technological innovations that encourage the development and productivity of agriculture, while on the other hand, the constant growth and development of cities are largely supported by productive agricultural farms.

The urban systems of EU are neither distributed rationally and evenly nor they have the same demographic size since they have been developing in different economic, social, cultural and historical milieus and contexts. There are significant regional differences in Europe with regard to the relation between the degree of urbanization and the GDP per capita.

Research shows that the economic growth of the RS, expressed as an increase in per capita income, is in **correlation** with the increase in the degree of urbanization. This trend is also present in other European countries, especially in Southeastern Europe, with some differences in the size and range of these indicators. Moldova has the lowest GDP per capita with 5.333 dollars and the share of the urban population in the total population of 45%. Bosnia and Herzegovina has the lowest share of the urban population in the total population (around 40%), while Belgium has the largest share of urban population of 98%. Luxembourg has the largest GDP per capita of $102.389. Based on the above, it can be assumed that the future regional growth in Serbia will continue to be accompanied by increasing urbanization.

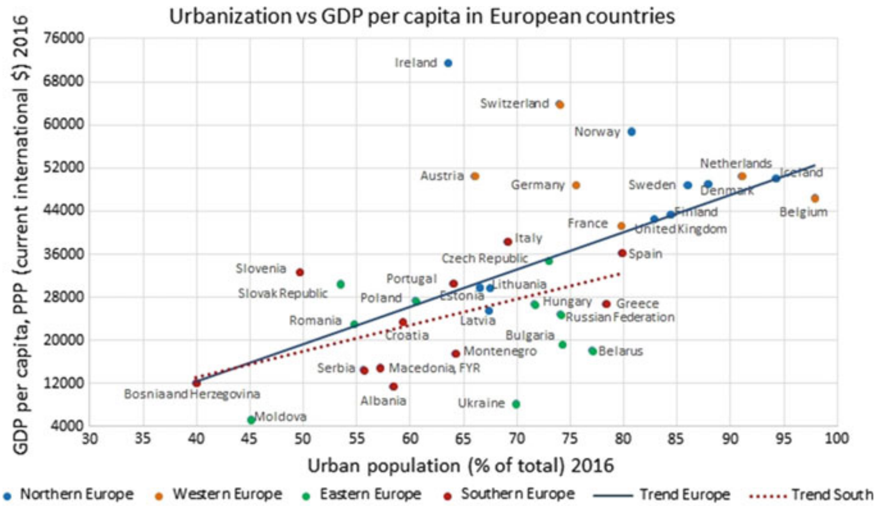

Fig. 1 Urbanization versus GDP per capita (PPP), Europe, 2018. *Source* World Bank (https://data.worldbank.org/data)

Table 2 Functional types of settlements in RS, 2011

Functional type of settlement	Number of settlements		% of the total number of settlements
Agrarian	1607	2489 (55%)	35.3
Agrarian-industrial	359		7.9
Agrarian-service	523		11.5
Industrial	189	617 (13, 5%)	4.1
Industrial-agrarian	97		2.1
Industrial-service	331		7.3
Service	405	1282 (28%)	8.9
Service-agrarian	226		5.0
Service-industrial	651		14.3
On the threshold	169	169	
Total-settlements	**4557**	**4557**	

Source Author's calculations based on the Census 2011 data, Statistical Office of the RS, 2017

Functional regions, as weaker or stronger labor markets, mostly concentrate secondary and tertiary activities, thus **increasing the overall productivity of the state**. Like in other countries in the region, the ongoing process of deindustrialization in Serbia has led to successive changes caused by the transition of a contingent of economically active population from the industrial to the tertiary sector.

Indicators of the structure of population activity, established on the basis of the model of functional types of settlements (Tošić 2012), reveal the intensity and degree of functional changes that have occurred in the settlements of the RS. The zones of direct influence of regional and subregional centers have the widest territorial scope of work functions in the urban settlements of Serbia (Table 2). These areas have had an increasing number of functionally transformed settlements of service and service-industrial character (28% in 2011). On the other hand, the zones of weaker influence of dominant centers have had an increasing number of functionally transformed settlements of agrarian type (55% in 2011). These changes result from the employment of population in non-agricultural activities and gradual development and somewhat more dispersive arrangement of public infrastructural facilities and social services in rural areas.

The trends in the growth of urban population in previous periods suggest that the urban population in Serbia and in the countries in the immediate environment will continue to grow in the future. Bearing this in mind, the fundamental dilemma is: how will FURs deal with a constant increase in population, the concentration of functions and economy and other challenges of the urban environment.

7 The Concept of FUR Governance: How to Achieve a Resilient FUR

The FUR Governance Concept is based on the assumption that a FUR is resilient if it has an efficient, competent and flexible system of governance and the capacity to promote participatory planning and decision-making. Strong management is able to raise the quality of spatial arrangement of settlements, environment, economic productivity of FUR and other segments of development.

A key to achieving FUR's resilience lies in such a **governance mechanism** that can easily adapt to sudden and unforeseen circumstances, i.e., manage effectively natural disasters and quickly restore public utility services, traffic, technical and energy infrastructure and establish the normal functioning of all the systems in the country.

The idea of governance at FUR level was a topic of earlier research. In recent research into regional issues and resilience of cities, some authors have proposed the establishment of the so-called "dual hierarchy" within states: administrative governance (formal) and the governance at FUR level (informal functional system) whose goals and basic requirements must be directed by national governments, but with the respect of EU governance mechanisms (Jacquier 2010; Tosics 2011; Atkinson 2014).

The lack of a clear regional policy in the RS, caused by the slow transformation of the still dominant centralism and unitarism in the socio-political and economic sphere of Serbia, has led to the questionable **significance** of the region. Consequently, **the principle of functionalism has been neglected**. The existing NUTS nomenclature at its third level (NUTS 3 areas), has not sufficiently taken into account the network of settlements and the functional organization of urban centers of Serbia as the bearer of the regional development of the territory of Serbia (Nevenić 2013). In some cases, city centers develop such functions that exceed territorial domains of their administrative-territorial or statistical frameworks (e.g. FUR of Belgrade settlement reaches beyond the administrative boundaries of the City of Belgrade (it is NUTS 2 and NUTS 3 at the same time), so that the territory of Pančevo, Opovo, Pećinci and other municipalities, are functionally complementary to Belgrade but belong to NUTS 2 Vojvodina).

If the ultimate goal of the state is **a sustainable and coherent territory in a functional sense**, then the regionalization based on the functional relations of the centers is more purposeful than the one based on statistical regions because the latter doesn't respect the assumption of functionality. It is gaining increasing importance since statistical units are currently used in the allocation of the EU structural funds.

Furthermore, the territorial coverage of FURs, their functional significance and population in Serbia are constantly varying. Therefore the potential borders of the regions raise the issue of their possible redefinition and adaptation to the existing demographic, social, economic and other processes. There are several **problems** here. First of all, it would be very difficult to change the existing administrative-territorial division of the RS because it would require Constitutional amendments (competencies and authorities). On the other hand, FURs in Serbia are dynamic systems whose borders are not fixed and represent functional territorial levels without the elected government.

The territorial level of FURs (urban settlements and their surrounding areas which are complementary in functional terms) doesn't necessarily have to be transformed into invariable administrative units, but into flexible territorial levels that would perform planned actions in a less formal way. The goal is not to form a new level of government in the territorial organization of Serbia, but **a new informal level of governance** and a new mode of cooperation between urban settlements and the territories of local communities with a strong functional connection and interdependence between them (the principle of good will and common interest).

By proposing an appropriate **model of governance at the FUR level**, the existing administrative regions and administrations of local communities wouldn't have to be changed and the principle of subsidiarity would not be disturbed. This would mean that: firstly, decision-making at the local level (about priority projects, budget, public transport, water and energy management, making the tourist offer, *etc.*) is channeled into the planning at FUR level; secondly, local self-governments voluntarily cooperate with each other within the area of influence of the dominant center and with the central city settlement itself and the local plans are developed and fitted into the strategy of the wider functional area; at the level of FUR, operational programs are defined for different sectors, while determining the development priorities; the participation of all stakeholders, from the local population to investors, is encouraged, *etc*.

The spatial coverage of potential FURs should be limited at a given moment, all stakeholders should be involved in the planning process and a strategic development plan based on the results of their mutual cooperation and communication should be developed. It also means that decisions must be made about the future actions to be taken (e.g., the preparation of a strategic plan, *etc.*) at the level of FUR and the roles of different actors in this process. For example, public transport as one of the key activities that could be performed at the FUR level would be the basis for the future cooperation in other planning segments.

By summarizing the previous proposals, it can be concluded that where there is a problem in the management of certain spatial/regional systems, such as infrastructure, social, and similar problems and where the key sectors (water, energy, forests, *etc.*) are managed by different institutions, one of the possible solutions is to connect local self-governments and establish their mutual cooperation with the goal of achieving coordination at the FUR level.

8 Conclusions

Starting from the assumption that FUR is a coherent system of interconnected elements between which there is weaker or stronger interaction, it can be noted that it always has certain sub-wholes that are more or less sensitive to external factors. This "vulnerability" of functional urban systems is becoming increasingly noticeable in modern times due to the increasing density of population in metropolitan areas, the increase in their productivity and, consequently their exposure to various environmental hazards caused by climate change.

The research shows that in the last Census cross-section (2002–2011) in Serbia, the size of the workforce decreased as a result of the economic stagnation of the whole country. The economic recession reduced the number of employees in labor centers. On the other hand, it reduced the number of working contingents from the villages that became part of the inactive or self-employed population. The aging of the rural population and the shrinkage of the total active rural population decreased the daily migration from these settlements, most of which are very distant from the centers of work. Getting further from the FUR cores, the intensity of functional changes in settlements also decreased, urbanity declined, and the agrarian settlements positioned mainly on the periphery of FURs.

At the same time, increasing population concentrations in city cores, i.e. the centers of large urban zones have put pressure on cities and their functional areas coping with the ensuing problems of water supply, energy consumption, traffic volume and density, environmental threats/degradation, the establishment of public spaces and the quality of the management of cities and their functional areas.

Since FURs and large metropolitan areas have become the most important actors in climate change management today, needed is an adequate approach to their governance in order to comprehensively understand the resilience of cities and their surrounding areas (Bulkeley 2010).

If we want to improve the management of urban climate change and challenges facing functional areas, we must increase the existing capacities and improve the basic segments of a compact functional system: water, natural and human environment, energy, security, construction, *etc*. This means that human capital must be strengthened, territorial capital secured, new institutions established, flexible planning solutions produced, FUR management system improved and the local autonomy increased through the process of subsidiarity.

The goal is to direct the planning towards a new way of cooperation (not a new level of government) between cities and their functional areas. This cooperation would be ensured by local communities and supported by the higher levels of government. The above-stated is closely related to Spatial plan of the RS 2010 proposals, which in the segment on the functional organization of the settlement network and FURs propose the formation of joint formal or informal institutions at the level of the FUR, which would coordinate activities and promote institutional cooperation between the Cities/municipalities within a FUR (RASP 2010).

Higher levels of authority could support and direct the cooperation in FURs not through the application of strict rules and the allocation of budgetary resources between the Republic and local governments (which is usually unfavorable for them), but through different planning and economic initiatives and through a variety of modalities of public fund allocation.

Comprehensive reform of the existing planning system (including scientific research, practice, governance and strategic decision making) is a good preparatory stage not only for the introduction of the approach of territorially-integrated implementation of strategies, projects and operational programs, but also for the possible future use of EU structural funds.

Vujošević et al. (2014) propose *a new approach to strategic management and decision making in planning* through: new instruments of territorial integration of general economic, sectoral, governance, territorial development policies and strategic projects at different territorial/governance levels (pilot phase); systematic and comprehensive ex ante evaluation of possibilities and constraints for the introduction of the latest instruments of EU regional development policy; systematic introduction of Integrated Territorial Investment (ITI) and Community-Led Local Development (CLLD) concepts or the components of Instrument for Pre-Accession Assistance (IPA).

In order to establish cooperation and governance mechanisms between the local governments within a FUR, the potential funds from the EU structural funds are not currently sufficient. This process requires the country's own sources of financing (national and local), the establishment of an adequate legislative framework, political will, true decentralization and a number of others factors.

Without an adequate approach to urban governance and a clear understanding of resilience, cities and their functional areas (especially the Belgrade FUR) in Serbia are in danger of becoming uncompetitive in the European competition.

References

Adger WN (2000) Social and ecological resilience: are they related? Prog Hum Geogr 24(3):347–364

Alberti M, Marzluff JM (2004) Ecological resilience in urban ecosystems: linking urban patterns to human and ecological functions. Urban Ecosyst 7(3):241–265

Atkinson R (2014) The urban dimension in cohesion policy: past developments and future prospects. Paper presented at RSA workshop on 'The New Cycle of the Cohesion Policy in 2014–2020'. Institute for European Studies, Vrije Universiteit Brussels

Banister D (2008) The sustainable mobility paradigm. Transp Policy 15(2):73–80

Berkes F, Turner NJ (2006) Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. Hum Ecol 34(4):479–494

Bulkeley H (2010) Cities and the governing of climate change. Annu Rev Environ Resour 35:229–253

Collier M et al (2013) Transitioning to resilience and sustainability in urban communities. Cities 32. https://doi.org/10.1016/j.cities.2013.03.010

Davoudi S (2013) On resilience. disP Plann Rev 49:4–5

Davoudi S, Brooks E, Mehmood A (2013) Evolutionary resilience and strategies for climate adaptation. Plann Pract Res 28(3):307–322

Dempsey N (2010) Revisiting the compact city? Built Environ 36:5–8

ESMAP (2014) Planning energy efficient and livable cities. World Bank, USA

European Commission (EC) (2013) The EU strategy on adaptation to climate change. https://ec.europa.eu/clima/sities/files/docs/eu_strategy_en.pdf. Accessed Nov 2017

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev Environ Resour 30(1):441–473

Gunderson L, Holling CS (eds) (2001) Panarchy: understanding transformations in human and natural systems. Island Press, Washington, DC

Hallegatte S (2014) Economic resilience: definition and measurement. Policy research working paper (WPS 6852). World Bank Group, Washington, DC

Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4:1–23

Jabareen Y (2009) Building conceptual framework: philosophy, definitions and procedure. Int J Qual Methods 8(4):49–62

Jabareen Y (2013) Planning the resilient city: concepts and strategies for coping with climate change and environmental risk. Cities 31:220–229

Jacquier C (2010) Challenges and opportunities of multilevel governance in Europe. Presentation at the Belgian Presidency Multi-level Urban Governance Conference, Liège, December 2010

Jeftić M (2017) Functional urban regions of the Republic of Serbia in spatial planning. Conference proceedings. University of Banja Luka, pp 332–338. ISBN 978-99955-21-53-0 (in Serbian)

Mahoney J (2010) After KKV: the new methodology of qualitative research. World Polit 62(1):120–147

Nevenić RM (2013) Functional urban region—the instrument of polycentric spatial development of Serbia. In: Conference proceedings of 2nd international scientific conference—regional development, Spatial Planning and Strategic Governance. IAUS, Belgrade, pp 479–487. ISBN 978-86-80329-76-5

Pelling M (2003) The vulnerability of cities: natural disasters and social resilience. Earthscan, London

Perić A (2016) The evolution of planning thought in Serbia: can planning be 'resilient' to the transitional challenges? Int Plann Hist Soc Proc 7:181–194

Petrakos G (2012) The spatial aspects of development in Southeastern Europe. Discuss Pap Ser 8(3):37–66

Porter L, Davoudi S (2012) The politics of resilience for planning: a cautionary note. Plann Theory Pract 13(2):329–33

Republic Agency for Spatial Planning (RASP) (2010) Spatial plan. http://www.rapp.gov.rs/en-GB/content/cid310/spatial-plan-for-the-republic-of-serbia

Rose A, Krausmann E (2013) An economic framework for the development of a resilience index for business recovery. Int J Disaster Risk Reduct 5:73–83

Sachs J (2014): The age of sustainable development. Službeni Glasnik, Belgrade (in Serbian)

Šećerov V, Filipović D (2017) Urban planning and public interest in Serbian towns today. Conference documents of Spa-ce.net "The Role of Public Sector in Local Economic and Territorial Development in Central, Eastern and SEE", University of Architecture, Sofia, SPECTRA Bratislava, Leibniz Institute for Environment and Urban Planning, Dresden, pp 43–43

Tošić D (2012) Principles of regionalization. Faculty of Geography, Belgrade (in Serbian)

Tošić D, Nevenić M (2010) Urban settlements network—instrument of the spatial-functional organization of the Republic of Serbia. In: Krevs M, Djordjević D, Pichler-Milanović N (eds) Challenges of spatial development of Ljubljana and Belgrade. Univerza v Ljubljani

Tosics I (2011) Governance challenges and models for the cities of tomorrow. Issue paper prepared for the European Commission—DG Regional Policy for the Cities of Tomorrow programme. January 2011

Tsenkova S (2011) Venturing into unknown territory: strategic spatial planning in post-socialist cities. Urban Challenge 22(1):5–21

UNISDR (2017) UN plan of action on disaster risk reduction for resilience. UN-Geneva

Vujošević M, Zeković S, Maričić T (eds) (2014) New European regionalism and regional governance in Serbia (2). IAUS, Beograd (in Serbian)

Walker B, Holling CS, Carpenter SR, Kinying A (2004) Resilience, adaptability and transformability in socio-ecological systems. Ecol Soc 9(2):5. https://www.ecologyandsociety.org/vol9/iss2/art5/

Climate Change and Protection Against Floods

Cedomir Crnogorac and Vesna Rajcevic

Abstract Today, there is little doubt in academic circles on global scale that the phenomenon of global warming is taking place, with the increase of carbon-dioxide due to burning of fossil fuels being labeled as the main reason. According to referent data, the average temperature will have risen for approximately 2–3.5 °C, which presents a true danger for the functioning of human population and numerous animal and plant species. In addition, climate change significantly affects the regime of watercourses in the geographic area of Bosnia and Herzegovina, where frequent phenomena of extreme drought periods and rainfall peaks are recorded, thus affecting the water management facilities and the health of people. In May 2014, at the occurrence of high waters and consequent flooding of numerous settlements in Bosnia and Herzegovina, it was not possible to record the values of water level and flow. With a view to protecting riverbanks and their surrounding terrain for future hydrologic support (for instance, project documentation, height of the embankment), these values must be set.

Keywords Climate change · River regime · Great water · Floods
Extrapolation of the flow curve

1 Introduction

Climate changes. According to the National Report of Bosnia and Herzegovina, in line with the United Nations Framework Convention on Climate Changes (UNFCCC), and long-term meteorological projections, there is a strong likelihood that one could experience climate changes by the end of this century. A further rise in

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the average air temperature and more frequent occurrence of both dry and rain spells, exerting intense influence on agriculture, waterworks, economy, as well as on human health, is forecast, with some devastating floods as an inevitable consequence.

However, it is necessary to remind one of the fact that climatology and its complementary disciplines use special methods to obtain relevant data on climate changes, in terms of both synchronic and diachronic research. What is implied under the term of climate change is either progressive improvement or deterioration of the long-term weather regime in an area of the Earth, determined by geographic conditions. The majority of prominent climatologists of the 20th century claim that such (directed) changes in meteorological elements are only possible with changes of factors affecting the formation of a certain climate, such as:

- the change in the amount of solar radiation absorbed by the surface of our planet, which can be caused by the change of the Earth's Axial Tilt relative to a stationary orbital plane;
- changes in the relief of our planet (orographic component, mountain range direction);
- change in land-sea relation;
- change in the relation between the solar radiation the Earth, together with the atmosphere, reflects back into the universe and the solar radiation that reaches the frontier of the atmosphere;
- geogenic or anthropogenic change of the structure of the Earth's atmospheric complex;

All the aforementioned elements may change the heat and water balance of the geographic layer, thus causing the transformation of climate in certain areas of our planet or setting in of new climate characteristics at the global level. Therefore, it is not unusual for some significant climate changes to have occurred in prolonged periods of time, close to the duration of some geological epoch.

When shorter periods of time are concerned, it is impossible to determine whether it is the climate change, that is, directed change of meteorological elements, or rhythmic changes of climate. The term rhythm signifies repetition of the complex of phenomena over time, which develops in a single direction. There are two forms of rhythmic changes in the geographic layer: periodical and cyclic. The latter implies the rhythm of equal duration, such as rotation and revolution of the Earth, whereas the former represents time spans in which certain phenomena occur in variable intervals (for instance, glacial and interglacial).

One of the issues imposed by the comprehensive process of globalization is the one of 'global warming', that is, already promoted 'climate changes'. There are numerous disputes in printed and electronic media over the issue of whether the climate is becoming 'ever hotter' or we 'are about to' face a new ice age, most of which having no scientific grounds whatsoever, due to the fact that the fluctuation of climate elements, whose range of instrumental readings has been known to us for merely a hundred years now, is misinterpreted as the climate change. As Lazarevic points out, our ephemeral existence as human beings and a short period of instrumental readings cannot corroborate the climate change with relevant facts. In short, we can only talk of spatial and temporal aspect of fluctuation of climate, but not of the climate change itself.

2 Formulation of the Problem

It is a common fact that imminent danger of climate, as well as a series of other natural disasters cannot be denied. Trenberth claims that the human population should undertake protective measures within every geographic area, especially in the domain of flood risk management. Adequate and timely hydrological forecast of extreme meteorological phenomena, hydrological ones in particular, is in function of assisting the human population to perform pre-emptive steps towards absorbing the effects of possible catastrophic disasters (casualties and material damage). It is not possible to pinpoint the current expansion of flood waves on the Earth, but it remains the fact that they are more and more frequent, with emphasis on sudden floods. They can occur in any river basin, that is, watercourse, featuring destructive energy, but lasting for a short period of time, 'from ten minutes to several hours' (Bonaci 2016). Although they are not spatially limited, they do differ in terms of consequences regarding various geographic areas (plains, mountainous regions, urban areas, karst, barren lands, forest soil etc.).

The consequences of flood waves are a result of a sudden increase in water level and flow, an increase in water speed in riverbeds, pronounced fluvial erosion, as well as building up of enormous quantities of deposits and pollutants. Therefore, the obvious causality of climate change and floods demands updating of climate modelling and flood waves forecast. One of the priorities is the design of flood danger and risk maps in Bosnia and Herzegovina, with a view to graphically representing flood areas with likely level of floods, especially in cases where there is evident danger for population, material goods and disturbance of the environment. If an adequate analysis of anthropogenic factors regarding danger maps is conducted (population density, economic potentials, land resources etc.), it is possible to define the flood risk level as well.

The ultimate goal concerning the design of 'The flood danger and risk map' according to the methodology of the Institute for Hydrotechnics of the Faculty of Civil Engineering, University of Sarajevo) is a document that is not only going to match its EU counterparts, but also to serve as foundation for complementary Flood risk maps in Bosnia and Herzegovina, which implies nivelation after a certain period of time.

3 The Influence of Climate Changes and Elements on River Regimes

River regimes are regular changes of water level, flow and speed over a certain period of time. They are a consequence of the way the river is fed by water, and there are following types: nival, pluvial, nival-pluvial etc. In most cases they are combined, with one type domineering as regards certain sections of the watercourse and various seasons.

It is obviuos that climate elements play a major role in terms of feeding water to watercourses and changing their conditions, rainfall (atmospheric water that reaches watercourses) in the first place, but also the elements that reduce the amount of water that runs off to watercourses by means of increased evaporation, such as: air temperature, air humidity, and wind speed and frequency. This influence was observed by the Russian climatologist A. I. Voyeykov (1842–1916), who claimed that 'rivers were a product of climates' and who presented the climate classification of water regimes in 1884.

Formulation of the problem.—The research conducted after the enormous damage inflicted by flooding the terrain stretching along major watercourses and their tributaries in Bosnia and Herzegovina provided nothing but gloomy forecast regarding the flood risk. It may cause extremely harmful consequences for population and material goods unless the basic principles, as well as the goals of the design of the Study of Water Basins Management in Bosnia and Herzegovina, are timely defined. With regards to that, the protection against harmful effects of water is certainly a priority, which is necessary to be harmonized with the rank and quality of the projects realized in terms of urban, economic, infrastructural and other systems that require protection against high waters. This principle is a result of the general one, stating that the protection of a geographic area is a dynamic category, and that it changes depending on the changes regarding validity of endangered material goods, as well as on the new approach to hydrological processing, morphological changes in the basin and changes in river regimes. While doing this, it is necessary to assess which of the levels of protection is the most suitable one.

Understanding high waters is crucial for dimensioning hydrotechnical objects, as well as for the profitability of buildoff and safety issues. As for dimensioning, if under-calculated, there is an increased flood risk and subsequent object collapse, with all other unfavourable consequences (Nakic 2010). On the contrary, over-dimensioned objects, not in line with safety requirements, present wasting of funds.

In order to assess the range of climate change, it is necessary to analyze, above all, anthropogenic influences on weather and climate. By means of felling trees over vast surface areas, and over the course of many centuries, the human population has changed the climate over large geographic areas. In addition, by clearing deciduous forests of the temperate climate belt, humans have created the cultural steppe with a different climate, featuring a series of variants of microclimate, without even realizing it. As for mountainous regions, clearing forests is responsible for changing the microclimate, speeding up erosion and altering the size of components of water balance (Blagojević et al. 2016).

In terms of protection against floods, the forthcoming Atlas of Climate of Bosnia and Herzegovina is going to be of great assistance. It is of interactive nature, developed as a web GIS application. It consists of climate maps for two climate elements, air temperature and precipitation. The climate periods processed are the 1961–1990 one, as well as the periods of 2001–2030 and 2071–2100 respectively, designed according to A1B and A2 scenarios pointing to future climate change.

In it, there are certain climate norms established, that is, the quantity characteristics of the climate have been gained statistically from annual (over 20 years) observations (median monthly, seasonal, and annual values of air temperature and rainfall). This atlas enables defining climate anomalies in the domain of deviation of the observed or median value of meteorological elements at certain place/metre station in Bosnia and Herzegovina from its perennial median value. Moreover, it is possible to determine the deviation of perennial median monthly or annual value of meteorological elements in the given place from the perennial median value of the element in question in terms of certain latitudinal belt of Bosnia and Herzegovina. Depending on the mark of deviation, it is possible to determine either positive or negative climate anomaly.

When it comes to assessing the value of the Atlas, one should be reminded of important facts regarding the connectivity of climatology and meteorology (the physics of atmosphere) with their close scholarly disciplines, hydrology (the physics of hydrosphere) and geology/geomorphology (the physics of lithosphere). As for hydrology, there is no strict divide from the disciplines of climatology and meteorology. In terms of water management, the Atlas is going to enable certain short-term and long-term forecast in water supply of settlements and economy, irrigation possibilities, development of fishery, tourism etc. As for the water management, the rainfall data are going to enable the realization of basin management projects, fight against erosion and torrents, protection against floods and draining of agricultural land. Regarding the protection and development of water resources, they are going to serve the purpose of prescribing measures for saving water, defining legislation regarding downstream and upstream interests, as well as determining future water resources. Also, it is evident that geomorphologic processes and phenomena are going to be largely determined by air temperature and rainfall too.

Excessive felling of trees in basins of numerous rivers in Bosnia and Herzegovina has disturbed regular runoff of rainfall, since plants are best regulators of the runoff regime over forest and agricultural land. As a result of increased disappearance of forests in basins of major rivers and their tributaries in Bosnia and Herzegovina, there are erosions and torrents now, with the disturbance of natural balance between vegetation, land, and specific runoff.

Forests and forest land account for 50% of the geographic area of Bosnia and Herzegovina, they represent common interest goods and, as such, they should be under the care of all levels of authority, from state to local ones. For that purpose, it is necessary to introduce a law defining forest resources management. In practical terms, this means that the export of timber should be stopped, and the manufacturing of final products encouraged.

The basic issue in terms of researching basins and watercourses in Bosnia and Herzegovina is structurally contained in defining characteristics of basin regions, researching into the complex of natural factors of basin regions, then in designing of water balance, and in analyzing water regimes and major water management problems in the basin. The referent nature of the research demanded the use of wide spectrum of methods and technics, used at design of specific potamologic research. Some of the results of research, to a certain extent, are going to serve as a basis for rational use and management of watercourses in basins in Bosnia and Herzegovina.

4 Problem Solution

The analysis of hydrometeorological data and data concerning water regime (water level and flow) in Bosnia and Herzegovina shows that this geographic area is at large risk of floods. On several occasions (the paper focuses on floods from May 2014) enormous damage has been inflicted to the economy and population, with the loss of human lives.

The damage inflicted in the basins of major rivers in Bosnia and Herzegovina (Una with Sana, Vrbas with Vrbanja, Bosna with Spreča, Usora and Drina) was caused by abundant precipitation in the Sava basin (200–250 l/m^2 in three days), non-existence of waterworks protective objects and a reduced level of protection or collapse of the existing objects for the protection of high waters. The protection against high waters should be an absolute priority, but it must be harmonized with the needs and level of threat.

When the legislation defining the area of protection against floods in Bosnia and Herzegovina (the Federation of Bosnia and Herzegovina and the Republic of Srpska) is concerned, it is obvious that it is a complex system, underequipped and hard to control, suffering from a lack of subordination and coordination, which renders it inadequate in times of need.

Therefore, we propose the following steps regarding solving the issue of high waters in river basins in Bosnia and Herzegovina:

- land survey scanning of riverbeds utilizing transversal profiles;
- analyze the whole of the basin (geographic position, borders of the basin, erosion
- processes in the basin, coefficient of forestation etc.);
- conduct a hydrological-morphological and hydraulic analysis in urban areas of the river and its tributaries;
- view how endangered the municipalities are by torrential erosion and landslides and propose adequate reclamation measures;
- analyze the objects erected in riverbeds of major rivers and its tributaries and their influence on the reduction of flow capacity of riverbeds;

– propose various solutions to increase the flow capacity of the rivers belonging to the basin, especially in urban areas;
– propose a general concept of sewage systems in the basin;
– multi-municipal action directed at protection measures;
– define pre-emptive monitoring system in case of high waters.

Positive effects of civil engineering aimed at preventing floods are visible in immediate physical protection of human population and their property in flood areas. Among these one can include transformation of great flood waves, where major part is played by accumulative lakes and retentions (retaining water from pouring out and flooding or using it for melioration etc.). Accumulative lakes have to be designed in such a way as 'to absorb the whole of the wave from its emergence up to the moment of its decline. If the purpose and size of the lake do not allow for the absorption of the whole wave, then retentions are built in upstream areas of the basin, with the sole task of reducing the natural flow of the wave, which is called flattening of the wave or transformation of the hydrogram'(7).

5 Harmonization of the Flood Protection System with the EU Directive 2007/60 EC on the Assessment and Management of Flood Risks

There have been four tasks identified within this measure, referring to the following:

(a) design of danger maps and flood risk maps for the whole of the territory of Bosnia and Herzegovina in line with the revised preliminary assessment of flood risk;
(b) design and introduction of Plans for flood risk management, information exchange, and coordination between the competent bodies in Bosnia and Herzegovina and abroad;
(c) need to connect the Plans for flood risk management and Plans for river basin management; and
(d) active participation of public and interested parties (EU Directive 2007/60 EC on the Assessment and Management of Flood Risks).

The design of danger maps and flood risk maps is a short-term measure, whose realization is a prerequisite for further activities regarding the introduction of the Plans for flood risk management. The preliminary flood risk assessments, already designed for both the Federation of Bosnia and Herzegovina and the Republic of Srpska, should be updated taking into account the 2014 floods, whereas for the Brcko District of Bosnia and Herzegovina the preliminary flood risk assessment is yet to be designed. Currently, there are activities undergoing aimed at obtaining IPA/WBIF funds for the realization of this project (Action Plan for Flood Protection and River Management in Bosnia and Herzegovina, 2014).

After the maps have been designed, it is necessary to start designing Plans for flood risk management, in line with provisions of the EU Directive 2007/60 EC on the Assessment and Management of Flood Risks, which makes this measure a medium-term one. The realization of the aforementioned activities implies intense cooperation with the competent bodies in Bosnia and Herzegovina, including institutions in charge of the environment protection, spatial planning, rescue and protection, as well as cooperation with institutions in the neighbouring countries and other international institutions dealing with this issue, such as the Sava River Commission and the ICPDR. When designing the Plans for flood risk management, it is necessary to take into account the connection with the Plans for river basin management and assessment of the climate change influence. In addition, it is crucial to ensure the participation of public and interested parties into the process of designing and introducing these plans.

6 Conclusion

In May 2014, Bosnia and Herzegovina was struck by the greatest floods since 1892, when the continuous measuring of hydrometeorological processes was introduced in the country. The intense precipitation led to the pouring out of several rivers from their riverbeds—the Bosna and the Sava in particular, as well as the rivers Drina, Una, Sana and their respective tributaries, causing sudden and extreme floods on numerous locations, with the maximum that exceeded the 500-year-recurrent period. Given the fact that the flood prevention system in Bosnia and Herzegovina is established, according to the law, for the 100-year recurrent period, it is obvious how devastating this disaster was.

So far, all the analyses conducted show that the high level of damage inflicted was the result of extreme precipitation in the April-May period of 2014. In order to minimize damage in the future, it is necessary to remove drawbacks in the flood protection and water management systems, in the systems of meteorological and hydrological monitoring, early warning and alarming systems, as well as in those dealing with the rescue and protection of people and material assets. All of these drawbacks need to be identified and analyzed in order for priority measures to be determined, whose implementation would lead to the improvement of the flood protection system.

Since 1992, the water management has been inefficient, and the existing institutional framework regarding numerous issues related to water management has been decentralized, both at the level of entity and local communities. So far, the authorities in Bosnia and Herzegovina have not undertaken adequate measures to compensate for the drawbacks concerning the coordinated and harmonized approach to water management at the state level, which is one of the remarks of the European Commission stated in its Annual Reports on the Progress in Bosnia and Herzegovina.

It is necessary to immediately start the process of designing a new multi-year programme of activities within the flood protection system, including a new long-term strategy of investments into the flood defense system, as well as assessment of future needs, taking into account the latest risk maps and economic analyses.

Bosnia and Herzegovina is a signatory of most international agreements and conventions, which obliges it, as a country involved in European integrations processes, to implement the EU acquis and the aforementioned agreements into its legislation. As for the EU, it has introduced a series of agreements and conventions for its member-states, which have, by applying them, harmonized and improved their legal, organizational, and management framework regarding the sector of waters and water management legislation.

References

AKCIONI PLAN ZA ZAŠTITU OD POPLAVA I UPRAVLJANJE RIJEKAMA U BiH 2014-2017 Sarajevo, novembar 2014. godine, BOSNA I HERCEGOVINA SAVJET MINISTARA (in Serbian)

Bajić D, Trbić G (2016) Klimatski atlas Bosne i Hercegovine, Temperature i padavine (1961-1990, A1B 2001-2030, A1B 2071-2100, A2 2071-2100), ONLINE Izdanje, Univerzitet u Banjoj Luci, Prirodno-matematički fakultet, Banja Luka, ISBN: 978-99955-21-48-6 COBISS.RS-ID: 6000920 (in Serbian)

Blagojević V et al (2016) Metodologija za izradu mape opasnosti i mapa rizika od oplava u BiH, I BiH Kongres o vodama, UKI BiH, Sarajevo, pp 1–13 (in Serbian)

Bonacci O (2016) Nagle poplave – Novi izazov pri upavljanju vodnim resursima, I BiH kongres o vodama. UKI BiH, Sarajevo, pp 1–9 (in Serbian)

Climate change, impact and vulnerability in Europe 2016, An indicator—based report, European Environment Agency, EEA Report, No. 1/2017. ISSN 1977-8449

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. Official J Eur Union L288 od 6.11.2007, str. 27–34

Đurđević V (2012) Development of climate models and scenarios for the SNC Bosnia and Herzegovina under the UNFCCC, 2012—Razvoj klimatskih modela i scenarija za Drugi nacionalni izvještaj Bosne i Hercegovine u okviru Okvirne konvencije Ujedinjenih nacija za klimatske promjene (UNFCCC) (in Serbian)

'Europe', The regional impacts of climate change: an assessment of vulnerability. In: Chap. 5, Intergovernmental panel on climate change. Cambridge University Press (1997)

Goran Trbić (2013) Climate change adaptation and low emission development strategy for Bosnia and Herzegovina. Technical Report (PDF available), October 2013, https://doi.org/10.13140/rg.2.1.1235.5443

Kupusović T, Vučijak B, Kovčić O (2015) Reservoir Modrac and its functioning during the floods in May 2014, Hrvatske vode, Časopis za vodno gospodarstvo 23(91):19–28. ISSN 1330-1144, ISSN 1849-0506 (Online), UDK 628.1 (497.5), Zagreb (in Croatian)

Kyoto Protocol to the United Nations Framework Convention on Climate Change, United Nations, 1998

Nakić Z (2010) Geologija okoliša, Sveučilište u Zagrebu, Rudarsko-geološko-naftni fakultet, Zagreb (in Croatian)

National Inventory Submissions (2012) Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol

NEAP – Akcijski plan za zaštitu životne sredine. Bosna i Hercegovina (2003)

Procjena ugroženosti Federacije Bosne i Hercegovine od prirodnih i drugih nesreća, Federalna uprava civilne zaštite, Arch Design, d.o.o., Sarajevo, decembar 2014 (in Bosnian)

Strategija prilagođavanja na klimatske promjene i niskoemisionog razvoja za Bosnu i Hercegovinu, juni 2013. godine; Strategija prilagođavanja na klimatske promjene i niskoemisionog razvoja za Bosnu i Hercegovinu usvojena je od strane Vijeća ministara Bosne i Hercegovine 08. oktobra 2013. godine (in Serbian)
The 2015 United Nations Climate Change Conference, Paris, France, 30 November–12 December 2015
The Initial National Communication (INC) of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change (UNFCCC), Banja Luka, October 2009
The Second National Communication (SNC) of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change (UNFCCC), June 2013
The Third National Communication (TNC) and Second Biennial Update Report on Greenhouse Gas Emissions (SBUR) of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change (UNFCCC), July 2016
UNDP Bosna i Hercegovina "Integrisanje klimatskih promjena u smanjenju rizika od poplava u slivu rijeke Vrbas". Početak projekta 01.04.2015, Završetak projekta 01.04.2020 (in Serbian)

Duration of the Snow Cover and the Need for Artificial Snow—A Challenge for Management in Ski-Centres of Serbia

Marko Joksimović, Dejan Šabić, Snežana Vujadinović, Rajko Golić and Mirjana Gajić

Abstract The production and use of artificial snow has become necessary in most ski centres in Europe. The lack of snow creates problems in ski centres that were built without the prior valuation of natural factors. The survey covered winter tourist centres in Serbia, which are facing problems due to the shortening of the tourist season caused by the lack of snow cover on the ski slopes. The duration of the snow cover is the result of several factors. Air temperature changes were analysed in mountain tourist centres in Serbia, as well as at undeveloped destinations with a potential for snow sports. On the basis of the quantitative indicators of the air temperature and the methodology by means of which snowmaking is carried out, the time periods during the year for making artificial snow are presented. Due to the forecast rise in air temperature, the issue of profitability of artificial snow in the ski centres of Serbia remains open.

Keywords Snow cover · Air temperature · Duration · Correlation Index · Serbia

In the last 40 years, winter tourist centres have faced a number of problems due to climate change. According to importance for the development of winter sports tourism in the mountains, climatic elements are indexed and ranked as follows: precipitation—index 6.04, thermal component (temperature and humidity) 5.84, insolation 5.55 and wind speed 5.41 (Scott and Lemieux 2010). Depending on climatic factors, the problems are different, but they are reduced to the lack of snow cover. Since 1966, higher air temperature and uneven precipitation have affected the 10% shorter retention of snow cover on the northern hemisphere (Folland 2001). Observations show significant reductions in the North Hemisphere's (NH) snow cover extent over the past 90 years, with most of the reduction occurring in the 1980s. Because of earlier spring snowmelt, the duration of the NH snow season has declined by 5.3 days per decade since the 1972/1973 winter (Stocker 2013). By the end of the 20th century, Alpine tourist centres rarely faced the lack of snow. However, for three years in a row

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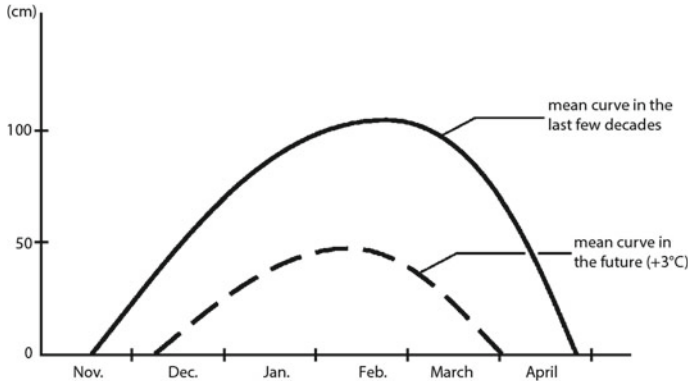

Fig. 1 Descriptive presentation of snow depth during snow cover period at the altitude of 1500 meters during the last few decades and a future scenario (Foehn 1990)

from 1987 to 1990, winters were unusually warm, affecting destinations by reducing the number of overnight stays and profits of resorts, transport companies and retail chains. A smaller number of tourists affected negatively the vulnerable rural areas in which tourism is the main economic sector, but also a reason for the survival of local population. The lack of snow cover was most expressed in lower altitude centres, with poor orientation of ski trails and sensitive ecosystems. During the winter season with the lack of snow in most visited centres, ski centres located at high altitudes (close to or above snow line) have benefited. According to most climate change scenarios in the Alps's winter tourist regions, the temperature of the air will be increasing, while the pattern of the future distribution of precipitation varies (Koenig and Abegg 1997; Moen and Fredman 2007; Wilcke et al. 2012). As a result of an increase in the air temperature in the Alps, the rising of the snow line, a delayed beginning of the tourist season and the shortening of the season by one month are expected. New strategies and plans for tourism development have been announced in order to adapt to climate change. So far, dozens of papers have been published on the effects of climate change on winter sports tourism. In relation to the methods of adaptation to climate change since then, various aspects have been studied: winter tourism adaptation to climate change (Abegg et al. 2007; Scott and McBoyle 2007; Wall and Badke 1994) stakeholder views and risk management (Trawöger 2014), costs of snow making (Hahn 2004) and the effects of artificial snow making (Caravello et al. 2006; de Jong and Barth 2007; Rixen et al. 2003) (Fig. 1).

Although most papers on the impact of climate change on ski tourism in Europe focus on Western and Northern Europe, some recent studies suggest that ski tourism is threatened by climate change in the countries of Central Europe and the Balkan Peninsula, such as Poland (Bil 2018), Slovakia (Mikloš et al. 2015), Slovenia (Ogrin et al. 2011; Vrtačnik Garbas 2009), Romania (Micu 2009), Bulgaria (Demiroglu 2016; Grunewald et al. 2009), and Serbia (Djordjevic et al. 2016; Stojsavljević et al. 2016). On the Bulgarian mountain Musala (period 1973–2006) the main changes are: a general decrease of days with temperatures below 0 °C, a significant longer vegetative period (>5 °C), and the tendency to shorter winters and longer summers (Grunewald et al. 2009). Some Romanian mountain areas (particularly in the Southern Carpathians) are supposed to experience more rainy than snow days, during winter ski season (December–March) and a rise of temperature by over 1.0 °C until 2050 (Micu 2009). Econometric studies for Romania (Dincă et al. 2014; Surugiu et al. 2010, 2011), Slovakia (Demiroglu et al. 2015), Slovenia (Vrtačnik Garbas 2007) and Bulgaria (Mochurova et al. 2010) confirm that observed climatic changes in the ski resorts could lead to losses in tourist business. Demiroglu et al (2015) predict that due to the anticipated temperature increases, sales in Slovak ski resorts in the 21st century will drop by 6.6–19.2%. Slovenian ski resorts are even more vulnerable in comparison to other ski resorts in the Alps, since they lie at lower elevations. Furthermore, this means that winter tourism will need to focus on other activities; they will also need to focus on the summer season and on transitional periods as well (Ogrin et al. 2011). Damm et al. (2016) predict that in the period 2035–2065 the ski season in Slovakia and Slovenia will be shorter compared to the period 1971–2000; in some resorts it will be shortened by more than 30 days.

Adaptation to the winter season with a shorter retention of snow cover includes several strategies: 1. relocation or construction of ski centres at higher altitudes, 2. development of special interest tourism, 3. artificial snow making and 4. cooperation between companies.

At the latitudes between 40 and 45° N, due to the theoretical height of the modern snow line (of about 3000 m), the *first strategy* is possible in mountains where there are spaces (e.g over 2500 m where ski runs and installations are not yet built) (Grunewald and Schiethauer 2010; Milivojević et al. 2008). Spaces above 2500 m in Serbia are negligible. They are located on Šara mountain and on Prokletije, so this strategy is not a solution. In addition, there are numerous works in which negative effects of mass construction in already existing ski centres with over 1200 m are proved (Bjedov et al. 2011; EJR 2018; Potić et al. 2015; Ristić et al. 2008a, b, c, d, 2009; Šušić and Đorđević 2013). Ski resorts of individual centres are located in fragile reserves within national parks (Kopaonik, Shar Planina) and nature parks (Zlatibor, Stara planina).

A good example of the *second strategy* is the Romanian mountain resort of Sinaia, whose profile is more for business, weekend and recreational tourism and not only for winter sports tourism. Research indicates that the Sinaia resort is not very vulnerable to climate change. Reduction in snow cover depth and increase in mean air temperature attract tourists and increase the number of overnights in Sinaia. Thus, climate change expressed through increase in temperature does not necessarily bring only negative effects, but depending on the profile of the resorts, it can also bring positive effects (Surugiu et al. 2011). In Serbia, the second strategy has a tradition of 10 years in the mountains like Kopaonik, Zlatibor, Zlatar, Stara planina, Suva planina and Maljen. There is an offer of special interest tourism where tourist activities take place during the spring, summer and autumn. This is a part of the year in which snow cover is not a critical climatic element (Joksimović et al. 2015; Vujadinović et al. 2013).

Consequently, the climate is not a limiting factor of tourism, but, depending on the nature of the changes, stimulates one and limits other forms of tourism.

The rising trend in air temperature in Serbia is in line with trend in Europe. Analysis of the time series of the North Atlantic Oscillation (NAO) and EA index showed that both factors influenced the increase in air temperature in Serbia. In the period during the winter, an increase in air temperature was recorded from 0.02 to 1.82 °C (Bajat et al. 2015; Unkašević and Tošić 2013). The increase in air temperature is influenced by modifiers such as altitude, terrain morphology, aspects, slope angle, vegetation, hydrographic objects and settlements. The *third* and *fourth strategies* have been implemented for 20 years in mountain centres. However, in the action plans and master plans of winter tourism, climate data are not analyzed in the context of climate change (ECOSIGN 2007; HTL 2009). Since climate change does not affect all destinations equally, research at the regional level is one of the ways that can effectively respond to the needs of winter sports centres. Regional climate models have been identified as the best solutions for climate change and impact scenarios (Wilcke et al. 2012). Among the climate change scenarios, the warm and dry climate scenarios, as well as the humid and cold climate for the periods 1961–2000 and 2001–2050, are used equally. The most widespread climate change strategy is investing in building a system for artificial snow making (Wolfsegger et al. 2008). Snow making has become the method most used to overcome immediate impacts of climate change in ski resorts worldwide (Demiroglu 2016). It often creates a conflict between investors and communities advocating environmental protection (environmentalists). Creation of artificial snow leads to permanent environmental impact which requires great energy and huge amounts of water. By building up the accompanying infrastructure, the ecosystems and the aesthetic properties of the area are disturbed. The most common problems arising from the unplanned construction of ski resorts and artificial snow systems are: deforestation, erosion processes, increased floods and torrents, and aesthetically degraded area without vegetation, unattractive outside the ski season.

Production of artificial snow was developed in North America in the fifties and sixties of the 20th century. It occurred in Europe during the seventies (Hahn 2004). The basic factors that influence production of artificial snow are: water, energy, air temperature and humidity. Water is dispersed during the day or night when the air temperature is below 0 °C and falls on the surface as snow. With the current technology, air temperatures ≤ -1 °C and air humidity of more than 40% are required to make artificial snow. On a wet thermometer, the air temperature is ≤ -5.1 °C. With the use of certain additives, the required air temperature can be higher. Resulting artificial snow differs from the natural one due to the different appearance of snowflakes. Water used for artificial snow is extracted from rivers, springs or lakes. Its composition is different from rainwater, which makes snow different (Rixen et al. 2003). For the production of artificial snow 30 cm thick, on an area of one hectare, 1000 m^3 of water is needed (Hahn 2004). Snow making systems are used mostly at night. Accordingly, the reference is air humidity after 21 h and the mean daily air temperature below 0 °C. The use of water from rivers, springs, underground water and water supply reduces the water level in the lower areas, which causes ecological

Table 1 Wet bulb temperature as a factor for artificial snow production

Air humidity (%)	Air temperature (°C)								
	3	2	1	0	−1	−2	−3	−4	−5
100	3	2	1	0	**−1**	**−2**	**−3**	**−4**	**−5**
80	1.7	0.7	−0.2	**−**1.1	**−2.1**	**−3**	**−4**	**−4.9**	**−5.9**
60	0.3	−0.5	−1.4	−2.3	**−3.2**	**−4.1**	**−5**	**−5.8**	**−6.7**
40	−1	−1.8	−2.6	−3.5	**−4.3**	**−5.1**	**−5.9**	**−6.8**	**−7.6**
20	−2.5	−3.3	−4.1	−4.8	**−5.6**	**−6.4**	**−7.2**	**−8**	**−8.4**

Source Lang 2009

consequences. The costs of snow making have been investigated in several papers (Abegg et al. 2007; Hahn 2004) (Table 1).

The objectives of artificial snow making are:

1. Artificial snow production should respond to the demands of the skiers—to match the lack of snow cover and to respond to the demands of a large number of tourists;
2. Production of artificial snow should bring profit to investing companies;
3. Providing the image of sports destinations where skiing competitions are held;
4. It should provide a framework for training, recreational ride and sporting competitions.

In addition to these, we emphasize that the construction of a snowmaking system should be in accordance with the environmental conditions and resources in order to avoid adverse effects on relief, water and habitats.

1 Climate Conditions as a Factor of Development of Winter Sports Tourism in Serbia

The development of winter sports tourism has a tradition of 90 years. Initially, the development of winter sports was related to mountains near major cities. In Avala near Belgrade, in 1929, a cross-country skiing competition was held at 8 km. With the opening of the first mountain hut on Kopaonik in 1935, the tourist stage of skiing in Serbia began. This also started the phase of valorization of climate indicators (air temperature, snow cover) for the purpose of opening ski centres. The number of competitors, recreationalists, trails and infrastructure facilities increased. The first competition in alpine disciplines in Serbia was held at Kopaonik in 1936 (Mišović and Nišavić 1951). Today, winter sports tourism in Serbia is developing on several mountains. Due to climate change, investments in ski tourism are becoming more risky. In the 1991–2016 period, on Kopaonik, there were 31% days with a snow cover of less than 30 cm, which led to the production of artificial snow. The duration of a snow cover suitable for skiing influences the tourist demand and the hosts of the offer are forced to produce artificial snow.

Winter sports tourism includes sports that take place on the snow cover or in relation to the snow cover: alpine skiing, cross-country skiing, ski jumping, climbing, sledding, curling, skating etc. In Serbia, artificial snow systems are developed in five ski centres: Kopaonik, Stara Planina, Zlatibor, Brezovica and Tara. The systems are used to provide ski trails with artificial snow in periods when there is no natural snow. This ensures the stability of the ski season, i.e a response to the demand of the skiers as well as the profit of the stakeholders.

The systems were built successively, with the extension of the cableway and the construction of new tracks. For the needs of snow making, mini accumulations were made, followed by pumping plants, piping installations of water and air, compression plant and snow machines. On Kopaonik, since 2008, the old system for regeneration has been revitalized and a new one has been set up in four phases: 2008, 2009, 2010, 2012. System management is regulated by software. In this way, relative to the current temperature, humidity and wind direction can be controlled by the process of snowmaking to obtain the desired quantity and quality of snow. For the production of artificial snow, natural, unprocessed water is collected in accumulation lakes without chemical additives. Kopaonik resort is equipped with 300 fixed and 15 mobile snowmaking devices (Infokop 2014).

On the basis of climatic indicators, the aim of our work was to underline regions with comparative advantages as well as a time frame for artificial snowmaking in Serbia. We believe that in our work the original methodology for allocating regions with comparative advantages for artificial snow making has been applied. Our standpoint is that it is necessary to use the natural conditions for skiing in the less valued ski centres in order to reduce tourist pressure on main ski centres developed in fragile areas. This would probably reduce the need for snowmaking and prevent further degradation of the environment.

2 Method and Observational Data

In order to determine climate potential for skiing in different regions of Serbia, the Kopaonik ski resort was selected as the basic model of research. The aforesaid centre has the longest tradition of winter tourism development and a complete database of climate data as compared with other stations. The determined indicators are the duration of the snow cover, the number of days with the average daily temperature below zero, the relative humidity, the average height of the snow cover by months at the daily level and the average number of tourist nights by months. Based on the Kopaonik model, the correlations of climate indicators were analysed and the need for artificial snowmaking was determined for other stations. At the regional level, ski resorts (ski runs and infrastructure for skiing without accompanying accommodation facilities) and ski centres (ski resorts with built accommodation facilities and a number of services) were allocated. Among ski centres, there are complex resorts, weekend resorts, city resorts and spa resorts. Based on the Kopaonik model, a regional climate model for the other existing 16 ski resorts and ski runs has been given.

These models required data at a different spatial level and are based on a different time series—the statistical data of the Republic Hydrometeorological Service of Serbia (RHSS 2017), the Statistical Office of the Republic of Serbia (SORS 2017), unpublished data of the Ski Resort of Serbia (Infokop 2014, the data obtained by field research and created by GIS software. The data related to the 1991–2016 period and a special focus was put on the winter tourist season (December 1–April 15). On DEM (digital elevation map) we determined regions with 900 m of altitude and higher, where the largest number of ski resorts is concentrated. Those regions are located mainly in the southern part of Serbia. Numerous valleys, mountains and plateaus are part of the Dinaric, Carpathian, Balkan, Šara-Pindus systems and the Serbian-Macedonian mass. A limit in the survey was the fact that in 10 of the 18 ski resorts climate station do not exist (Table 2). Due to the lack of climatological stations, we used informal sources of data on the number of days with snow cover (Stara planina, Golija) and data from near stations that do not represent ski resorts but are at a similar altitude (e.g. RC Kamenički vis for Bojanine vode – Suva planina).

We used the correlation method to determine the connection between the average values of the number of days with snow cover, the average number of days with the average air temperature below 0 °C and the number of overnight stays in individual centres. To determine the correlation (Correl) of the time series of these indicators, equation was used:

$$Correl(X, Y) = \frac{\Sigma\left(x - \bar{x}\right)\left(y - \bar{y}\right)}{\sqrt{}\Sigma\left(x - \bar{x}\right)^2\left(y - \bar{y}\right)^2}$$

where x and y are the average values of given variables (climatic elements and indicators of tourism) of time series x and time series y. If the obtained value is closer to number 1, the correlation is higher, and vice versa, if it is further than the number one, the correlation is lower.

In order to determine the ratio of snow cover and air temperature as a factor determining the need for artificial snowmaking, we suggest a new index of artificial snow (IAS) with the proposed equation:

$$I_{as} = \frac{N_{ds}}{T_{avg<0\,^{\circ}\mathrm{C}}}$$

where N_{ds} is the average number of days with snow cover over the year and $T_{\mathrm{avg}<0\,^{\circ}\mathrm{C}}$—number of days with average daily air temperature below 0 °C. If the index is closer to number 1, climatic conditions are more suitable for artificial snowmaking.

For the mapping of the results, we used tools in the Global Mapper v15.2—points styles based on attributed values (temperature data) and Voronoi diagram (average

Table 2 Basic data of ski resorts and ski runs in Serbia

	Ski resort/ski run	NUTS 3 region	Climate station/ski run altitude (m)	Climate data time series	Type of winter sports destination	Snowmaking (number of ski runs of total)
1	Kopaonik	Raška, Rasina	1710	1991–2016	Complex resort	27/37
2	Babin Zub—Stara planina	Zaječar, Pirot	1758	n/a	Complex resort	2/8
3	Tornik—Zlatibor	Zlatibor	1028	1991–2016	Complex resort	4/5
4	Brezovica—Šar Planina	Prizren	915	1991–2008	Complex resort	1/8
5	Crni Vrh—Divčibare	Kolubara	980	n/a	Complex resort	1/2
6	Golijska reka—Golija	Moravica	1420	n/a	Ski-run	0/1
7	Odvraćenica—Golija	Raška	1620	n/a	Weekend resort	0/4
8	Goč	Raška, Pomoravlje	990	1991–2016	Weekend resort	0/1
9	Iver-Tara	Zlatibor	1250	n/a	Complex resort	2/4
10	Vlasina	Pčinja	1190	1991–2016	Weekend resort	0/1
11	Sjenica	Zlatibor	1038	1991–2016	Ski-run	0/1
12	Crni Vrh	Bor	1037	1991–2016	Ski-run	0/2
13	Nova Varoš—Zlatar	Zlatibor	985	n/a	Town resort	0/1
14	Lukovska Banja	Toplica	770	n/a	Spa resort	0/1
15	Bojanine vode—Suva Planina	Nišava	864	n/a	Ski-run	0/1
16	Kraljevica—Zaječar	Zaječar	144	1991–2016	Ski-run	0/1
17	Besna Kobila	Pčinja	1480	n/a	Weekend resort	0/1
18	Rajkovo—Majdanpek	Bor	750	n/a	Ski-run	0/1

Source field survey taken from 2013 to 2018

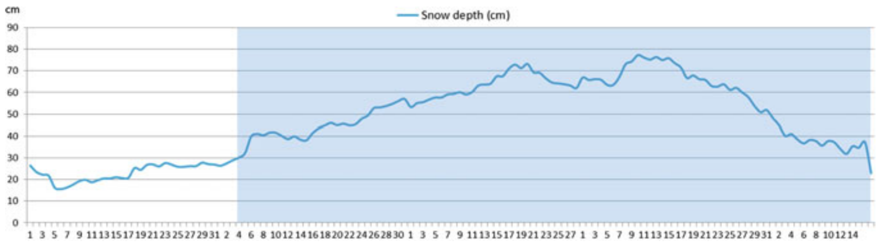

Fig. 2 Average natural snow cover depth on Kopaonik ski resort (1710 m) (season 1 Dec–15 Apr) in period 1991–2016. *Source* RHSS 2017

number of days with show cover) were used. The equation for the Voronoi diagram is:

$$reg(p) = \bigcap_{q \in S - \{p\}} dom(p, q)$$

where the area of region (*reg*) is the proportion dominated by point *p*, *p* and *q* are two adjacent centres/stations, *S* is a series of *n* points (climatological stations) and *dom* (*p*, *q*) domination of *p* over *q*.

3 Results

During the second half of the 20th century, modern ski centres in the northern hemisphere were considered destinations of winter sports if in 7 of 10 winters a snow cover 30–50 cm deep appears at least 100 days between 1 December and 15 April (Abegg 1996). According to that criterion, as well as the available data, in Serbia, over the last 20 years, it is only Kopaonik that stands out as there the natural snow cover with an average depth of more than 30 cm lasts on average from January 4 to April 15 (101 days) (Fig. 2). The number of days with an average daily air temperature below 0 °C is 67, adding the number of days with the air temperature below 0 °C at 21 h. With the average air humidity of 85% from December to April, the air temperature forms the basis of a high-quality tourist season. Compared with other mountain centres in Serbia, Kopaonik has the highest number of overnight stays in the winter season—an average of 66% of annual overnights. Because of this, this centre is the most sensitive to climate change.

In the 2008–2016 period, on Kopaonik there were five winter seasons with an average of 43 days of snow cover and with a minimum depth of 30 cm. Therefore, the justification for the construction of an artificial snow system is encouraged. During the winter season 2013/2014, the depth of the natural snow cover exceeded 30 cm only for a few days (Fig. 3). With systems for artificial snow, the depth was held at a relatively uniform level of 15–30 cm because the air temperature did not have a

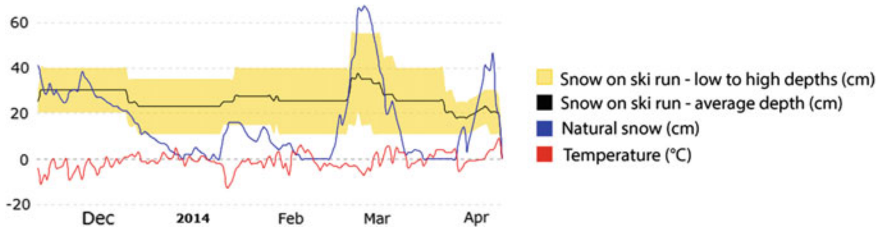

Fig. 3 Snow cover on Kopaonik during winter season 2013/2014. *Source* Infokop 2014

continuity of rise, that is, it allowed for snow making. The production of 1 m^3 of snow on Kopaonik costs 20 dinars (0.15 euro cents), which is significantly less than the price in Alpine centres, where it ranges from 2 to 5 euros per 1 m^3 (Badre et al. 2009; Hinnerth 2012). In addition to other factors, this is due to lower electricity prices and the use of natural water that is not paid. For example, 1 kWh of electricity in Germany costs 30.5 cent, in Italy 21, in Austria 19.5, in France 16.9, in Slovenia 16.1 while in Serbia it costs 5 euro cents. It is interesting that a one-day ski pass in these countries, depending on the ski centre, costs from 30 to 40 euros, while on Kopaonik, in the 2016/2017 season, it cost 26.8 euros. The price of a one-day ski pass during the 2010/2011 season, which was only 18 days with a snow cover of 30 cm deep, was 19.6 euros. The price of a ski pass during the 2013/2014 season, in which there were only 21 days with a natural snow cover above 30 cm, reached 28 euros.

It is obvious that the costs of snow production are not correlated with the price of a ski pass in Serbia, i.e. that the price is unrealistically high in relation to the cost of artificial snow production. The price of a ski pass determines the tourist demand and, vice versa, the price of a ski pass is stimulated by the tourist demand. If one compares this with the prices of ski passes in other ski resorts in Serbia, the price in Kopaonik winter resort is twice as high.

In other ski resorts and ski runs in Serbia, the number of snow-covered days ranged from 41 (Zaječar) to 123 (Crni vrh). The number of days with the age daily air temperatures below 0 °C was from 15 (Zaječar) to 58 (Crni vrh). Among the stations where there are no ski runs, as a potential, we can point out the mountain Kukavica (1442 m) in the Jablanica District, where there were 130 days with snow cover and 52 days with daily air temperature below 0 °C. The average monthly relative air humidity at 21 pm was above 80% at all stations, which at 0 °C allowed −1.1 °C and, thus, the production of artificial snow.

Correlation of N_{ds}—average number of days with the snow cover and number of days with $T_{avg<0\,°C}$ for the selected stations is high, but the difference between stations is not significant (Table 3). This indicates that low air temperatures are important for the maintenance of snow cover in ski centres. Correlation $T_{avg<0\,°C}$ and H_{avg}—average humidity by month (at 21 pm) indicated a relatively significant correlation between air temperature and air humidity. Among the stations, only Kopaonik, as the highest station, recorded a minor correlation between humidity and frosty days. This can be

Table 3 Correlation between climate and tourism data

	Correl (N_{ds}, T_{avg} < 0 °C)	Correl (T_{avg} < 0 °C, H_{avg})	Correl (N_{ds}, N_o)	IAS
Kopaonik	0.96	0.30	**0.75**	2.46
Brezovica	0.94	0.77	n/a	3.48
Zlatibor	0.94	**0.81**	-0.30	3.00
Goč	0.96	0.77	0.03	2.41
Vlasina	0.93	n/a	n/a	2.91
Crni vrh	**0.97**	0.71	n/a	2.12
Dragaš	–	–	–	3.20
Kamenički vis	–	–	–	**1.82**
Kar. bunari	–	–	–	2.58
Kučevo	–	–	–	2.64
Kukavica	–	–	–	2.50
Sjenica	–	–	–	2.86
Zaječar	–	–	–	2.73

Explanation: N_{ds}—average number of days with snow cover by month, T_{avg} < 0 °C—average number of days with average temperature bellow 0 °C by month, H_{avg}—average humidity by month, N_o—average number of tourist overnights

attributed to the altitude and the micro-climate of a climatological station located in a forest environment. The correlation of N_{ds} and the number of tourist overnights indicates the affirmation of tourist centres for snow sports. Kopaonik had a significant correlation and it was primarily the snow cover that attracted tourists. The high correlation of the number of days with snow and the number of overnight stays indicates the sensitivity of the tourist season in relation to the snow cover. Therefore, Kopaonik on one side and other potential centres of winter sports tourism on the other can be identified as a priority for the construction of a system for artificial snow. On Zlatibor and Goč, the correlation between N_{ds} and N_o was not significant, which points to orientation towards other forms of tourism (Fig. 4).

The results of the artificial snow index calculation (IAS) indicate the different potentials for artificial snow. The Kamenički vis station near Niš had the most favourable index—1.82, which could refer to the Bojanina voda ski run on Suva planina, due to a similar altitude and relative proximity. The Brezovica station had the most unfavourable snow index—3.48 due to a small number of days with $T_{avg<0\ °C}$. That can be explained with specific location and southern latitude compared to other stations. According to the snow index, among the built ski centres and ski runs the order is following: 1. Crni vrh, 2. Goč, 3. Kopaonik, 4. Zaječar, 5. Sjenica, 6. Vlasina, 7. Zlatibor and 8. Brezovica. Among the explored mountains, according to the snow index, the biggest potential for the construction of ski resorts is on Kukavica and Carpathian Mountains around Majdanpek. In addition to these results, we note that climatological data are missing for some developed ski runs and ski resorts

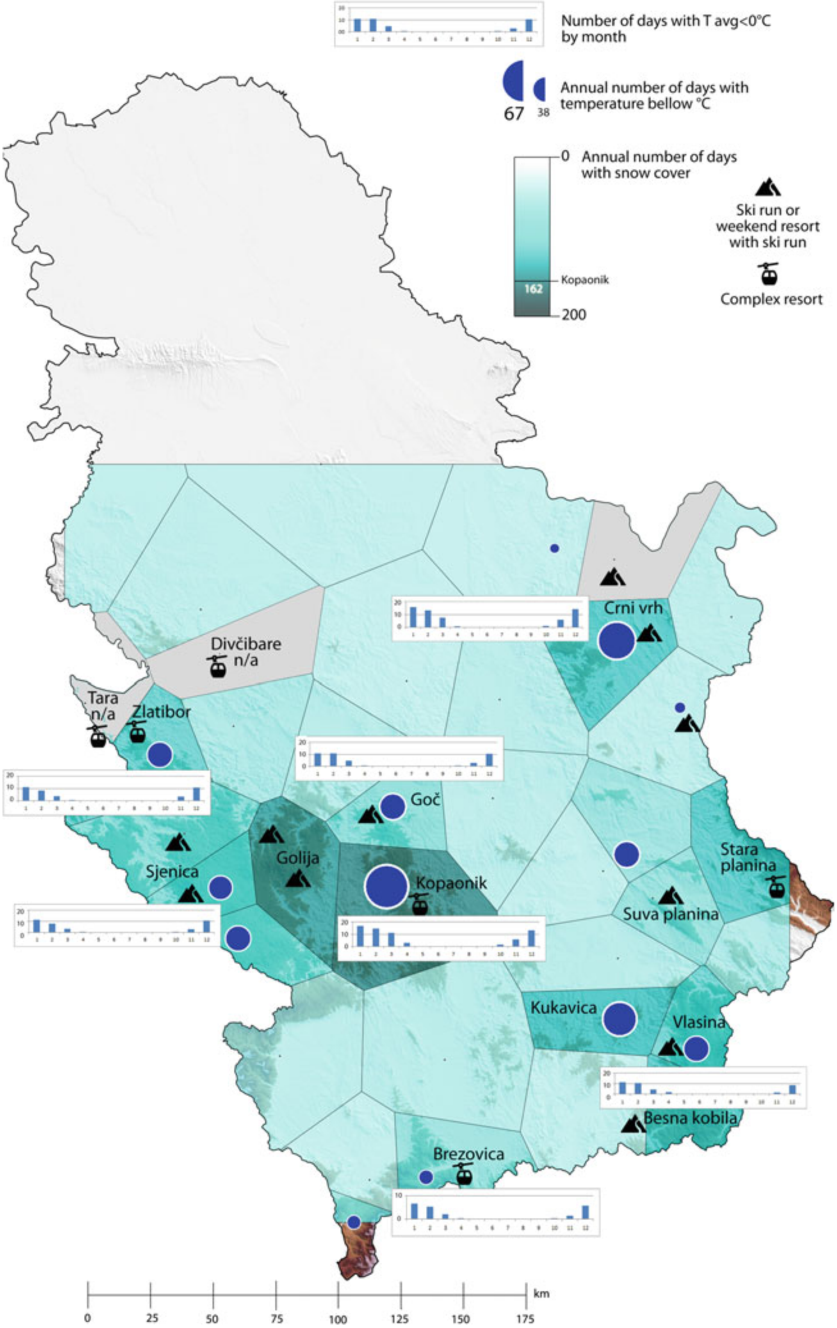

Fig. 4 Climate conditions for artificial snow production in Serbia

(Divčibare, Stara planina, Golija, Tara and Besna kobila) where de facto there is a potential for snowmaking and ski season maintenance.

4 Conclusion

Research on the snow cover as a factor for the development of winter tourism in Serbia is based on the fact that this niche of tourism provides much more than recreation for tourists. The pragmatism of applied regional climatology lies in the natural conditions that enable winter tourism and affect the area in which it develops. Experiences from ski centres in the Alps indicate that climate change is subject to all but the most vulnerable ski centres in rural areas where tourism is the main industry. Among the modes of adaptation to climate change applied in European ski centres, the only one known in Serbia is the practice of artificial snowmaking with the constant monitoring of environmental indicators. Stakeholders in all winter destinations should consider the type of adaptation to further warming and less frosty days.

Among the limitations in our research, we point out the small number of relevant climatological stations in Serbia, because of which the climatic data base is incomplete. Also, we point out the lack of data about snow cover created by snowmaking in developed ski centres (except Kopaonik). We believe that, allowing for limitations and methodological imperfections, the contribution of this work lies in determining natural conditions for the existence of a quality season for winter sports. The paper presents ski centres, ski resorts and mountains where there are qualitative advantages for lowering tourist pressure on ski resorts of mass winter tourism. Reducing number of tourists, stopping the construction of new paths and infrastructure in ecologically sensitive areas guarantees the preservation of ecosystems and the value of the landscape of mountain areas in Serbia. The monopolistic impact of the leading stakeholders in winter tourism would be dropped and would open a path for projects of local self-governments and districts on whose territory there are mountains with comparative climate benefits. The results show comparative advantages in terms of climatic conditions for the duration of the ski season as well as possibilities for artificial snowing as a necessary form of adaptation to warmer winters with less natural snow.

By means of further research, the climatic conditions of importance for the duration and quality of snow cover at the daily level for the complete network of climatological stations in Serbia remain to be investigated. Also, we believe that our research could encourage the creation of prognostic models for the duration of the snow cover and thus the responsible planning of a snow making system.

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References

Abegg B (1996) Klimaänderung und tourismus – Klimafolgenforschung am beispiel wintertourismus in den Schweizer Alpen. Vdf Hochschulverlag, Zurich

Abegg B, Agrawala S, Crick F, de Montfalcon A (2007) Climate change impacts and adaptation in winter tourism. In: Agrawala S (ed) Climate change in the European Alps. OECD, Paris, pp 25–60

Badre M, Prime JL, Ribiere G (2009) Neige de culture: Etat des lieux et impacts environnementaux, note socio-économique. Conseil Général de l'Environnement et du Développement Durable, Paris

Bajat B, Blagojević D, Kilibarda M, Luković J, Tošić I (2015) Spatial analysis of the temperature trends in Serbia during the period 1961–2010. Theor Appl Climatol 121(1–2):289–301

Bil A (2018) Climate change impacts on ski tourism: the case of Tatra Mountains, Poland. International Ecotourism Club. https://ecoclub.com/education/articles/914-131219-tatra-mountains-tourism-climate-change. Last accessed 13 Mar 2018

Bjedov I, Ristić R, Stavretović N, Stević V, Radić B, Todosijević M (2011) Revegetation of ski runs in Serbia: case studies of Mts. Stara planina and Divčibare. Arch Biol Sci 63(4):1127–1134

Caravello G, Crescini E, Tarocco S, Palmeri F (2006) Environmental modifications induced by the practice of "Artificial snow-making" in the Obereggen/Val D'Ega Area (Italy). J Mediterr Ecol 7(1–4):31–39

Damm A, Greuell W, Landgren O, Prettenthaler F (2016) Impacts of + 2 °C global warming on winter tourism demand in Europe. Clim Serv 7:3–46

de Jong C, Barth T (2007) Challenges in hydrology of mountains ski resorts under changing climate and human pressures. In: Benveniste J et al (eds) Proceedings of the second space for hydrology workshop, Surface water storage and runoff: Modeling, in-situ data and remote sensing. European Space Agency, Geneva

Demiroglu OC (2016) Technical climate change adaptation options of the major ski resorts in Bulgaria. In: Koulov B, Zhelezov G (eds) Sustainable mountain regions: challenges and perspectives in Southeastern Europe. Springer, Cham, pp 77–88

Demiroglu OC, Kučerová J, Ozcelebi O (2015) Snow reliability and climate elasticity: case of a Slovak ski resort. Tourism Rev 70(1):1–12

Dincă AI, Surugiu C, Surugiu M, Frenţ C (2014) Stakeholder perspectives on climate change effects on tourism activities in the northern Romanian Carpathians: Vatra Dornei resort case study. Hum Geographies 8(1):27–41

Djordjevic DS, Secerov V, Filipovic D, Lukic B, Jeftic MR (2016) The impact of climate change on the planning of mountain tourism development in Serbia: case studies of Kopaonik and Zlatibor. Fresen Environ Bull 25(11):5027–5034

ECOSIGN (2007) Stara planina Master plan. http://www.jpstaraplanina.rs/cir/master-plan/. Last accessed 27 Feb 2018

EJR (2018) Nature park Stara planina, Serbia. Environmental Justice Atlas. http://ejatlas.org/conflict/nature-park-stara-planina-serbia. Last accessed 10 Mar 2018

Foehn P (1990) Schnee und lawinen. VAW Mitteilungen 108:33–48

Folland CK et al (2001) Observed climate variability and change. In: Houghton JY et al (eds) Climate change 2001: the scientific basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 99–181

Grunewald K, Schiethauer J (2010) Europe's southernmost glacier: response and adaptation to climate change. J Glaciol 56(195):125–142

Grunewald K, Scheithauer J, Monget JM, Brown D (2009) Characterization of contemporary local climate change in the mountains of Southwest Bulgaria. Clim Change 95(3–4):535–549

Hahn F (2004) Künstliche beschneiung im Alpenraum – ein hintergrundbericht. CIRPA International, Schaan

Hinnerth A (2012) Artificial snow production in winter sport destinations—strategies and challenges in Sälen. Högskolan Dalarna, Falum, Sweden

HTL (2009) Master plan za turističku destinaciju Kopaonik – finalni izveštaj poslovnog Master plana. Horwath i Horwath Consulting, Zagreb. http://www.kopaonik.rs/kopaonik/wp-content/dokumenti/pdf/Horwath-Master-plan-Kopaonik.pdf. Last accessed 10 Mar 2018

Infokop (2014) Sistem veštačkog osnežavanja na Kopaoniku. http://www.infokop.net/staze-i-zicare/sistem-za-vestacko-osnezavanje-5.html. Last accessed 4 Mar 2018

Joksimović MM, Gajić MR, Vujadinović SM, Golić RM, Vuković DB (2015) The effect of the thermal component change on regional climate indices in Serbia. Therm Sci 19(Suppl. 2):S391–S403

Koenig U, Abegg B (1997) Impacts of climate change on winter tourism in the Swiss Alps. J Sustain Tour 5(1):46–58

Lang T (2009) Energetische bedeutung der technischen pistenbeschneiung und potentiale für energieoptimierungen. Bundesamt für Energie (BFE), Zurich

Micu D (2009) Snow pack in the Romanian Carpathians under changing climatic conditions. Meteorol Atmos Phys 105(1–2):1–16

Mikloš M, Slobodníková L, Babálová D, Škvarenina J, Ujházy K (2015) Effect of snowmaking on vegetation of submontane ski area. Acta Facultatis Forestalis Zvolen 57(1):47–61

Milivojević M, Menković Lj, Ćalić J (2008) Pleistocene glacial relief of the central part of Mt. Prokletije (Albanian Alps). Quatern Int 190(1):112–122

Mišović M, Nišavić M (eds) (1951) Smučarstvo u Srbiji. Smučarski savez Srbije, Beograd

Mochurova M, Kaloyanov T, Mishev P (2010) Impacts of climate change on winter tourism in Borovets. Econ Stud J 2:98–126

Moen J, Fredman P (2007) Effects of climate change on Alpine skiing in Sweden. J Sustain Tour 15(4):418–437

Ogrin M, Ogrin D, Rodman N, Močnik M, Vengar R, Smolej A, Bunčič G (2011) Climate change and the future of winter tourism in Slovenia. Croatian Geogr Bull 73(1):215–228

Potić I, Joksimović M, Golić R (2015) Changes in vegetation cover on Stara planina: towards sustainable management of ski resorts in sensitive areas. Bull Serb Geogr Soc 95(2):25–40

RHSS (2017) Climate statistical data. Republic hydrometeorological Service of Serbia, Belgrade. http://www.hidmet.gov.rs/eng/meteorologija/klimatologija_srednjaci.php, http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php. Last accessed 11 Mar 2018

Ristić R et al (2008a) Main project of erosion control works on ski-runs in ski resort Tornik-Zlatibor. Faculty of Forestry, Belgrade

Ristić R et al (2008b) Main project of erosion control works in ski resort Kopaonik. Faculty of Forestry, Belgrade

Ristić R et al (2008c) Main project of erosion control works on ski-run Briježđa-Nova Varoš. Faculty of Forestry, Belgrade

Ristić R et al (2008d) Main project of erosion control works on ski-run Crni vrh-Divčibare. Faculty of Forestry, Belgrade

Ristić R, Vasiljević N, Radić B, Radivojević S (2009) Degradation of landscape in Serbian ski resorts—aspects of scale and transfer imapcts. Spatium 20:49–52

Rixen C, Stoeckli V, Ammann W (2003) Does artificial snow production affect soil and vegetation of ski pistes? Perspect Plant Ecol 5(4):219–230

Scott D, Lemieux C (2010) Weather and climate information for tourism. Procedia Environ Sci 1:146–183

Scott D, McBoyle G (2007) Climate change adaptation in the ski industry. Mitig Adapt Strat Gl 12(8):1411–1431

SORS (2017) Statistical releases, Tourist turnover (UT10). Statistical Office of the Republic of Serbia, Belgrade. http://www.stat.gov.rs/WebSite/Public/PageView.aspx?pKey=182

Stocker TF et al (2013) Technical summary. In: Stocker TF et al (eds) Climate change 2013: the physical science basis. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York, pp 31–115

Stojsavljević R, Božić S, Kovačević M, Bubalo-Živković M, Miljković Đ (2016) Influence of selected climate parameters on tourist traffic of Kopaonik and Zlatibor mountains (Republic of Serbia). Geogr Pannon 20(4):208–219
Surugiu C, Dincă AI, Micu D (2010) Tourism destinations vulnerable to climate changes: an econometric approach on Predeal resort. Pet Gas Univ Ploiesti Bull Econ Sci Ser 62(1):111–120
Surugiu C, Surugiu MR, Frent C, Breda Z (2011) Effects of climate change on Romanian mountain tourism: are they positive or mostly negative? Eur J Tourism Hospitality Recreation 2(1):42–71
Šušić V, Đorđević DŽ (2013) Turistički centar na Staroj planini – ekološki ili ekonomski neuspeh? Teme 37(1):459–478
Trawöger L (2014) Convinced, ambivalent or annoyed: tyrolean and their perceptions of climate change. Tourism Manage 40:338–351
Unkašević M, Tošić I (2013) Trends in temperature indices over Serbia: relationships to large-scale circulation patterns. Int J Climatol 33(15):3152–3161
Vrtačnik Garbas K (2007) The potential influences of climate changes on tourist demand in winter sport centres in Slovenia. In: Matzarakis A, de Freitas SR, Scott D (eds) Developments in tourism climatology. In: 3rd international workshop on Climate, Tourism and Recreation. International Society of Biometeorology, Commission on Climate, Tourism and Recreation, Freiburg, pp 199–206
Vrtačnik Garbas K (2009) Developmental possibilities of winter-sport centres in Slovenia in the light of climate change. Acad Turistica 2(1–2):56–73
Vujadinović S, Šabić D, Joksimović M, Golić R, Gajić M, Živković L, Milinčić M (2013) Possiblities for mountain-based adventure tourism: the case of Serbia. Bull Geogr Socio-Econ Ser 19:99–111
Wall G, Badke C (1994) Tourism and climate change: an international perspective. J Sustain Tour 2(4):193–203
Wilcke RAI, Leuprecht A, Gobiet A (2012) CC-Snow: effects of climate change on future snow conditions, winter tourism and economy in Tyrol and Styria, final report—Climate. University of Graz, Wegener Center of Climate and Global Change, Graz
Wolfsegger C, Gossling S, Scott D (2008) Climate change risk appraisal in the Austrian ski industry. Tourism Rev Int 12(1):13–23

Sustainability of Rural Areas in Bosnia and Herzegovina Under the Global Climate Change Conditions

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Abstract Theoretically and practically, the paper discusses the real and potential risks and limitations in rural areas in Bosnia and Herzegovina within the context of global climate changes. Rural areas cover approximately 90% of Bosnia and Herzegovina territory and they represent a pertinent commercial potential in sectors of agriculture, forestry, waters, energetics and tourism. The distinctive geo-diversity causes different development opportunities and restrictions. Hence, B&H region is differentiated into, more or less, prosperous areas with specific development issues and risks, many of which are conditioned by global climate changes. Unique variable values of climate elements caused by geospatial factors and global climate changes are typical of B&H geo-space. These are manifested through frequent occurrence of extreme values (temperature, precipitation, winds, etc.), deviations from regular weather conditions and frequent bad weather followed by negative consequences in agricultural sector. In addition, strong sensitivity and inefficient prevention actions are common in problem rural areas. The aim of the paper is to single out rural areas in B&H based on the exposure to natural disasters and potential risks (floods, hail, drought and fires). We analyze the sustainability of geo-systems vulnerable to climate changes (agriculture, forests, hydro-systems, infrastructure, settlements, etc.) and the necessity to undertake essential actions which might help reach a solution. The adequate methodology and research procedures are capitalized on in order to single out areas threatened by climate changes. The nature, geo-distribution and consequences of bad weather conditions are defined. Furthermore, we propose mechanisms to help the identification, monitoring and prevention actions which would protect B&H rural areas under the conditions of intensive bad weather and its consequences due to global climate changes. What our research deals with is the mitigation of

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consequences caused by climate changes, the protection of rural area geo-systems and the sustainability of spatial development.

Keywords Rural areas · Bosnia and Herzegovina · Geo-systems
Climate changes · Bad weather · Problem areas · Sustainable development

1 Introduction

The global population increase and the uncontrolled commercial growth threaten the environment. The sustainable development concept emerged from the complex analyses of economic and social-demographic indicators and projections by examining the limits of their growth and opportunity to preserve the environment and resource quality for the needs of future generations (Cotner 2009). This problem is vital for the future growth of humanity and it has been intensively discussed ever since 1972 as *the Declaration on Environment* was adopted at the 1st UN Conference on Human Environment in Stockholm, as well as *The Limits to Growth* commissioned by the Club of Rome. What followed were numerous discussions which should have raised consciousness on the human responsibility for the actions which might have affected future generations and the life on Earth.

It was in 1987 that the World Committee on Environment and Development submitted a report to the UN General Assembly and named it *Our Common Future*. On that occasion, the term "sustainable development" was used for the first time. Once it was supported by environmental activists, the term was encouraged in scientific, economic and political circles as well.

The 1992 UN Conference on Environment and Development took place in Rio de Janeiro and on that occasion the *Agenda 21* was adopted only to become a basis for numerous activities in nearly all spheres of social and economic life, both globally and locally. The Conference defined recommendations and strategic goals in all fields of spatial planning development in 21st century. Consequently, the idea of sustainability was integrated into the mind, education and actions of people in order to harmonize the development and ecological-spatial capacities. The concept of sustainable development turned into a priority and became a paradigm (Tosic and Krunic 2011).

Eventually, the term itself resulted in different conceptions of development and sustainability of specific geo-systems and their structures. A specific terminology integrated different sciences, scientific disciplines and social practice in order to minimize disproportions between the needs of population and economy in certain countries and the ability to restore ecosystems. Reaching consensus between the aforementioned dichotomies means a responsible approach to finding a solution which might help achieve the concept of sustainable development. Hence, we may refer to sustainable development as "improvement of life quality within the framework of capacity of Earth's ecosystems" (Jakobs 2007). Both theoretically and practically, the concept of sustainable development grew into an independent science (*Sustainable Development Science*).

Within the sustainable development concept, a special attention is paid to the sustainability of rural development. Rural areas cover around 90% of Earth's surface and almost 50% of world population. Furthermore, these areas are being challenged by the dynamics of demographic growth, exploitation of natural resources, food and water demands, as well as the need for energetic and recreational facilities. In terms of modern scientific-technological and urban development, rural space has been undervalued for a long time. Natural resource crises and threats to environment have affected the perception of rural space and its economic and ecological pertinence. Along with the establishment of the sustainability concept came the concepts of rural development and strategies of rural area integrations into modern development processes (decrease of development disparities, territorial cohesion within European development strategies—INTERREG, ESSPON, etc.). A novel approach to evaluation and assessment of rural space inevitably focuses on the sustainability of rural areas, i.e. their geo-diversity—natural systems (mineral resources, soil, landscape units, hydro-systems, forests and ecosystems) and anthropo-geographic systems (commercial system, agro-system, infrastructure, and settlements). These geo-systems are exposed to consequences of climate changes which negatively affect the ecological sustainability and indirectly influence the economic growth and social-economic and demographic sustainability of rural areas.

Climate changes are manifested through worldwide fluctuations of climate elements causing bad weather conditions. Multiple risks, extensive material damage and human victims caused by bad weather in specific parts of the world are being characterized as natural disasters. It is the regional distribution of these disasters and its impact on geo-systems and national economies that demand necessary involvement in international activities and strategies to help adapt to climate changes (UN Framework Convention on Climate Changes, International Panel on Climate Changes, The Kyoto Protocol, etc.). Climate changes have grown into a global problem. In addition, they have become a study matter of many sciences depending on the theoretical aspects and practical needs.

Rural space covers most of our planet. Rural geo-systems are pertinent due to development resources (minerals, energetics, arable land, water, forests, etc.). Consequences of climate changes displayed through bad weather conditions directly decrease the value of rural land threatening the diet of the population, water supplies, as well as maintenance of settlements and infrastructure. Hence, it is crucial to harmonize the rural development with the recent climate conditions. The concept of sustainable rural areas under the conditions of global climate changes stipulates monitoring, strong institutional and infrastructural capacities, risk management, as well as adaptation and protection of rural geo-systems.

The growing disparities in spatial development resulted in the formation of problem areas. In turn, problem areas indicate a high level of sensitivity to different risks. For the purpose of our paper, we carried out a differentiation of B&H geo-space based on the sensitivity to natural hazards (hail, flood, erosion, drought, fire) intensified by global climate changes which further determined specific development problems and sustainability of rural areas. Therefore, the paper focuses on the evaluation of climate risks as well as the adaptation and sustainability of B&H rural geo-systems under the conditions of climate changes. Generally, the concept of sustainability entails the improvement of life quality by preserving life conditions and ecosystem capacities and it is equally based on economic, ecological and social principles (Penfield 1996).

In line with models of climate predictions, we may expect the increase of mean annual temperatures and decrease of precipitation in the following decades. There is a high possibility of droughts and fires due to frequent extremely high temperatures. Extremely high amounts of precipitation in a short time period may initiate floods. Predictions of the International Panel on Climate Change indicate the potential risk in South-East Europe. Intensive climate changes impair the values of ecosystems (agro-systems, forests, hydro-systems, etc.) and infrastructural systems as they negatively affect the local development and national economies turning into a global problem.

Consequently, it is crucial to apply the concept of sustainability of rural areas in the context of modern climate changes. The designation of problem areas and design of adequate strategies are initial steps toward the adaptation and protection of rural environment. Modern practice has proved that the condition of environment is primarily defined by legal and institutional protection framework, and the ecological element of environment is determined by economic and social components (Gnjato et al. 2011). Along with Capra's thesis that causes of most ecological and social problems lie in economic systems (Capra 2004), the aforementioned statement is practically corroborated by B&H institutional and economic growth, the condition of environment and the efficiency of reacting to natural risks.

2 Methodological Approach

The paper has both theoretical and practical pertinence which influenced how we defined the methodological approach. The paper defines the concept of sustainable development and relevance of its application to rural areas under the conditions of global climate changes. We analyzed the genesis of the concept itself and its implementation to different spheres of development. Furthermore, we elaborated on the change of perception and relevance of rural areas within the total spatial development. Also, rural geo-systems, exposure to climate elements and bad weather conditions caused by them are defined.

The analyses focus on Bosnia and Herzegovina (B&H) geo-space, i.e. its entities (B&H Federation and the Republic of Srpska). We analyze changes of climate elements and consequences to agro-systems, hydro-systems and forest systems. Based on the characteristics of geo-systems, we differentiate the region in line with benefits for agricultural production, forestry, energetics and tourism. We also differentiate the same region based on occurrence of climate elements and consequences caused by them. Some analyses focus on the entity of the Republic of Srpska as it covers the more valuable arable land and should be adequately protected. A comparative analysis and interpolation of indicators of climate changes are performed and some adequate measures are suggested.

Results of meteorological observations at several B&H weather stations for the following time periods were used: amount of precipitation (1981–2010), temperature (1961–2010), occurrence of drought (2003–2012) and occurrence of hail (1995–2014). Different periods of monitoring are result of discontinuity and changes in methodology of weather monitoring. We analyzed shifts in mean annual values of the aforementioned climate elements and occurrence of extreme values which corroborated the existence of climate changes. Results of institutional weather monitoring (Weather Bureau of B&H Federation, Weather Bureau of the Republic of Srpska) and outcomes of scientific research in the field of climate changes over the past two decades (Dejanovic 2015; Trbić 2008; Trbić and Bajic 2011; Trbić et al. 2013, 2014, 2018; Jovanovic-Popovic and Milincic 2016; Popov et al. 2018) were used. Indicators of climate changes in B&H supported by other studies (2013s National Report of B&H) had already been addressed.

The paper focuses on consequences that climate changes such as floods, hail, drought and fires (2000–2014 monitoring period) have on the sustainability of rural systems. For this purpose, we analyzed risks and consequences, possibility of adaptation and prevention actions. Also, we singled out problem areas and suggested measures which should decrease risks caused by climate changes.

Bosnia and Herzegovina has no Spatial plan or national development strategies. The country has only local strategies (entity, canton and municipal levels) which accounts for the lack of an integral approach to spatial planning. Hence, the adoption of strategic goals of sustainable development is complex and the efficiency of prevention actions in the field of climate changes is debatable. Rural development is defined by its strategies (at the entity level and lower levels of planning), spatial plans and partly by the strategies of development of agriculture, tourism, water management, protected areas and special purpose areas. In the paper, we performed a comparative analysis of pertinent spatial planning documents (Spatial Plan of RS, RS Strategy of Rural Development, and Proposal of the B&H Strategic Plan of Rural Development adopted in 2017). All the aforementioned facts interfere with the acceptance of a scientific methodology crucial for an integral perception of the problem.

3 Definition and Elaboration of the Problem

Geospatial Determinants of Bosnia and Herzegovina Within the Context of Sustainable Rural Development

Climate changes in B&H must be observed within the context of monitoring climate changes in South-East Europe. Bosnia and Herzegovina is not an EU member and does not belong to the European Spatial Planning Observation Network (ESSPON) which, among other activities, tracks the impact of climate changes and natural disasters and develops adequate strategies. Ever since 2009, Bosnia and Herzegovina has been a part of the UN Convention on Climate Change. It is this Convention, along with the Kyoto protocol, that binds its signatories to responsible performance in developing strategies for mitigation of climate changes and adaptation to new climate conditions. This means cooperation with international institutions and countries within the field of climate observation, research and education at different levels. Belgrade Initiative on Climate Change (2007), Regional Framework Plan for Climate Change (2008) and CCA Forum (2012) mark the beginning of a strong cooperation in the field of climate change in South-East Europe including B&H.

B&H region is exposed to airflows of land and maritime air masses of different physical characteristics which are formed above the Atlantic, Siberia and Mediterranean. The circulation of these airflows and the resulting weather conditions in B&H are modified by the terrain height, the mountain lines and the features of lithosphere basis and vegetation. In summer, these local factors and the sudden soil warming affect the formation of local depression and occurrence of downfalls such as showers and hail.

B&H geo-space covers 50,129 km^2 and is characterized by heterogeneous relief morphostructure and the resulting geo-systems (soil, hydro-systems, forests and other ecosystems) which indirectly shape the distribution of specific climate elements in a relatively small region. The following three macro-regional units may be singled out based on the natural-geographic characteristics: the Pannonian region in north (bottom and rim of the Pannonian basin, the mountain and basin region in the middle parts of the country and the Adriatic (sub-Mediterranean) region in south.

The Pannonian region covers north B&H and it is located south from the Sava River (Fig. 1). It is predominantly a lowland region with the temperate continental climate. In addition, it is the country's most densely populated natural-geographic region with a broad network of rural and urban settlements and infrastructure. Until early 20th century, the region had been flooded and partly covered in marsh. The construction of the hydro-technical infrastructure (canals, dykes, drainage stations, irrigation systems) transformed it into the most valuable agrarian area in Bosnia and Herzegovina. The maintenance of hydro-technical infrastructure is of an utmost pertinence for the sustainability of agricultural and other ecosystems (Fig. 2). From the eco-climate point of view, it is characterized by four seasons, warm summer and moderately cold winter. The annual precipitation distribution is relatively balanced and it increases only in spring and autumn as floods occur. In summer, there are frequent thunderstorms accompanied by hail and occasional drought which cause large damages. All branches of agricultural production are registered. The sustainable rural development is based on a complex agricultural production and potential agro-industry and tourism. This geographic region is almost entirely located in the Republic of Srpska.

As the altitude increases, the conditions of eco-climate and eco-vegetation change. ***The mountain and basin region***, located in the middle parts of the country covers the area between the Pannonian basin in north and the Adriatic region in south. (Figure 1). It mostly encompasses the Dinaric mountain range and is intersected with meridian-oriented river valleys along which the roads connect all the three natural-geographic regions. The complexity of terrain morpho-physiognomy results in the diversity of

Fig. 1 Differentiation of B&H geo-space in line with the type of natural disaster and risk

climate elements which range from temperate continental to severe mountain climate. There are different types of soil the structure and quality of which is conditioned by the geological composition and precipitation. At higher altitudes, the soil is shallow and barren and at some points there is the bare soil resulting from erosion. This type of soil is usually covered in mountain meadows, pastures and forests. From the agricultural point of view, the cattle-breeding prevails. The cultivated soil is mostly located in river valleys where urban settlements exist. Due to terrain elevation, the river floods and erosion resulting from high amount of precipitation wash off the pedologic layer and decrease the value of the soil. As a result, agricultural production is disabled, and ecosystems and anthropogenic systems are threatened. In the mountain region, there are scattered rural settlements but the agricultural valorization is limited due to the intensive depopulation process. The sustainable development of the mountain and basin region is based on the evaluation of eco-climate and eco-vegetation, e.g. forests and development of tourism (Fig. 2). One such concept of development entails preserved values of natural complexes. The valorization of natural potentials is conditioned by a responsible conduct in the domain of environment protection (forests, hydro-potential, etc.), particularly regarding erosion.

Sub-Mediterranean region encompasses south-east Bosnia and Herzegovina (Fig. 1). It is a highly heterogeneous region from the morpho-physiognomical and bio-geographical points of view. Morphology-wise and hydrology-wise, the entire

Natural-geographic regions	**Typical climate shifts, natural backsets, risks**	**Geo-systems threatened by backsets**	**Social activities threatened by natural backsets**	**Weaknesses**	**Measures**
Pannonian region	-changes in pluviometric regime, increase of the flood intensity, occasional droughts and hail	-agrarian systems, hydro-systems	-agriculture (agriculture, vegetable breeding, fruit breeding)	-poor construction and maintenance of irrigation systems, incomplete coverage in anti-hail protection, poorly organized protection against natural backsets	- construction of melioration systems, adjustment of agrarian structure, improvement of anti-hail systems, efficient weather monitoring, improvement of civil defense
Mountain and basin region	-changes in the amount of snow, floods, erosion, landslides	- eco-vegetation systems (forests), soil	-forestry -tourism	-uncontrolled felling, inadequate water valorization	-forestation, control of construction, water resource management
Sub-Mediterranean region	- increase in number of days characterized by high temperatures and zero precipitation (drought, fires), decreased hydro-potential	- eco-vegetation (Mediterranean forests, agrarian production in karst fields), hydro-systems	-Sub-Mediterranean agriculture (viticulture, fruit breeding, vegetable breeding), hydro-energy	-irrational disposal of resources, poor institutional organization, low population figures	- forestation, protection of arable land, management of surface water streams, construction of accumulations, prevention services (fire brigades), population training

Fig. 2 Exposure to climate risks and measures of adaptation

space is covered in karst and is susceptible to the Mediterranean climate impact. Agrarian valorization is based on viticulture, and sub-Mediterranean and vegetable products from karst fields. Water shortage occurs frequently due to the karst terrain (massive permeability) and annual precipitation regime. In cases of high summer temperatures, the bare lithosphere base is exposed to summer fires. Hence, it is crucial to control the water flows in order to improve agriculture, water supplies and hydro-energy. The population is mostly located in urban settlements whereas the rural areas are characterized by poor population density and depopulation. The sustainable rural development demands an optimal valorization of hydro-potentials, the limited agrarian soil, and natural-geographical and anthropogeographical tourist values. It requires a highly responsible human conduct and coordination of activities of local communities in order to valorize this geographical region.

Hence, geo-diversity in B&H is characterized by the three climate and eco-vegetation regions (continental, mountain and sub-Mediterranean) which in turn have different rates of occurrence of climate elements and potential risks. In addition, the physical-geographical features of B&H define the settlement structure (distribution of population, settlements, infrastructure, agricultural production and other commercial activities) and development opportunities. In line with different criteria (morpho-physiognomy, settlements, demography, social-economy), we may consider around 90% of B&H space as rural. Forest ecosystems (around 50%) dominate the rural space structure. These ecosystems are distributed all over B&H and prevail in the mountain region. The meadows and pastures are many and they are bio-ecologically diverse with the massive spatial dispersion. Plough fields are typically located in the Pannonian region in the Republic of Srpska territory. It is 51% of RS area that is covered in agrarian soil, more than half of which are plough fields and plots (more than 600 000 ha). There are more than 120,000 agrarian households in the Republic of Srpska (2013 Population census). Also, 38,000 households are registered at the Ministry of Agriculture and Forestry inventory and only 4000 households are profitable. In average, one RS citizen disposes of around 0.8 ha of arable soil and only half of it is being cultivated. Irrigation systems cover around 6000 ha (less than 1%) of agrarian land (Documentation, Ministry of Agriculture and Forestry). Annually, around 2000 ha of soil is lost partly due to erosion and landslides caused by intensive precipitation. The aforementioned indicators illustrate a low level of market-oriented agricultural production, a high level of commercial inactivity, land abandonment, insufficient hydro-melioration systems and poor organization of prevention activities in cases of bad weather condition.

4 Climate Changes and Exposure of B&H to Natural Disasters

Results of years of meteorological observations of climate elements in B&H display climate variability in cases of temperature increase, fluctuation of pluviometric regime, longer and more frequent droughts and floods, and increase of days characterized by tropical air temperatures higher than 30 °C (Trbić and Bajic 2011; 2013s National Report; Trbić et al. 2018). The occurrence and dynamics of the variability are different throughout the region. The air temperature measurements in 1961–2010 periods indicated ***the annual increase of mean temperature*** of 0.4–0.8 °C in the whole region. The increase is most evident during the vegetation period and it is up to 1.2 °C in the Adriatic region. In spring and winter, the increase is most evident in central regions. The smallest mean temperature increase occurs in autumn and it ranges from 0.1 to 0.3 °C (Weather Bureau of B&H Federation, Weather Bureau of the Republic of Srpska).

Precipitation (1961–2010 periods) indicated an insignificant increase mostly in central mountain region. The precipitation deficit of more than 300 mm or 20% is most evident in south B&H (sub-Mediterranean region) in spring and summer. It is manifested in water shortage which negatively affects agriculture and causes fires. The disturbed pluviometric regime impinges on the annual precipitation distribution. Number of days with precipitation less than 1 mm decreased in almost entire territory but the number of days with extremely large amount of precipitation increased (Trbić et al. 2013). Annually, there is shortage of 100–200 mm of water crucial for agriculture in Pannonian region. In mountain and basin region, the shortage is 50–100 mm. The variability of precipitation is corroborated by the comparative analysis of the annual precipitation sums in RS in 2010 and 2011. "In 2010, there was a 42% precipitation surplus, and in 2011 the deficit was 38% when compared with the annual average over the previous decade" (Trbić and Bajic 2011, 93).

The decrease of precipitation in the vegetation period along with the increase of air temperature causes the more frequent ***drought occurrence*** (2000, 2003, 2007, and 2012). In the context of our paper, the drought is referred to as agro-meteorological drought, i.e. the water shortage in vegetation period negatively affecting the agriculture. Being an agrarian area, Pannonian region is exposed to drought risks due to climate changes. Simultaneously, the region marks an increase in number of days with intensive precipitation accompanied by hail. Large amounts of precipitation in short time period result in rivers effusing from their river beds causing floods. Occasionally, underground waters reach the surface. It is these high waters that threaten around 60% of lowland, i.e. agrarian systems and settlements. In addition, the entire agrarian surface is not covered by the melioration systems (canals, dykes, drain stations) which would regulate water shortage and surplus. Melioration systems date back to 1992 (before the civil war started). In B&H, there are around 420 km of dykes, 220 km of canals and 30 drain stations to fight the high water. Water stream regulation is partial. Maintenance of the existing melioration systems and their improvement is a top priority crucial for the agrarian production, preservation of bio-vegetation system and other geo-systems (settlements, roads, infrastructure, etc.).

The mountain and basin region is characterized by the occurrence of erosion and landslides. It is pertinent to act in order to prevent destructive anthropogenic activities (felling, destruction of vegetation, poor maintenance of water stream, uncontrolled construction).

The monitoring of water levels and flood erosion, i.e. the climate and hydrological observations and the design of landslide register, are the basis for a systematic approach to addressing the problem in order to preserve values of specific geo-systems. As the water streams in north and east represent the state borderline (the Sava and Drina rivers), an efficient regulation of their water levels is conditioned by the quality of cross-boundary cooperation with the Republic of Croatia and the Republic of Serbia.

Hail occurrence in B&H is monitored at the RS level where agro-systems are most common (Pannonian region) and the anti-hail protection systems are constructed. When compared with 1995–2004 periods when there were 10.5 hail days in average, the hail occurrence increased up to 27.6 days a year in 2004–2014 periods (Documentation, RS Anti-hail prevention). In order to adapt to the frequent hail events and minimize the hail damage, the anti-hail systems are constantly being upgraded as the regional and cross-boundary cooperation builds up. The cooperation is evident when it comes to the monitoring, information exchange and technology transfer but there is still a lack of joint prevention action which demands a higher level of interstate cooperation.

If we consider consequences of the exposure to bad weather conditions (flood, hail, drought, extreme temperatures, fire), ***negative effects*** are most evident in economy (agriculture, tourism, roads), settlements, ecosystems (forests), environment and human health (Fig. 2). The rural space of different ecosystems demands different measures of prevention and the infrastructure which should provide protection from bad weather and its outcomes. Agriculture covers 20% of employments structure and GDP. The vanishing forest complexes still occupy around 50% of B&H territory and they share an economic, ecological, touristic and health significance. In poorly developed areas, forest potentials are the basic resource with a multiple valorization opportunities (forestry, tourism, hunting, wood industry). Water resources are not only relevant due water supplies but also due to their large energetic and touristic potentials. Variability of precipitation influences the economic effects in agricultural production and energetics. "Droughts from 2012 and floods from 2014 had decreased agricultural income per around 50%" (Trbić et al. 2014, 2).

Initially, climate changes are manifested through variation in water amounts and water regime. Indirectly, the changes cause other consequences (floods). Therefore, it is crucial to analyze the occurrence and frequency of bad weather as well as the quantity of negative effects, after which the adequate prevention and adaptation actions should be taken. In order to set an efficient spatial organization which should support prevention actions, it is pertinent to summarize the total development capacities in B&H (demography, settlements, infrastructure, and economy). Bosnia and Herzegovina is not a densely populated country. The state's average is 63 people per km^2 (2013 Population census) and the regional differences are large: more than 100 people per km^2 in the agrarian north and around 15 people per km^2 in east and south. One fifth of B&H settlements are vanishing "as their average population density reaches only 0.5 people per km^2 which disables the sustainability of the space and the basic valorization of the existing resources" (Mandic 2015, 57). Around 400 settlements and their territories have zero population (ibid.). In some units of local self-governance, these "settlements" represent compact and demographically void spatial units without any commercial or other activities. By different criteria (demography, settlements, social economy, functions, infrastructure, etc.), these poorly populated settlements are referred to as problem areas from the development-wise point of view (Mandic and Zivkovic 2014). These areas encompass more than half of B&H territory and are typically located in mountain and Adriatic regions. Due to under-developed anthropogenic systems, these areas are normally difficult to defend from bad weather conditions and the adaptation to climate changes is very unlikely.

The area of intensively market-oriented agriculture located in north B&H (Pannonian region) is most exposed to risks of flood, hail and occasional summer drought. The area has relatively high population density and rather good protection systems (canals, dykes, drain stations, anti-hail protection, and civil guard). At the time of the atrocious ***flood*** caused by vast amounts of precipitation which had occurred in May 2014, the inadequate maintenance and technical weakness of hydro-technical systems along with the poorly organized local communities resulted in huge material damage and ecological consequences. It was even the 2015 Report from the Internal

Displacement Monitoring Center (IDMC) that registered the inability of the system to effectively respond to floods back in 2014 (IDMC 2015, 34). At the same time, the mountain and basin region faced vast amounts of precipitation which started strong water flows affecting forests and soil. In turn, the erosion and landslides severely damaged the agriculture, housing and commercial facilities, road infrastructure and energetic sector. It was the largest flood event in the previous 120 years. The damage was estimated to more than €2 billion which was around 15% of B&H GDP. More than 1,200,000 people were in a great threat and around 90,000 people were relocated (Government of B&H 2014: 10, 16). A donor conference organized in order to help repair the damage was held in Bruxelles.

South B&H is most exposed to ***fires*** due to long summer drought. The terrain is difficult to reach and the population density is low which is why it is not easy to react to fire efficiently and in time. The fires expand quickly and cover a huge space which gives them a regional character demanding cross-boundary cooperation in order to extinguish them. Furthermore, the eventual damages affect Mediterranean vegetation, crops and tourism. Due to karst terrain and precipitation regime, it is essential to construct and manage water accumulations in order to sustain water supplies, agriculture, energetic, tourism and fire protection.

Hazards caused by bad weather conditions over the past decade have grown more frequent and covered large areas. In order to prevent them and mitigate the consequences, it is crucial to coordinate activities of B&H national institutions and harmonize the development strategies and infrastructural investments. In addition, there is a necessity to initiate relevant institutions for the observation and monitoring of weather conditions and disasters which they cause. We should also raise awareness of a responsible conduct and educate the population who may help the efficient prevention actions. It is the poor demographic and social-economic potential of problem areas that affects the efficiency in bad weather protection, which is why infrastructural investments and spatial-functional reorganization are vital. “These areas demand specific development policies” (Mandic and Zivkovic 2014, 769).

Similar development problems are also typical of bordering areas in Croatia, Serbia, and Montenegro. An efficient solution to development problems stipulates “the initiation of cross-boundary cooperation without which it will be impossible to join the modern development processes in the region” (Zivkovic et al. 2016, 327). What this entails is an efficient response to climate changes and international obligations.

5 Results and Discussion

Based on the results of meteorological observations and monitoring, it is evident that B&H geo-space is exposed to climate changes resulting from global climate movements. Scientific studies over the last decade have corroborated climate changes, particularly when it comes to pluviometric regime and occurrence of extreme values of some climate elements (amount of precipitation, extreme air temperature), as well as drought, floods, hail and fires.

Having analyzed structural and qualitative features of the rural area geo-systems and the accompanying processes, we reached the following results:

- We defined the features of natural disasters and risks. These include flood, drought, hail and fires.
- We performed differentiation of the geo-space (regionalization) of B&H in line with the type of risks caused by bad weather conditions. The following regions were singled out along with their typical bad weather conditions:

  Pannonian region—flood, hail, occasional drought;
  Mountain and basin region: strong water flows, erosion, landslides;
  Sub-Mediterranean region—drought, fires.

- We registered the impaired values of specific geo-systems of rural areas (land erosion, variability of hydro-systems, decreased agro-system productivity, endangered forests). In addition, variability of water regime indirectly sets off other risks.

Erosive processes devastate more than 2000 ha of arable soil within a year, which constantly decreases the arable surface and negatively affects finances within agricultural production. Furthermore, the variability of hydro-systems has a negative impact on water supplies and electricity production or even causes fires, floods and erosion. It is these negative consequences of the water regime variability that affect the entire B&H territory. It takes enormous infrastructural investments, a modern spatial organization, raising awareness and population participation in order to mitigate the risks. The Pannonian region is characterized with high population density, a high level of economic growth and complex infrastructure. Hence, the region displays a high level of organization and adaptation despite the fact that it is exposed to climate change.

- The obtained results indicate a correlation among the specific elements of anthropogenic systems, the exposure to climate change and the possible adaptation.

The development and spatial-functional organization of settlements and physical infrastructure are of an utmost relevance. Erosion, high water flows and fires are typical of poorly populated mountain and basin and sub-Mediterranean regions where the human activity and spatial organization are inadequate and have no demographic or technical capacities to efficiently respond to bad weather conditions.

- The measure we suggest is the spatial-functional reorganization targeting the design of a more efficient system for weather monitoring, the adjustment of geo-system and improvement of the system for the defense from natural risks.

This measure entails an efficient administrative-territorial organization of B&H, particularly the reorganization of local self-governance units. It is pertinent to strengthen the institutions of local self-governance and improve their total capacities.

- We provide a framework proposal to an integral solution of the problem of institutional capacities (at the levels of entities, state, as well as cross-boundary cooperation).

6 Conclusion

The theory on global climate change is corroborated in Bosnia and Herzegovina territory through the variability of rates and increased frequency of extreme climate values supported by meteorological monitoring. The problem of climate change and the Convention recommendations are addressed in several development strategies and spatial-plan documents adopted at different B&H levels for the purpose of a range of commercial sectors (agriculture, rural development, water management, energetic, tourism) and other social activities. Adaptations to climate change and risk mitigation are treated from the aspect of geo-system sustainability which is the basis for the sustainability of demography, social economy and ecology. The weakness of the existing development strategies lies in partial analyses of the problem resulting from the administrative-territorial and political organization of B&H. Thus, an integral consideration of the problem and a systematic approach are starting points in order to efficiently organize and adapt both natural and anthropogenic geo-systems to climate change.

The example of Bosnia and Herzegovina shows that the response to natural disasters and bad weather conditions in order to preserve rural geo-systems is proportional to the level of total development, institutional structure, spatial organization and infrastructural equipment. In this regard, Bosnia and Herzegovina's rural space has numerous weaknesses which threaten values of the state's geo-systems, as well as sustainability and adaptation to climate change. It is the poorly populated rural areas where local communities require reorganization and stronger capacities that are most threatened. Negative consequences of climate change and the resulting risks have a negative impact of development opportunities and impair the territorial cohesion.

As the studies and experience on this topic in Bosnia and Herzegovina are insufficient, it is the current research that represents pioneer results. Therefore, it is virtually impossible to design a more specific spatial model of prevention from climate change effects, which is the basic limitation of our paper. The lack of a larger number of social-economic and other indicators which would support an elaborate analysis imposes a necessity to establish a unique geospatial database (GIS base). Hence, our geospatial differentiation of B&H in line with sensitivity to climate change and sustainability opportunities is conditional and based on the existing geospatial indicators, as well as the weather monitoring results and the evident consequences.

References

Capra F (2004) The hidden connections. A science for sustainable living. Anchor Books, New York
CCA Forum (2012) South East European conference on climate change adaptation. In: Estimation of vulnerability to climate change. CCA Forum, Belgrade
Cotner D (2009) Livable human communities. A sustainability narrative. Spacium No. 1. Institute of Architecture and Urban and Spatial Planning of Serbia, Belgrade
Dejanovic T (2015) Hail as a natural disaster in the Northern Part of Republic of Srpska. Master paper, Faculty of Natural Sciences and Mathematics, University of Banja Luka
Documentation and Materials, Anti-hail Prevention of the Republic of Srpska (2002–2014), Gradiska
Documentation and Materials (1961–2012), Hydrometeorological Institute of Republic of Srpska, Banja Luka, http://rhmzrs.com
Documentation and Materials (1961–2014), Hydrometeorological Institute of Federation of Bosna and Herzegovina, Sarajevo, https://www.fhmzbih.gov.ba
Documentation and Materials, Ministry of Agriculture and Forestry of FB&H and RS, Sarajevo-Banja Luka
Government of Bosnia and Herzegovina, UN, World Bank, EU (2014) Bosnia and Herzegovina Floods, 2014; Recovery Needs Assessment. http://www.ilo.org/wcmsp5/groups/public/ed_emp/documents/publication/wcms_397687.pdf
Gnjato R, Popovic S, Popovic G, Trbić G (2011) Sustainable rural development and environment of Republic of Srpska, Geographic Society of Republic of Srpska, Banja Luka, vol 15, pp 53–79. ISNN 2232-8629, www.gdrsbl.org
IDMC (2015) Global estimates 2015 people displaced by disasters. http://www.internaldisplacement.org/assets/library/Media/201507-global/Estimates-2015/20150713-global-estimates-2015-en-v1.pdf
Jakobs M (2007) Introduction: the new polities of the environment. In: Jacobs M (ed) Greening the millennium?, Blackwell Publishers, Maldenm, USA, Oxford, UK, pp 1–17
Jovanovic-Popovic D, Milincic M (2016) Impact of climate changes floods and internal displacement in Southeastern Europe, Geographic Society of Republic of Srpska, Herald, Banja Luka, vol 20, pp 111–122. ISSN: 2232-869
Mandic M (2015) Geospatial consequences of demographic development of Republic of Srpska within the context of changes in the settlement system. In: Academy of Sciences and Arts of Republic of Srpska, Scientific symposiums, Demographic politics of RS—reality and needs, Book 34, Banja Luka, pp 53–70
Mandic M, Zivkovic M (2014) Problem areas of Republic of Srpska within the context of demographic change. In: Proceedings of Matica Srpska for social sciences, vol 148, Novi Sad, pp 767–776
Penfiled G (1996) Beyond sustainability. Indic Local Environ 1(2):151–153 (Journal Oxford Ltd Carfas Publishing Company, Abington Oxfordshire)
Popov T, Gnjato S, Trbić G, Ivanisevic M (2018) Recent trends in extreme temperature indices in Bosnia and Herzegovina. Carpathion J Environ Sci 13(1):211–224. https://doi.org/10.26471/cjees/2018/013/019
Population Census of Bosnia and Herzegovina (2013) Federation of Bosnia and Herzegovina, Institute for statistics of F B&H, Sarajevo; Republic of Srpska, Institute for statistics of RS, Banja Luka, www.fzs.ba/ and www.rzs.rs.ba/
Second National Report of Bosnia and Herzegovina according to the Framework Convention of United Nations (2013) Council of Ministers B&H, Banja Luka, Sarajevo
Tosic D, Krunic N (2011) Geographic determinants of sustainable development. In: The 3rd Congress of Serbian Geographers, Congress Proceedings, Banja Luka, pp 759–768
Trbić G (2008) Direct impact of climate change on biodiversity and ecosystem service in Bosnia and Herzegovina. European Centre for Nature Conservation, Tilburg, Netherlands, pp 31–35

Trbić G, Bajic D (2011) Specificity of climate changes in Republic of Srpska and the possibilites of adaptation. In: Third Congress of Serbian Geographers, Congress Proceedings, Banja Luka, pp 149–157. ISSN 2232-8629

Trbić G, Bajic D, Popov T, Oprasic S (2013) Drought issues in Bosnia and Herzegovina, Geographic Society of Republic of Srpska, Herald, Banja Luka, vol 17, pp 103–120. ISSN 2232-8629, www.gdrsbl.org

Trbić G, Djurdjevic V, Bajic D, Vukmir G, Popov T (2014) Climate change and adaption options in Bosnia and Herzegovina—case study in agriculture. In: International conference, ADAPT to Climate, Filoxenia Conference Centre

Trbić G, Bajic D, Djurdjevic V, Ducic V, Cupak P, Markez Dj, Vukmir G, Dekic R, Popov T (2018). Limits to adaptation on climate change in Bosnia and Herzegovina: insights and experiences. In: Limits to climate adaptation. Springer, Berlin, pp 245–259

Zivkovic M, Mandic M, Papic D, Stanojevic M (2016) Cross-Frontier cooperation in service of development of Bosnia and Herzegovina—the sample of priority backward areas along the borderline. WEAS Trans Environ Develop 12:326–331. E-ISSN 2224-3496

Alleviation of Negative Climate Change Effects on Maize Yields in Northern Bosnia by Liming and Phosphorus Fertilization

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Abstract The very acid reaction, low levels of available phosphorus (P) and unfavorable physical properties of soils are often limiting maize yields in Bosnia and Herzegovina (BIH): average yield 4.42 t ha^{-1} and annual yield variation from 2.74 to 5.13 t ha^{-1} in 2001–2010 period. Lately, lower yields are mainly in close relation with drought and higher air temperature stress. Alleviation of these fluctuations is possible by corresponding soil and crop management. Aim of this study was testing liming and P fertilization impact on maize yields in 2007 and 2012 growing seasons. Two stationary field experiments were conducted in the spring of 2005 on Gradiska hydromorphic soils. Under unfavorable weather conditions in 2007 (Gradiska: 61 mm precipitation and 24.0 °C mean air temperature in July + August; averages 1961–1990 = 136 mm and 21.7 °C) maize grain yields were increased for 43% (liming effect: 3.99 and 5.69 t ha^{-1}, for control and liming with 15 t ha^{-1} of hydratized lime, respectively) and for 30% (P effect: 3.18 and 4.12 t ha^{-1}, for control and 1310 kg P_2O_5 ha^{-1}, respectively). The stationary field experiment with liming (10 t of hydratized lime per ha) in combination with rates of monoammonium phosphate up to 1500 kg P_2O_5 ha^{-1} was started in autumn 2008 in Lijevce polje area (Mahovljani locality). Under drought stress in 2012 (Banja Luka: 54 mm precipitation in July + August; mean air temperature 24.8 °C; averages 1961–1990 = 188 mm and 20.2 °C) due to liming maize yield was increased for 25% (2.08 and 2.49 t ha^{-1}, for control and liming, respectively), while P effect was non-significant. Low yield of maize was induced by the high proportion of barren plants. Additional climate change adaptation and alleviation of stress caused by drought in maize growing is

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possible by ploughing combined with fertilization in autumn instead in spring, by weed control and by growing more drought tolerant hybrids.

Keywords Maize · Grain yield · Drought stress · Climate change
Bosnia and Herzegovina

1 Introduction

Recent climate changes characterized by global warming and higher frequency of extreme weather conditions (OSCE 2017) have often adverse impacts on field crop yields. Annual global temperatures have increased by about 0.4 °C since 1980, with even larger changes observed in several regions (IPCC 2001). The earlier estimates of the Intergovernmental Panel on Climate Change (IPCC) have proven to be true, more precisely, increase in temperature, decrease in rainfall during the summer months and increase in the intensity and frequency of extreme climate events (Cramer et al. 2001). According to the fifth report of the IPCC (WGII), Southern Europe is particularly vulnerable to climate change (high level of confidence), as several sectors will be affected (tourism, agriculture, forestry, infrastructure, energy, health of the population) (Kovats et al. 2014). The increase in mean annual air temperature is evident on the whole territory of Bosnia and Herzegovina. The largest increase goes up to 1.3° annually. Changed distribution of precipitation, and the largest deficit during the delivery period of the summer are also evident. (Trbić et al. 2013). However, the climate change in the Western Balkans has not yet been sufficiently explored, hence the lack of published scientific papers in the field and hence the lack of representation in the IPCC reports is also felt.

Lobell and Field (2007) estimated that about 30% variations of global average yields for the world's main field crops are the result of growing season precipitation and temperature variations. In that regard, the lower precipitation and the higher air-temperatures in summer, especially in July and August, are in close connection with the lower yields of maize in Romania, Serbia, Hungary, Croatia and Bosnia and Herzegovina (Kovacevic et al. 2013).

Rising average temperatures in Croatia were indicated, being especially evident during the last 20 years. The increase of mean annual air temperature in the twentieth century in Zagreb was 0.07 °C per ten years. There has been a trend of slightly declining rates of annual precipitation during the twentieth century, continuing at the beginning of the twenty-first century, and an increase in the number of dry days all over Croatia. The increasing temperatures and declining precipitation brings an increased risk of droughts. Out of ten warmest years, since the beginning of the twentieth century, seven of them were recorded after the year 2000 in Zagreb (Peleikis et al. 2014). Extreme climate events in Bosnia and Herzegovina have become increasingly frequent. Out of the last twelve years, six were very dry to extremely dry (2003, 2007, 2008, 2011, 2012 and 2013). In addition, years with large to catastrophic floods have been very frequent (2001, 2002, 2009, 2010 and 2014) (Trbić et al. 2018).

Alleviation of detrimental effects of climate change is possible by adaptation of soil and crop management practices, particularly soil tillage and fertilization (Komljenovic et al. 2013a, b; Stojic et al. 2012) and by growing more tolerant cultivars (Simic 2018).

Soil degradation is a limiting factor for field crop yields (Várallyay 2007; Kádár 2007; Pepo 2007). In Bosnia and Herzegovina (BIH) soils are poor in fertility, mainly because of less favorable physical and chemical properties.

The problem of liming and application of ameliorative level of phosphate, and their extended effect on chemical and physical properties of soil in dry cropping, is complicated by conditions of global warming. Periods of increased amounts of precipitation condition the occurrence of surface waters or floods. Similarly, frequent periods of drought during the vegetation of field crops make the effects of agromeliorative measures difficult to record statistically, at least not to the extent expected.

Acid reaction and nutritional imbalances, mainly low levels of plant available phosphorus (P), as well as unfavorable physical properties, are a limiting factor of pseudogley fertility (Okiljevic et al. 1997; Todorovic et al. 2003). Liming and increased fertilization (mainly with P) under agroecological conditions of northern Bosnia are the usual recommendations for improving fertility of pseudogley soils (Petosic et al. 2003; Kovacevic et al. 2004; Markovic et al. 2006).

The aim of this study was to examine our recent experiences of liming and ameliorative phosphorus fertilization on maize yield in northern Bosnia focused on interaction with unfavorable weather conditions, particularly drought and high air temperatures.

2 Materials and Methods

The first field experiment with liming was conducted on April 14, 2005 on hydromorphic soil (pH in 1MKCl = 4.30; 4.5 mg P_2O_5 100 g^{-1} and 6.3 mg K_2O 100 g^{-1} according to AL-method; humus 0.93%) in Gradiska (45°08′ N; 17°15′ E; el. 163 m, Republic of Srpska, BIH). Research on this field experiment were performed from 2005 to 2008 growing seasons.

Hydratized dolomite meal (47% CaO + 34% MgO) was used in the amounts as follows: 0 (control), 5, 10, 15 and 20 t ha^{-1}. The trial was conducted by randomized block design replications (basic experimental plot 7.0×8.5 m = 59.5 m^2). NPK fertilization (kg ha^{-1}: 160 N + 120 P_2O_5 + 120 K_2O) was applied in spring, before presowing soil tillage, in form of NPK 15:15:15 and urea (46% N). Maize (hybrid NS444—creation of Novi Sad Institute for Field and Vegetable Crops, Serbia) was sown in the first ten-day period of May by pneumatic sowing machine (distance in row 28.0 cm; inter-row spacing 70.0 cm). Maize was harvested manually (4 internal rows from each basic plot). Grain yields were calculated on realized plant density and 14% grain moisture basis (Markovic et al. 2008).

Second field experiment was carried out on the Djurasinovic Family Farm in Mahovljani locality, Laktasi municipality, RS, BIH, (44°46′32″ N, 17°11′08″ E; el. 158 m) during four consecutive growing seasons, from 2009 to 2013, on pseudogley soil (pH in 1MKCl = 4.28) low in plant available P and rich in potassium (K). The treatments included liming and P fertilization. P distribution as monoammonium phosphate (MAP: 12% N + 52% P_2O_5) was conducted on November 10, 2008, before ploughing. The rates of P on basic fertilization (160 N + 75 P_2O_5 + 75 K_2O kg ha^{-1}) were as follows: 0; 500; 1000 and 1500 kg P_2O_5 ha^{-1}. Immediately after P fertilization the experiment plot was ploughed up to 30 cm in depth. Liming of the experiment by 10 t ha^{-1} of powdered hydratized lime (73% CaO + 2–3% MgO + 21% of bound water) was made on November 16, 2008 (four replicates and basic plots 40 m^2 and 640 m^2 for P and liming treatments, respectively). Maize, the hybrid NS444, was grown in monoculture. Detailed information regarding crop management practice, soil properties, weather characteristics, statistical analysis, grain yield, grain moisture, protein-, starch- and oil-determinations until 2013, were shown in the previous studies (Komljenovic et al. 2013a, b, 2015a, b, and 2017).

Statistical Yearbook of RS (SZRS 2013), Hydrometeorological Service of RS in Banja Luka (RHMZRS 2012), TuTiempo (2012) and Saric et al. (1996) were the sources of meteorological data. Calculations of potential evapotranspiration (PET), actual evapotranspiration (AET), water deficit (WD) and water surplus (WS) were made according to Thornthwaite and Mather (1955) and (1957), as follows:

$$PET = 16\left(\frac{10T}{I}\right)^{a}$$

$$I = \sum_{1}^{12} i$$

$$i = \left(\frac{T}{5}\right)^{1.514}$$

$$a = 0.00000075 \times I^3 - 00.0000771 \times I^2 + 0 - 0.01792 \times I + 0.492339$$

where:

PET mean monthly potential evapotranspiration (mm)
T mean monthly air temperature (°C)
I annual heat index;
i monthly heat index

This article was written as a review of previously published papers that were the result of research by the same authors of the impact of ameliorative fertilization with phosphorus and liming on the yield of corn grains in Banja Luka region. The published results of the authors' research which were used in this paper are from the following sources: Markovic et al. (2008), Komljenovic et al. (2013a, b, 2014, 2015a, b, 2017), Radic et al. (2017) and Kovacevic et al. (2013).

3 Results and Discussion

Lijevce polje is an area in the northern part of BIH, encompassing Gradiska, Laktasi and Srbac municipalities. It is a lowland area in the lower flow of the Vrbas river, extending from the Sava river on the north and the mountains: Prosara on the west, Motajica on the east and Kozara on the southwest. The climate of this area is moderate continental climate. Soils of the area are more fertile in comparison to the majority of agricultural areas in the country, although serious problems of aluminum toxicity were sporadically found (Okiljevic 1982; Kovacevic et al. 1988; Komljenovic et al. 2017).

The climate conditions are important factors of maize growing and yields. The water shortage, especially in July, is related with low maize yields (Josipovic et al. 2005), in general. As it can be seen in Table 1, the growing seasons 2005 and 2006 were favorable, because of the adequate precipitation needed for maize growth, while drought stress was the main weather characteristic of the 2007 growing season. Global climate change forecasts and their impact on field crops growing have been discussed in the recent studies (Mikulec and Stehlová 2006; Balla et al. 2006; Stekauerová and Nagy 2007).

Although the data on air temperature in Banja Luka have been collected since 1892, the first continuous data series for a ten-year period refers to the period between 1900 and 1909 with an average annual temperature of 10.7 °C (Komljenovic et al. 2014).

Table 1 Meteorological data (meteorological station, Gradiska RS, BIH)

	Precipitation (mm) and mean air-temp. (°C) in Gradiska							Total	Mean
		April	May	June	July	Aug.	Sept.		
		3-year period (2005–2007) of investigation							
2005	mm	47	58	39	61	140	68	413	–
	°C	11.6	16.9	19.1	21.9	19.5	16.6	–	17.6
2006	mm	74.0	64.2	67.0	22.6	133.6	35.3	397	–
	°C	12.6	16.1	20.6	23.8	19.8	17.9	–	18.5
2007	mm	9	54	63	15	46	111	298	
	°C	14.3	18.6	23.0	24.7	23.2	15.5		19.9
Long-term (75 years) means (1931–2005)									
1935–2005	mm	77	72	68	57	79	77	430	–
	°C	11.8	17.5	20.3	22.4	20.9	16.5	–	18.2

Source Markovic et al. (2008)

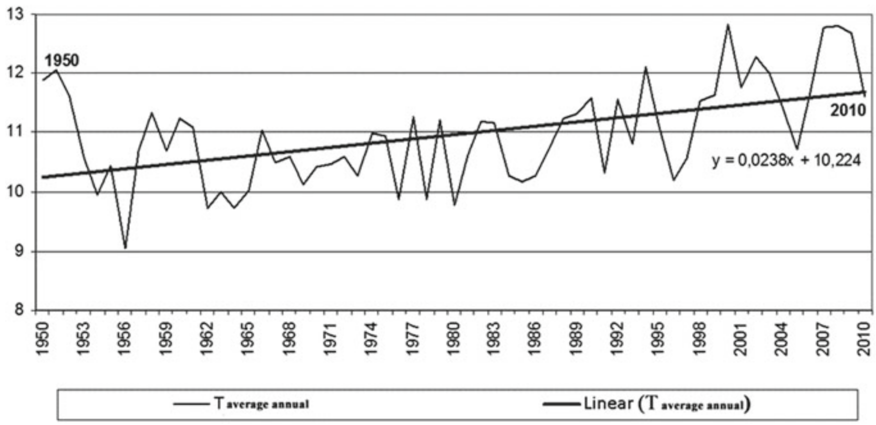

Fig. 1 Mean annual temperature (in °C) in Banja Luka for the period 1950–2010. *Source* Komljenovic et al. (2014)

In the period from 1950 till 1959, the average annual temperature was 10.8 °C, while in the period from 2001 till 2010, the average annual temperature was 12.0 °C, where the temperature increase of 1.2 °C is evident. From 1950 till 2010 the average annual temperature increased by 2.3 °C. Thus, an obvious trend (Fig. 1) is noticeable Markovic (2012), there is increase in air temperature in Banja Luka region, which confirms the interpretation given in the previous subsection (Komljenovic et al. 2014). In addition, it leads us to the conclusion that if these trends (Figs. 1 and 2) continued in the future, by the mid twenty-first century, we could expect that the average annual temperature in Banja Luka reaches 13 °C, Komljenovic (2013b). All this leads us to the conclusion that there is a realistic necessity for application of irrigation in agricultural production if we want to get high rate and stable yields of cultivated plants (Markovic 2012, Komljenovic et al. 2014).

In general, low yields of maize were found on the control treatment and it is an indication of low fertility status of the soil. Excess of water in May 2006 could be responsible for plant density reductions of about 30% compared to the planned density. Application of the highest lime rate increased the maize yield in 2005 growing season for 100%, compared to the control.

In treatments where a smaller amount of lime was applied (5 t ha^{-1}), the maize grain yield increased by 40%, and in treatments with 10 and 15 t ha^{-1} of lime, the yield was increased by 71% compared to the control (without application of lime). In the second year of the study (2006), liming led to the increase in yield by 44% compared to the control (without liming). In general, the low maize grain yield in the conditions of drought stress in the 2007 growing season, was particularly evident within the treatments where a higher amount of lime was applied.

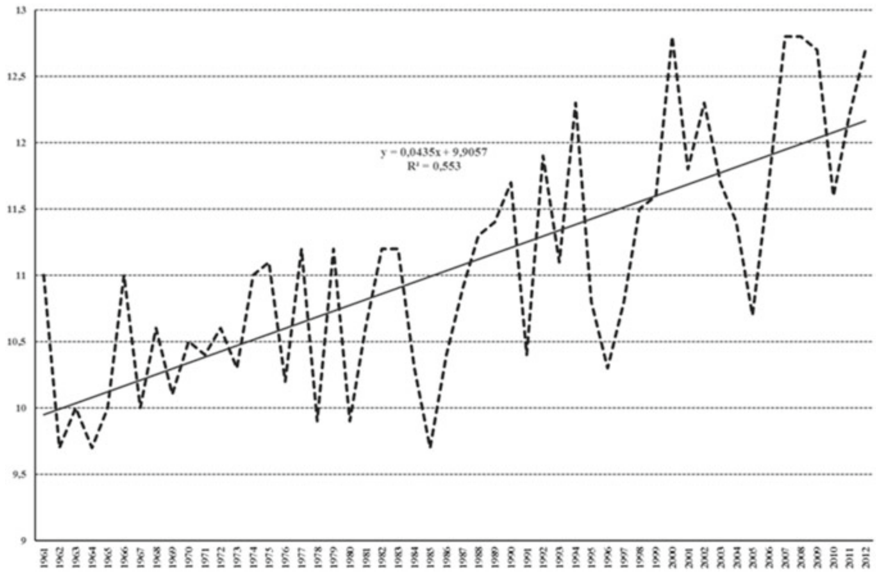

Fig. 2 Trend of average annual temperature (in °C) in Banja Luka from 1961 to 2012. *Source* Komljenovic et al. (2014)

Table 2 Response of maize (NS444 hybrid) to liming on hydromorphic soil in Gradiska

Lime t ha^{-1}	Realized plant density (RPD in % of the planned = PPD*), grain moisture (GM) at harvest and grain yield (t ha^{-1} on 14% GM and RPD basis) for 3-year period								
	2005			2006			2007		
	Yield	Percent		Yield	Percent		Yield	Percent	
	t ha^{-1}	RPD	GM	t ha^{-1}	RPD	GM	t ha^{-1}	RPD	GM
0	3.61	70.7	28.3	4.96	67.9	27.6	3.99	83.7	22.9
5	5.06	85.8	29.5	6.49	67.9	24.8	4.11	84.6	21.8
10	6.18	87.6	29.5	6.56	67.5	25.8	4.55	81.9	22.0
15	6.17	91.2	28.1	6.72	72.0	24.5	5.69	81.0	21.9
20	7.26	91.8	27.6	7.12	72.4	23.1	4.32	83.0	22.2
LSD5%	0.85			0.62			0.33		
LSD1%	1.19			0.87			0.46		

*PPD (100%) = 51,020 plants ha^{-1}
Source Markovic et al. (2008)

Using 15 t lime ha^{-1} resulted by yield increase for 42% compared to the control (Table 2).

Also, in the four-year period from 2009 till 2012 liming affected considerably the grain yield of maize by average yield increase of 31%, with the variations among years from 18% in 2010 to 47% in 2011. As for 2013 growing season, P fertilization impact was considerably lower because yields were increased in three years from 6% in 2009

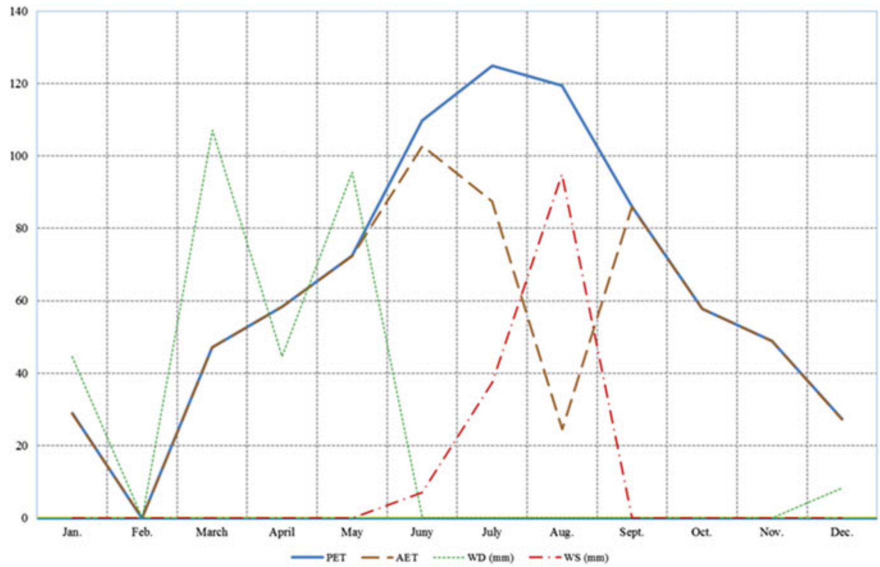

Fig. 3 Diagram by Thornthwaite for 2012 growing season in Banja Luka area. *Source* Original

to 19% in 2011, while in 2012 the differences between yield among P treatments were non-significant. Comparing the yield realized by the three ameliorative P rates and the control, P effect on maize yield was only 8% (4-year averages: 6.14 and 6.65 t ha^{-1}, for control and P rates, respectively). With the exception of the first year of testing, the lowest rate of applied P in the amount of 500 kg P_2O_5 ha^{-1} was adequate for the significant increase of maize yield (Table 4). The response of maize to liming and P fertilization in 2009–2012 period was elaborated in our earlier studies (Komljenovic et al. 2013a, 2015a, b).

Observing a long-term average of the soil moisture, PET and AET, for Banja Luka area (from 2009 till 2013) for the June-August period, the most evident water surplus was in 2010. On the other hand, contrary to the year 2010, in the analyzed year 2012 there was a very significant deficit of moisture (WD) and considerable difference between PET and AET. This led to a very dry period and the lack of moisture in the soil (Fig. 3; Table 3).

As a consequence of these stress conditions, maize was dried at the end of August, without the green color of leaves. Maize covers about 26% (status 2012 according to FAO 2012) of arable land in the countries of the region. It is the main field crop in Serbia (37.2%), Romania (28.7%), Hungary (26.8%), Croatia (21.5%) and BIH (19.4%). For this reason, unfavorable weather conditions for maize, as experienced in 2012, are a considerably negative factor for agriculture and economic development in these countries. Under the influence of the lack of moisture in the soil in 2012, yield reduction of maize in the countries of the region compared to normal 2010,

Table 3 Precipitation and air-temperatures in Banja Luka

The weather data (Banja Luka meteorological station: LTM = long term averages 1961–1990)										
Year	Jan–April	May	June	July	Aug.	Sept.	Oct.	May–Oct.		
Precipitation (mm)										
2009	235	49	153	44	138	33	73	489		
2010	419	148	235	66	87	196	84	816		
2011	153	63	37	113	9	26	62	310		
2012	244	168	70	53	2	92	88	473		
2013	63	120	54	27	36	70	68	438		
LTM	87	98	111	95	93	92	93	505		
Main air-temperatures (°C)										
2009	5.9	18.9	20.0	23.3	22.8	18.6	11.4	19.2		
2010	5.5	16.5	20.3	23.1	21.8	15.7	9.4	17.8		
2011	5.9	16.0	21.2	23.1	23.7	20.2	11.0	19.2		
2012	5.3	16.1	23.0	25.2	24.4	18.9	12.5	20.0		
2013	13.4	16.6	20.4	23.0	23.5	16.7	13.7	18.2		
LTM	10.9	15.6	18.9	20.6	19.7	15.9	13.1			
Absolute and average maximum of air temperatures (°C), PET AET, WD, WS (mm) in Banja Luka										
	Absolute max. temp.			Average max. temp.			PET*	AET*	WD*	WS*
	June	July	Aug.	June	July	Aug.	June–August (sum)			
2009	33	37	38	29.9	25.1	29.5	366.6	326.4	40.2	0.0
2010	34	38	35	27.9	24.9	27.7	361.0	329.1	32.0	119.0
2011	33	37	36	28.4	27.0	30.2	379.6	213.2	166.4	0.0
2012	35	40	37	31.3	28.4	32.6.	414.7	219.3	195.3	0.0
2013	32	37	36	29.3	30.3	29.4	374.0	210.7	164.1	0.0

*PET (Potential evapotranspiration), *AET (Actual evapotranspiration), *WD Water deficit, *WS (Water surplus)
Source SZRS (2013), RHMZRS (2012), TuTiempo (2012), Radic et al. (2017)

was as follows: 53% in Serbia, 49% in Romania, 40% in BIH and 38% in Hungary and Croatia (Kovacevic et al. 2013; Komljenovic et al. 2015a).

More drastic changes in the index values are anticipated for the June–August season. The average index value is expected to be less than one in the entire territory of Bosnia and Herzegovina, which corresponds to very dry conditions. For certain locations, such as Banja Luka, shifts of three categories are expected, from category wet to category dry, (Trbić et al. 2016).

Based on Walter's climate diagram for Banja Luka area for the two tested periods (2010 and 2013), it can be clearly noted that in 2010 between mid-June to late August there was enough and even surplus rainfall. In contrast, the same period in 2012 experienced extreme drought (Fig. 4). This is the most critical period for

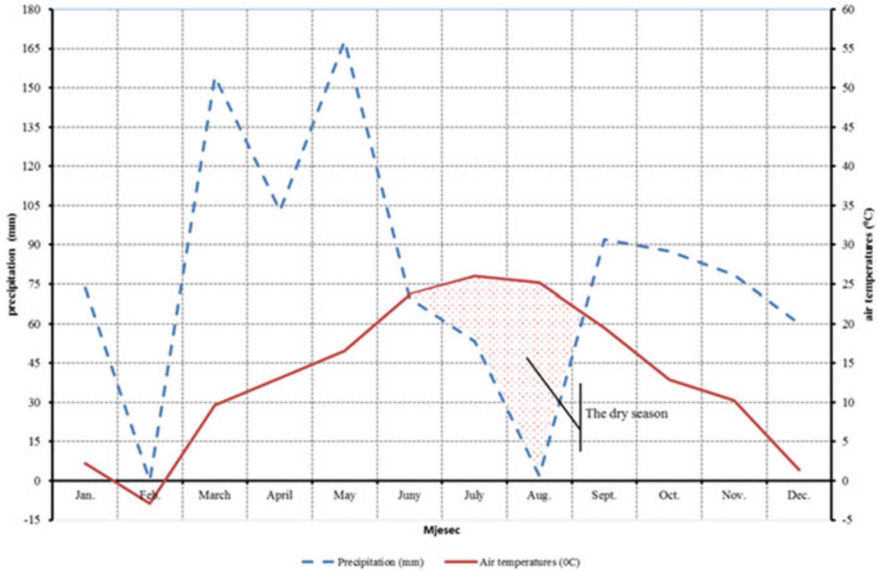

Fig. 4 Climate diagram by H. Walther for 2012 growing season in Banja Luka area

flowering, fertilization and grain filling of maize. Lack of moisture during this period caused a significant drop in the yield of corn (Table 4).

This suggests that irrigation of cultivated crops, with their growing period coinciding with the mentioned period of the lack of water, becomes necessary in the agricultural production within the area (Komljenovic et al. 2014). Irrigation in the critical periods is a direct management practice for overcoming drought stress in plants (Josipovic et al. 2012). Indirect managing for alleviation of this stress is ploughing for spring crops in autumn-winter period, instead in spring, together with incorporation of adequate quantities of mineral fertilizers, weed control, etc. (Komljenovic et al. 2015a, b).

4 Conclusion

Effects of ameliorative fertilization by phosphorus and liming on growth, development and corn yield can be achieved only if other vegetative factors, predominantly agro-climatic ones, are in favorable interconnection.

In doing so, the rainfall schedule and the corresponding height of the air temperature during the vegetation, and especially in the most susceptible phases of maize growth, strongly influenced the flowering and early stage of grain filling. This is indicated by the yield of corn in 2012 growing season in the area of Mahovljani. Namely, the average amount of precipitation for the period of vegetation of maize

Table 4 Response of maize to liming and P fertilization in the 2009–2013 period in Laktasi municipality

	2009			2010			2011			2012			2013		
P_2O_5* kg ha^{-1}	Lime			Lime			Lime			Lime			Lime		
	A_1	A_2	x B	A_1	A_2	x B	A_1	A_2	x B	A_1	A_2	x B	A_1	A_2	x B
	Grain yield (t ha^{-1})			Grain yield (t ha^{-1})			Grain yield (t ha^{-1})			Grain yield (t ha^{-1})			Grain yield (t ha^{-1})		
B_1	7.30	10.07	*8.68*	7.97	9.92	*8.94*	4.40	5.53	*4.97*	1.82	2.08	1.95	2.50	6.55	4.52
B_2	7.37	10.65	*9.01*	8.66	10.28	*9.47*	4.59	7.19	*5.89*	1.98	2.24	2.11	2.74	7.00	4.87
B_3	7.61	10.66	*9.13*	9.23	10.24	*9.73*	4.60	7.09	*5.85*	1.85	2.36	2.11	2.90	7.33	5.15
B_4	7.82	10.60	*9.21*	8.55	10.17	*9.36*	4.68	7.06	*5.87*	1.67	2.49	2.08	3.29	8.65	5.97
x A	*7.52*	*10.49*	**9.00**	*8.60*	*10.15*	**9.38**	*4.57*	*6.72*	**5.65**	*1.83*	*2.29*	**2.06**	2.86	**7.38**	
A effect		+39%			+18%			+47%			+25%			+61%	
B effect			+6%			+9%			+19%			ns			
	A	B	AB	A	B	AB	A	B	AB	A	B	AB	A	B	AB
P 0.05	0.81	0.43	ns	0.32	0.33	ns	0.45	0.34	0.49	0.17	ns	ns	0.85	0.53	1.38
P 0.01	1.49	ns	ns	0.59	0.45		0.83	0.47	0.67	0.30			1.22	0.76	1.92

Liming (the factor A) by hydratized lime (A_1 =0, A_2 =10 t ha^{-1}) and ameliorative phosphorus (P_2O_5 kg ha^{-1}: B_1 =0, B_2 =500, B_3 =1000, B_4 =1500) fertilization (the factor B) in autumn 2008: impacts on maize status in the 2013 growing season (realized plant density: 100% = 57,143 plants ha^{-1})
*Basic fertilization of all treatments (160 N + 75 P_2O_5 + 75 K_2O kg ha^{-1}); in the next years (2009–2013) only basic fertilization of the experiment
Source Komljenovic et al. (2013a, b, 2015a, b, 2017)

in 2012 growing season was within the average, but the precipitation schedule was extremely unfavorable (lack of moisture in fertilization and filling phase with very high daily air temperatures in June, July and August).

Intensive development of agricultural crops will have to adapt to the changing climate and bioclimatic conditions. This will primarily involve development and improvement of irrigation systems, and the choice and selection of new varieties of crops.

The fact that these extreme conditions have already been registered during 2012, almost throughout the entire territory of Bosnia and Herzegovina, is immensely concerning. This indicates the need for practical planning and adaptation measures based on the most extreme scenario. It is important to emphasize that the impact of future climate change on the agricultural sector will be significantly, but not entirely, negative.

References

Balla K, Zoltán Bedő Z, Veisz O (2006) Effect of heat and Drought stress on the photosynthetic processes of wheat. Cereal Res Commun 34(1):381–385

Cramer W et al (2001) Working Group II: impacts, adaptation and vulnerability, IPCC AR3, Chap. 13-Europe, https://www.ipcc.ch/ipccreports/tar/wg2/pdf/wg2TARchap13.pdf

FAO (2012) The state of food and agriculture. Food and agriculture organization of the United Nations. Rome. www.fao.org/docrep/017/i3028e/i3028e.pdf

IPCC (2001) Book of climate change 2001. Impacts, adaptation, and vulnerability. Contribution of working group II to the third assesment report of the intergovernmental panel of the climate change. Cambridge University Press, pp 75–1005

Josipovic M, Kovacevic V, Petosic D, Sostaric J (2005) Wheat and maize yield variations in Brod-Posavina area. Cereal Res Commun 33(1):229–233

Josipovic M, Kovacevic V, Sostaric J, Plavsic H, Markovic M (2012) Irrigation and nitrogen fertilization needs for maize in Osijek-Baranya County. Növénytermelés 61:45–48.

Kádár I (2007) Sustainability of soil fertility nutrient levels. Cereal Res Commun 35(2):573–576

Komljenovic I, Markovic M, Djurasinovic G, Kovacevic V (2013a) Response of maize to liming and ameliorative phosphorus fertilization. Adv Crop Sci 3(3):225–232

Komljenovic I, Jug D, Markovic M, Kovacevic V, MiSic M (2013b) Reduced tillage as the agricultural technique in agricultural productivity and to mitigate climate change in Croatia and Bosnia and Herzegovina. In: Proceedings, scientific-technical conference with international participation "Environment protection between science and practice—status and perspectives" 13 December 2013, pp 401–412

Komljenovic I, Misic M, Markovic M, Pesevic D, Markovic M (2014) The climate data analysis of Banja Luka area as the basis of agricultural adaptation to climate change planning. In: Conference proceedings of people, buildings and environment 2014, an international scientific conference, Kroměříž, Czech Republic, pp 592–603

Komljenovic I, Markovic M, Djurasinovic G, Kovacevic V (2015a) Response of maize to liming and ameliorative phosphorus fertilization. Novenytermeles 64(3):35–38

Komljenovic I, Markovic M, Djurasinovic G, Kovacevic V (2015b) Response of maize to liming and phosphorus fertilization with emphasis on weather properties effects. Columella J Agri Environ Sci 2(1):29–35

Komljenovic I, Kovacevic V, Markovic M, Djurasinovic G, Radic V (2017) Maize response to liming and phosphorus fertilization in Lijevce polje region of Bosnia and Herzegovina. Book of proceedings – VIII international agriculture symposium Agrosym 2017, Jahorina 5–8 October 2017. Bosnia and Herzegovina, pp 67–72

Kovacevic V, Banaj D, Brkic I, Antunovic M, Petosic D (2004) Fertilization impacts on the yield and nutritional status of maize (*Zea mays* L.). Cereal Res Commun 32(3):403–410

Kovacevic V, Vukadinovic V, Bertic B. (1988) Excessive iron and aluminum uptake and nutritional stress in corn (*Zea mays* L.) plants. J Plant Nutr 11(6–11):1263–1272

Kovacevic V, Kovacevic D, Pepo P, Markovic M (2013) Klimatske promjene u Hrvatskoj, Srbiji, Mađarskoj i Bosni i Hercegovini: usporedba vegetacije kukuruza 2010. i 2012. godine (Climate change in Croatia, Serbia, Hungary and Bosnia and Herzegovina: comparison of the 2010 and 2012 growing seasons). Poljoprivreda/Agriculture 19(2):16–22

Kovats RS, Valentini R, Bouwer LM, Georgopoulou E, Jacob D, Martin E, Rounsevell M, Soussana JF (2014) Europe. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 1267–132. https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap23_FINAL.pdf

Lobell D, Field C (2007) Global scale climate–crop yield relationships and the impacts of recent warming. Public Health Resources. Paper 1. (http://digitalcommons.unl.edu/publichealthresources/152)

Markovic M, Komljenovic I, Delalic Z, Kovacevic V (2006) Phosphorus a limiting factor of the field crops yield under conditions of the northern Bosnia. Lucrari Stiintifice, Seria Agronomie, Universitatea de Stiinte Agricole si Medicina Veterinaria Iasi 49:218–222

Markovic M, Todorovic J, Biberdzic M, Delalic Z (2008) Response of Maize to Liming in Northern Bosnia. Cereal Res Commun 39:2079–2082

Markovic M (2012) Land and soil resources. In: State of the environment report in Bosnia and Herzegovina (SoER BIH). MDG-F Program "Environment and Climate Change", UNDP, UNEP, UNESCO, FAO and UNV

Mikulec V, Stehlová K (2006) Application of the climate change scenarios on selected meteorological characteristics for the purposes of water content course prognosis in time horizons 2010, 2030 and 2075. Cereal Res Commun, pp 45–48

Okiljevic V (1982) Toksično dejstvo Al na neke sorte pšenice i ječma, na tipu zemljišta pseudoglej u Bosanskoj Krajini. Zemljište i biljka 31(1):45–54

Okiljevic V, Predic T, Lukic R, Markovic M (1997) Poljoprivredno zemljište Republike Srpske\Agricultural soils of Republic of Srpska). Agroznanje I 1:15–23

OSCE (2017): Climate change and security—Eastern Europe. Organization for Security and Co-operation (OSCE) in Europe (http://www.osce.org/secretariat/331901)

Peleikis J, Gratz M, Brnada E (2014) Adaptation to climate change in Croatia. Country Brief. Baltic Environmental Forum, Hamburg, http://www4.unfccc.int/nap/Documents%20NAP/Adaptation%20Strategies%20and%20Plans/Adaptation%20to%20Climate%20Change%20in%20Croatia.pdf

Pepo P (2007) The role of fertilization and genotype in sustainable winter wheat (*Triticum aestivum* L.) production. Cereal Res Commun 35(2):917–920

Petosic D, Kovacevic V, Josipovic M (2003) Phosphorus availability in hydromorphic soils of Eastern Croatia. Plant Soil Environ 49(9):394–401

Radic V, Kovacevic V, Komljenovic I, Majdancic M, Figurek A (2017) Effects of weather conditions in Bosnia and Herzegovina from 2011 to 2015 Growing seasons regarding maize growth and climate change. In: Proceedings of VIII international scientific agricultural symposium "Agrosym 2017" Jahorina, October 05–08, 2017, Bosnia and Herzegovina, pp 111–117

RHMZRS (2012) Climate data for 2012 growing season. Hydrometeorological Service of RS, Banja Luka http://rhmzrs.com/

Saric T, Djikic M, Gadzo D (1996) Dvije žetve godišnje, Biblioteka “Savremena poljoprivreda”, NIP “Zadrugar” Sarajevo i “EDIS” Sarajevo

Simic D (2018) Maize and climate change—coping with multiple stress. In: Proceedings of 53 Croatian and 13th international symposium on agronomy. Vodice, Croatia, pp 7–16, 18–23 Feb 2018

Stekauerová V, Nagy V (2007) The influence of extreme meteorological phenomena on soil water regime of lowlands. Cereal Res Commun 35(2):1097–1100

Stojic B, Kovacevic V, Seput M, Kaucic D, Mikoc V (2012) Maize yields variation among years as function of weather regimes and fertilization. Növénytermelés 61:85–88

SZRS (2013) Statistical yearbooks of Republic of Srpska, Banja Luka

Thornthwaite CW, Mather JR (1955) The water balance. Laboratory of climatology publication 8. Centerton, NJ

Thornthwaite CW, Mather JR (1957) Instructions and tables for computing potential evapotranspiration and the water balance. Publ Climatol 10:185–311

Todorovic J, Lazic B, Komljenovic I (2003) Ratarsko-povrtarski priručnik Grafomark. Laktaši, RS, BIH

Trbić G et al (2013) Problems of drought in Bosnia and Herzegovina, Herald, 17. Banja Luka, pp. 103–120. http://www.gdrsbl.org/3/izdanja/17/17.pdf

Trbić G et al (2016) The impact of climate change on the modification of bioclimatic conditions in Bosnia and Herzegovina. Int J Environ Sci 1:176–182. http://iaras.org/iaras/journals/ijes

Trbić G et al (2018) Limits to adaptation on climate change in Bosnia and Herzegovina: insights and experiences. In: Leal Filho W, Nalau J (eds) Limits to climate change adaptation. Climate change management. Springer, Cham. https://doi.org/10.1007/978-3-319-64599-5_14

TuTiempo (2012) https://en.tutiempo.net/climate/2012/ws-404160.html

Várallyay G (2007) Láng István, Csete László és Jolánkai Márton (szerk): A globális klímaváltozás: hazai hatások és válaszok (A VAHAVA Jelentés). Agrokémia és Talajtan 56(1):199–202

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Temperature Risk Assessment in Urban Environments During Heat Wave Periods: A Case Study on the City of Novi Sad (Serbia)

Stevan Savić, Daniela Arsenović, Vladimir Marković and Dragan Milošević

Abstract The main goal of this research is to assess risk and map methodologies for the study of intensive heat waves in Novi Sad's urban area. Novi Sad is the second largest city in the Republic of Serbia, with a built-up area of 102 km^2 and the population of 330,000 (data as of 2017). Intensive heat waves are a frequently occurring hazard in Central and Southeastern Europe and they may lead to a higher mortality of urban populations. Therefore, for the heat wave risk assessment, in situ air temperature (T_a) measurements from urban stations and the mortality rates of urban populations were used. The methodology used in this heat wave risk assessment is based on European Commission's Guidelines for Risk Assessment and Mapping. The nocturnal air temperatures from 9 PM to 5 AM during the summer of 2015 (as one of the hottest summer in the past few decades) were used. The nocturnal urban heat island (UHI) intensity values between the various built-up zones and natural surrounding areas were used for the hazard level calculation. The average daily number of deaths by local climate zones (LCZs) was used to define the impact level of the vulnerability index. The results show that the most densely built-up areas (LCZs 2 and 5) had very high or high risk values and a higher rate of mortality. According to these results, local authorities could define hot spots where they could place medical and rescue teams and install points with water supplies. Furthermore, local and regional authorities, medical and urban planning institutions can use the obtained results and maps to prevent and mitigate climate-related hazards.

Keywords Heat wave · Risk assessment · Air temperature · Local climate zone Human mortality · Urban area

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1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC 2007), climate change is defined as a statistically significant change in the mean state of the temporal variability of the climate due to the natural variation of external forcing, anthropogenic changes in the composition of the atmosphere, or changes in land use. The Hewitson et al. (2014) projection of climate change in Southern Europe (i.e. a part of Eastern and Southeastern Europe) shows that the strongest temperature increase and, at the same time, decrease in the precipitation amount occurs in the summer season. Furthermore, the IPCC classifies heat waves as one of the extreme weather events associated with climate change (Field et al. 2012). In the 20th century, the climate of Central and Eastern Europe was marked by an overall temperature increase, which was more pronounced in the Alps and their surroundings than in other parts of this region. By the mid-21st century the mean annual temperature is expected to increase by 1–3 °C and by the end of the century the temperature will be by 5 °C higher. The projected temperature increase will be the greatest during summer and the smallest during winter (Anders et al. 2014). In Central Europe, a substantial increase in heat wave frequency is projected. The frequency is expected to double in the near future (2020–2049) and the increase is to result in three to four heat waves per summer between 2070 and 2099 (Lhotka et al. 2018). This study focuses on heat wave risk assessments in urban areas, as heat waves are one of the most frequent climate change hazards in Central and Southeastern Europe. Furthermore, heat wave risk assessments will be particularly important for urban areas, which are exposed to modified climate impacts and are substantially affected by high temperatures. Therefore, according to Papathoma-Köhle et al. (2016a), risk assessment analysis is very important in defining the vulnerability of the elements at risk to a specific hazard.

Heat waves have strong negative impacts in urban areas due to large areas of rough artificial surfaces (densely built-up areas), local and regional climates, and the lack of trees and green spaces. This leads to the modification of air temperatures and the emergence of intense urban heat islands (UHI) (Wilhelmi and Hayden 2010). The UHI represents the difference in temperature between cities and the surrounding rural areas (Depietri et al. 2011), and the UHI intensity is positive in urban areas (Memon et al. 2009). According to Memon et al. (2009), air temperature-based UHI intensities were higher and positive during the night but lower and negative during the day. Huang and Lu (2018) presented the most important UHI research in the past 25 years.

An increasing number of studies have documented that the frequency, intensity and duration of heat waves are significantly associated with human mortality (Le Tertre et al. 2006; Baccini et al. 2008). Due to these results, heat-related mortality is identified as one of the most important hazards to public health. The population groups vulnerable to heat waves include the elderly, socially isolated and people with chronic diseases (Baccini et al. 2008; Muthers et al. 2017).

So far, a heat wave risk assessment for the urban area of Arad (Romania) has been done based on a number of paramedic interventions and UHI data (Papathoma-Köhle et al. 2016a, b). A similar study has been conducted in Novi Sad (Serbia) based on nocturnal UHI data and the average daily number of deaths (Savić et al. 2018). The results show that the risk is the highest for the health of populations in the most urbanized areas.

The goal of this paper is to present the heat wave risk assessment and mapping for the urban area of Novi Sad based on nocturnal temperatures, differences in built up areas and the number of deaths. An additional goal of this paper is to connect science with local and regional institutions and authorities in order to help identify vulnerable groups of people and hot spots in urban areas. Hence, the main aim is the application of scientific research and results in resolving local and regional environmental issues.

2 Research Area, Methodology and Data

2.1 Geographical Characteristics of the City of Novi Sad

The City of Novi Sad is the second largest urban area in the Republic of Serbia, with a built-up area of 102 km^2 and the population of 330,000 (data as of 2017). It is located in Central Europe in the Carpathian Basin and the greatest part of built-up areas are set in a relatively gentle relief between 80 and 86 m a.s.l. This southeastern built-up area is located on the edge of the northern slope of the low mountain of Fruška Gora and is separated from the main body of the built-up urban area by the Danube River (260–680 m wide). The Novi Sad region has a Cfb climate (temperate climate, fully humid, and warm summers, with at least four $T_{mon} \geq +10$ °C) according to the Köppen-Geiger climate classification (Kottek et al. 2006). The mean monthly air temperature ranges from −0.7 °C in January to 21.3 °C in July and the mean annual precipitation is 597 mm (reference period 1961–2000).

2.2 Risk Assessment and Mapping Methodology

Through the Southeast Europe Transnational Cooperation Programme project called "Joint disaster management risk assessment and preparedness in the Danube macro-region" or the SEERISK project, a generic and adaptable risk assessment methodology for the Danube macro-region has been developed and tested for five climate change-related hazard types: flood, drought, heat wave, wildfire and extreme wind (SEERISK 2014; Papathoma-Köhle et al. 2016b). "The methodology has been developed in order to improve the consistency in risk assessments among countries and provide the local authorities and other end-users with a tool that will enable them to conduct risk assessments and mapping for a range of hazard types, focusing on different scales and elements at risk" (Papathoma-Köhle et al. 2016a). The methodology has three steps:

- definition of the context and risk,
- risk analysis,
- risk evaluation.

Risk identification is the first step of the methodology where working groups and end-users identify the context of and the basis for risk assessment. An important stage of risk assessment is defining the risk criteria (e.g. the number of deaths, the number of medical interventions, material damages, financial loss). Risk analysis is the second step of risk assessment and it includes a hazard analysis, an impact analysis and a risk analysis. In the third step of risk assessment, the results of the risk analysis and risk criteria are compared. Risk evaluation is the procedure of deciding which risk is acceptable or tolerable and which risk needs to be addressed. A detailed description of the risk assessment methodology steps is presented in SEERISK (2014) and Papathoma-Köhle et al. (2016b).

2.3 LCZs and Station Network Patterns

The definition and delineation of different built-up areas in Novi Sad is based on the Local Climate Zone (LCZ) classification system (Stewart and Oke 2012), the Lelovics-Gál methodology (Lelovics et al. 2014) and the guidance to obtain representative meteorological observations at urban sites (Oke 2004; Muller et al. 2013). Seven built LCZ classes are detected: LCZ 2—Compact midrise, LCZ 3—Compact low-rise, LCZ 5—Open midrise, LCZ 6—Open low-rise, LCZ 8—Large low-rise, LCZ 9—Sparsely built and LCZ 10—Heavy industry (Fig. 1a). Additionally, the land cover classes A, D and G representing dense trees, low plants and water, respectively, have been detected in Novi Sad and its surroundings. The advantages of the LCZ system lie in the fact that it is a global classification scheme with a limited number of classes, which are separated by the main thermal characteristic of the urban surface (Stewart and Oke 2012). Furthermore, it can be used for mapping and spatial analysis, as well as for the characterization of measurement sites (Lelovics et al. 2016).

Novi Sad's urban network (NSUNET) was created in 2014 and it includes 25 stations installed in seven built LCZs and two stations in land cover LCZs A and D (Fig. 1a). The stations were equipped with air temperature and humidity sensors in radiation protection screens to obtain long-term and effective measurement data within Novi Sad's urban area. The sensors and the equipment were installed at least 4 m above the ground on arms fixed to selected lampposts (Fig. 1b). The stations were activated each minute to perform data measurements and each 10 min they sent the averaged readings to the main server installed at the University of Novi Sad, Faculty of Sciences (Šećerov et al. 2015).

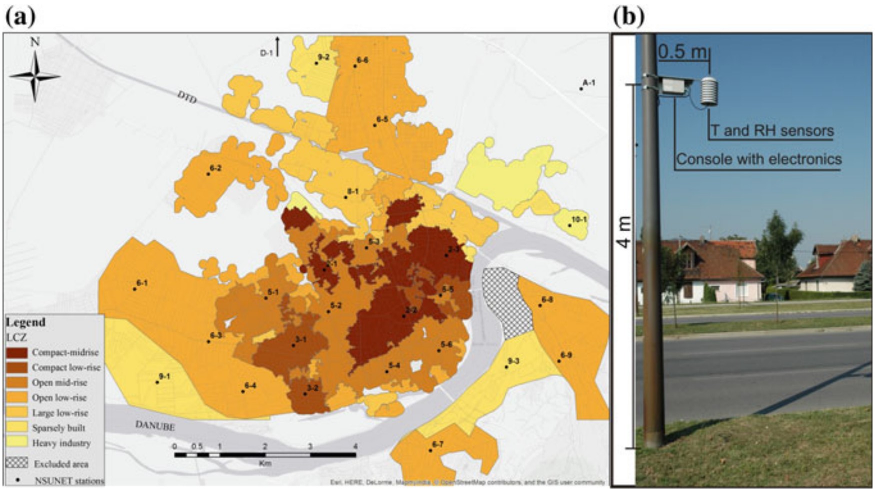

Fig. 1 **a** LCZ pattern and station locations; **b** Station 5-2 with air temperature and relative humidity sensors. *Source* Savić et al. (2018)

2.4 *Temperature and Population Data*

According to Dong et al. (2016) the summer of 2015 was one of the hottest summers in the past few decades, and it was chosen for further analysis as an adequate period for a heat wave risk assessment in the urban area of Novi Sad.

Additional criteria were applied (Savić et al. 2018) to select the days within very strong and intensive heat wave periods. The criteria were as follows: (1) the heat wave lasted ≥5 days; (2) the maximum daily T was ≥5 °C than the average daily temperature; and (3) the maximum daily T ≥ 8 °C than the average monthly (June, July or August) temperature. Two intensive heat wave periods were identified based on additional criteria, i.e., from 17 to 25 July (e.g., average daily T_a from 27.6 to 29.5 °C; maximum daily T_a from 36.2 to 37.9 °C) and from 4 to 15 August (e.g., average daily T_a from 26.4 to 28.9 °C; maximum daily T_a from 33.5 to 38.2 °C). The results presented in this study were obtained during 2016 and in early 2017.

The current results for medium-sized Central European cities (Fortuniak et al. 2006; Doborvolny and Krahula 2015; Gál et al. 2016) showed that strong UHI intensities appeared during early night (Oke 1981; Hart and Sailor 2009), i.e., started at 1 PM, and lasted for 9 h after the sunset. Hence, the T_a data were analysed for the period between 9 PM (current day) and 5 AM (next day), i.e. 8 h per day, when the UHI intensity had a relatively strong signal. According to this, the final T_a database included 30618 measurements (Savić et al. 2018).

The database for mortality in the summer of 2015 was obtained from the Institute for Public Health of the Vojvodina Province, Republic of Serbia, and the total population number was taken from the population register of the City of Novi Sad. The daily number of deaths from all causes (ICD-version 10) was used, and the final

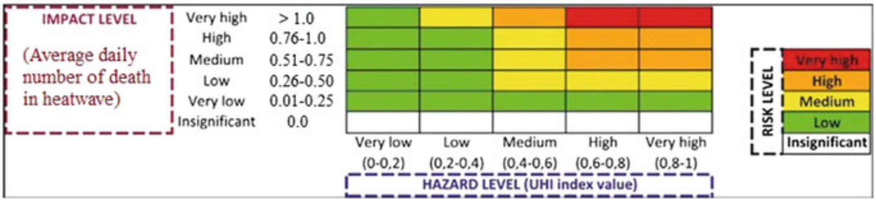

Fig. 2 Heat wave risk matrix for the urban area in Novi Sad. *Source* Savić et al. (2018)

analysis was performed on 559 deaths. The number of deaths was recorded daily (24-hours) for the selected heat wave periods. Only the permanent residents of the city who died in Novi Sad were included in the analysis. Using the residence information for each person, the spatial delineation of the deaths was calculated for each LCZ (Savić et al. 2018).

3 Results

The main purpose of this study is to make heat wave risk assessments for different LCZs in Novi Sad's urban area and calculate the heat wave mortality risk for the local population. Based on daily mortality data for the summer of 2015 and the UHI intensity for two intensive heat wave periods, a risk matrix was developed (Fig. 2). The vertical axis shows the impact level expressed as the average daily number of deaths (M_{avg}), and along the horizontal axis, the hazard level is expressed as a standardized UHI intensity index value (Fig. 2). In the heat wave risk matrix, the hazard and impact levels are scaled from insignificant to very high, and the risk level has five levels (insignificant, low, medium, high and very high).

Heat wave hazard maps (Fig. 3) are based on nocturnal air temperature differences between the diverse built-up and land cover LCZs. The UHI intensity index was obtained by subtracting the minimum value of the domain from each station temperature. In the next step, the index was standardized by dividing each difference with the maximum. The greatest difference corresponds to the maximum UHI intensity effect, and its value is 1 (Fig. 2) (Savić et al. 2018).

Figure 3 shows the spatial distribution of the UHI intensity hazard maps between the urban and non-urban stations. The heat wave in July (Fig. 3a) shows the UHI intensity values from 0.8 to 1.0, which cover the majority of the densely built-up areas, such as LCZs 2 and 5. Hence, the highest T_a differences between the built-up and land cover areas could be observed in central urban areas. Most industrial areas (LCZ 8) and the peripheral parts of the densely built-up areas had a UHI intensity index from 0.6 to 0.8. The city areas mostly characterized by moderately dense built-up zones (LCZs 3, 6, 8 and 10) had values between 0.4 and 0.6. Only the northern, southwestern and southeastern outskirts (LCZ 9) had the UHI intensity values lower

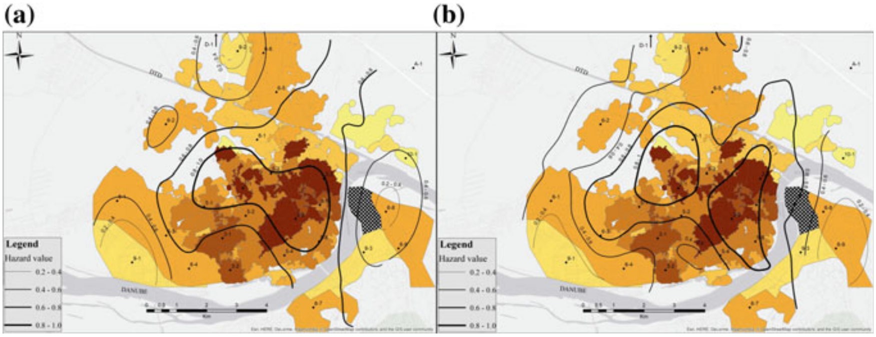

Fig. 3 Heat wave hazard maps: **a** July and **b** August. See the legend for LCZs pattern in Fig. 1a. *Source* Savić et al. (2018)

than 0.4. The spatial pattern of hazard values during the August heat wave shows very similar results (Fig. 3b).

Heat wave hazards significantly influence urban populations, particularly vulnerable groups, such as elderly people, children, people with chronic diseases, and disabled people. The impact map used the M_{avg} as the impact index for the selected heat wave periods in the summer of 2015. As the lag effect for heat-related mortality is 0–3 days (Yu et al. 2011; Huang et al. 2014; Bao et al. 2016), heat wave periods covered the days of the heat wave and 3 subsequent days. The impact level indicators were limited only to the total number of deaths from all causes because the analysis covered weather periods with extreme temperatures in a medium-sized city.

The total number of deaths in each LCZ during the heat wave periods was obtained. Furthermore, the number of days for both heat wave periods was determined—-namely, there were 12 days in July and 15 in August. Finally, M_{avg} was calculated using the total number of deaths and the number of days for the heat waves. This calculation was done for each LCZ. Figure 2 shows the impact level scale of M_{avg}, where the values >1 have a very high impact level, and the impact is lower as the values are closer to 0. The minimum value of the impact level was defined (0.01) if at least one death a day was registered during the observed period. Figure 4 shows very high impact level values in the central and western parts of the city, characterized by dense midrise buildings (LCZ 2), and there is an open arrangement of midrise buildings in the western and southeastern urban areas (LCZ 5). LCZ 6 and LCZ 3 represent moderately dense buildings with high and medium impact levels, respectively. Near the outskirts of the city, there are less urbanized areas (LCZ 9) with very low impact levels. LCZs 8 and 10 were excluded from the impact level analysis because there were no residential buildings in these areas (Savić et al. 2018).

The risk matrix was created based on the hazard level of the UHI intensity and the impact level of the M_{avg} from the heat wave periods in the summer of 2015 (Fig. 2). The risk map was generated based on the equation *risk value = 10 * hazard level + impact level*. The calculated risk values were reclassified to risk levels (insignificant,

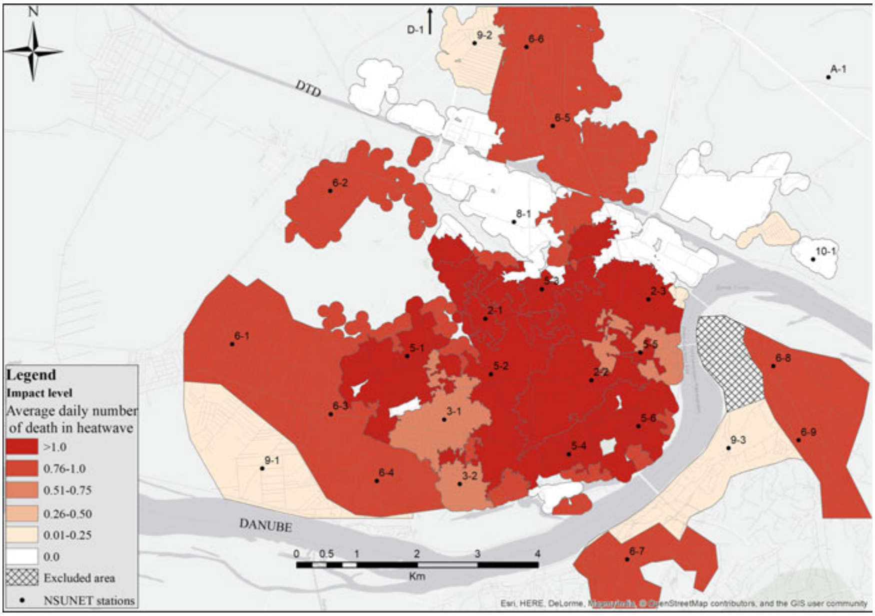

Fig. 4 Impact level pattern. *Source* Savić et al. (2018)

low, medium, high, very high) according to the colouring of the risk matrix, and these were used to develop the risk maps (Perge et al. 2014).

Figure 5 presents the heat wave risk assessment for the two periods from July (17–25) and August (4–15). Avery high risk level was observed in the most urbanized areas, which are represented by LCZs 2 and 5. High risk levels were mostly recorded in LCZ 3 and some parts of LCZ 6, characterized by densely built houses and low buildings. LCZ 9 has a low risk level and covered the outskirts of the city. The spatial patterns of heat wave risk levels in July and August were very similar and they can be seen in Fig. 5a and b (Savić et al. 2018).

4 Discussion

There are few papers dealing with heat waves risk assessment in urban areas. They are mostly based on satellite data and the land surface temperature (LST)—e.g. the studies conducted in Atlanta (Jedlovec et al. 2017) and Athens (Keramitsoglou et al. 2013). In Southeastern Europe, the first studies were those conducted within the framework of the SEERISK project (SEERISK 2014) and by Papathoma-Köhle et al. (2016a) for the city of Arad (Romania) based on the number of paramedic interventions and one meteorological station located in the outskirt of the urban area. The results showed that the negative effects of heat waves on the population's health was

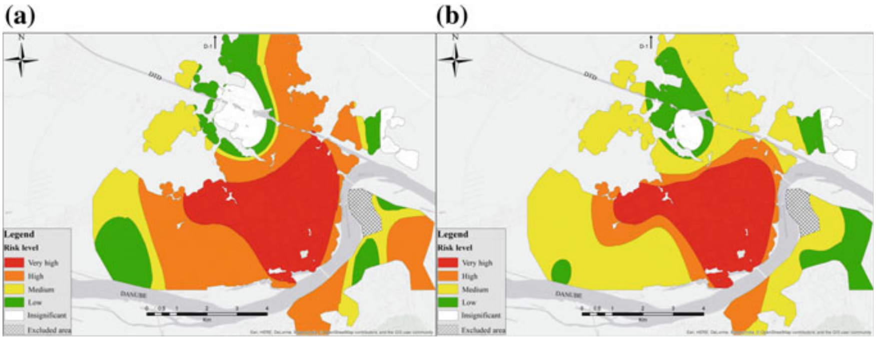

Fig. 5 Heat wave risk mapping: **a** July and **b** August. *Source* Savić et al. (2018)

higher in the most urbanized parts of the city. However, the heat wave risk assessment of different built-up areas based on detailed spatiotemporal air temperature monitoring in urban areas is still a serious challenge.

Therefore, in this study, the risk assessments for the urban area of Novi Sad were based on the air temperature differences (nocturnal UHI intensity) between the various built-up areas (LCZs) and non-urbanized surroundings and their impact on population mortality. The UHI intensity was the highest during the night, particularly during the periods of heat wave events, and the consequences on vulnerable groups of people could be fatal. In this study, the UHI intensity was not the same for the LCZs that had different ratios of building density and height, traffic infrastructure, green areas, water bodies, and other factors. The results show that in LCZs 2 and 5, heat wave risks had the highest values. At the same time, in these LCZs, the elderly people and people with chronic diseases made a significant share of the total population. LCZ 5 had the oldest population, i.e. the average age was by 4.2 years higher than the average age for the whole city. In both LCZs, cardiovascular diseases were the leading cause of death (in more than half of all recorded deaths). In LCZ 2, the population was not the oldest, compared to the other LCZs, but the vulnerability to risk was very high according to the built-up type of development, i.e. dense buildings patterns and many impervious surfaces. This situation led to a higher mortality rate, which was in line with the highest risk level (Savić et al. 2018).

However, developing a risk assessment methodology that is scientifically founded for a variety of hazard types and for various elements at risk is a very challenging task.

5 Conclusions

The results and analysis for Novi Sad (Serbia) presented in this study suggest that the urban areas with the most developed built-up features (LCZs 2 and 5) negatively impact urban populations and the environment. According to the heat wave risk assessment and the maps of urban areas, the local authorities (emergency service, police, fire service) and institutions that are in charge of preventing climate change-related hazards (medical institutions, urban planners, building companies and ancillary services) could use these results when designing and implementing mitigation and prevention strategies. Also, local authorities and rescue teams could plan prevention and mitigation actions more effectively. Finally, according to the risk assessment, local authorities and end-users could decide which kind of specific actions must be taken based on high, medium or low risk levels.

The benefits of the heat wave risk assessment methodology are the following:

- it can be applied in urban areas with different climates and topography, as well as sizes, levels of development and population densities,
- the heat wave risk matrix could be adjusted to the needs of other cities based on T_a differences between various built-up and land cover areas as well as hazard values, population data and impact values,
- this methodology could ensure an analysis of other segments of the urban environment, such as other climate extremes (extreme precipitation or drought), water management (pluvial floods), problems with the population (mortality, population ageing, health) and sustainable urban planning.

There are some limitations such as:

- the poor quality of spatiotemporal monitoring of air temperatures, as urban areas in Europe or in other continents are still very rarely supplied with adequate urban meteorological networks (UMNs) (Muller et al. 2013),
- problems with the standardization of the impact level data, mostly if population data, e.g. mortality data (Savić et al. 2018) or paramedical data, are used (SEERISK 2014; Papathoma-Köhle et al. 2016a),
- the issue of defining the boundaries of urban areas is still under consideration, because the delineation based on the district level (SEERISK 2014; Papathoma-Köhle et al. 2016a) or different built-up areas has had some logical results, but further research with a higher spatial resolution (i.e. for building blocks) is needed in order to ensure a more precise risk assessment (Savić et al. 2018).

In the further research of heat wave risk assessment the focus should be placed on the standardisation of the risk matrix in order to obtain comparable results for multiple cities. It is also necessary to compile a comprehensive database related to the urban metabolism and high spatiotemporal resolution of meteorological values within urban areas.

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References

Anders I, Stagl J, Auer I, Pavlik D (2014) Climate change in Central and Eastern Europe. In: Rannow S, Neubert M (eds) Managing protected areas in Central and Eastern Europe under climate change. Advances in global change research, vol 58. https://doi.org/10.1007/978-94-007-7960-0_2

Baccini M, Biggeri A, Accetta G, Kosatsky T, Katsouyanni K, Analitis A, Anderson HR, Bisanti L, D'Ippoliti D, Danova J, Forsberg B, Medina S, Paldy A, Rabczenko D, Schindler C, Michelozzi P (2008) Heat effects on mortality in 15 European cities. Epidemiology 19(5):711–719. https://doi.org/10.1097/EDE.0b013e318176bfcd

Bao J, Wang Z, Yu C, Li X (2016) The influence of temperature on mortality and its lag effect: a study in four Chinese cities with different latitudes. BMC Public Health 16:375. https://doi.org/10.1186/s12889-016-3031-z

Depietri Y, Renaud FG, Kallis G (2011) Heat waves and floods in urban areas: a policy-oriented review of ecosystem services. Sustain Sci 7(1):95–107. https://doi.org/10.1007/s11625-011-0142-4

Doborvolny P, Krahula L (2015) The spatial variability of the temperature and nocturnal urban heat island intensity in the city of Brno, Czech Republic. Morav Geogr Rep 23(3):8–16. https://doi.org/10.1515/mgr-2015-0013

Dong B, Sutton R, Shaffrey L, Wilcox L (2016) The 2015 European heat wave. B Am Meteorol Soc 97(12):S57–S62. https://doi.org/10.1175/BAMS-D-16-0140.1

Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner GK, Allen SK, Tignor M, Midgley PM (eds) (2012) Managing the risks of extreme events and disasters to advance climate change adaptation—special report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York, USA, p 582

Fortuniak K, Klysik K, Wibig J (2006) Urban—rural contrasts of meteorological parameters in Lodz. Theor Appl Climatol 84(1):91–101. https://doi.org/10.1007/s00704-005-0147-y

Gál T, Skarbit N, Unger J (2016) Urban heat island patterns and their dynamics based on an urban climate measurement network. Hung Geog Bull 65(2):105–116. https://doi.org/10.15201/hungeobull.65.2.2

Hart M, Sailor D (2009) Quantifying the influence of land-use and surface characteristics on spatial variability in the urban heat island. Theor Appl Climatol 95:397–406. https://doi.org/10.1007/s00704-008-0017-5

Hewitson B, Janetos AC, Carter TR, Giorgi F, Jones RG, Kwon WT, Mearns LO, Schipper ELF, van Aalst M (2014) Regional context. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1133–1197

Huang Q, Lu Y (2018) Urban heat island research from 1991 to 2015: a bibliometric analysis. Theor Appl Climatol 131:1055–1067. https://doi.org/10.1007/s00704-016-2025-1

Huang J, Wang J, Yu W (2014) The lag effects and vulnerabilities of temperature effects on cardiovascular disease mortality in a subtropical climate zone in China. Int J Env Res Pub He 11(4):3982–3994. https://doi.org/10.3390/ijerph110403982

IPCC (2007) Summary for policymakers. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate change 2007: the physical science basis. Contribution of Working Group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge/New York, p 18

Jedlovec G, Crane D, Quattrochi D (2017) Urban heat wave hazard and risk assessment. Results Phys 7:4294–4295. https://doi.org/10.1016/j.rinp.2017.10.056

Keramitsoglou I, Kiranoudis CT, Maiheu B, De Ridder K, Daglis IA, Manunta P, Paganini M (2013) Heat wave hazards classification and risk assessment using artificial intelligence fuzzy logic. Environ Monit Assess 185:8239–8258. https://doi.org/10.1007/s10661-013-3170-y

Kottek M, Grieser J, Beck C, Rudolf B, Rubel F (2006) World Map of the Koppen-Geiger climate classification updated. Meteorol Z 15(3):259–263. https://doi.org/10.1127/0941-2948/2006/0130
Le Tertre A, Lefranc A, Eilstein D, Declercq C, Medina S, Blanchard M, Chardon B, Fabre P, Filleul L, Jusot JF, Pascal L, Prouvost H, Cassadou S, Ledrans M (2006) Impact of 2003 heat wave on all cause mortality in 9 French cities. Epidemiology 17:75–79. https://doi.org/10.1097/01.ede.0000187650.36636.1f
Lelovics E, Unger J, Gál T, Gál CV (2014) Design of an urban monitoring network based on Local Climate Zone mapping and temperature pattern modeling. Clim Res 60:51–62. https://doi.org/10.3354/cr01220
Lelovics E, Unger J, Savić S, Gál T, Milošević D, Gulyás Á, Marković V, Arsenović D, Gál CV (2016) Intra-urban temperature observations in two Central European cities: a summer study. Idojaras 120(3):283–300
Lhotka O, Kysely J, Farda A (2018) Climate change scenarios of heat waves in Central Europe and their uncertainties. Theor Appl Climatol 131:1043–1054. https://doi.org/10.1007/s00704-016-2031-3
Memon RA, Leung DYC, Liu CH (2009) An investigation of urban heat island intensity (UHII) as an indicator of urban heating. Atmos Res 94:491–500. https://doi.org/10.1016/j.atmosres.2009.07.006
Muller CL, Champan L, Grimmond CSB, Young DT, Cai X (2013) Sensors and the city: a review of urban meteorological networks. Int J Climatol 33:1585–1600. https://doi.org/10.1002/joc.3678
Muthers S, Laschewski G, Matzarakis A (2017) The summers 2013 and 2015 in South-West Germany: heat waves and heat-related mortality in the context of climate change. Atmosphere-Basel 8(11):224. https://doi.org/10.3390/atmos8110224
Oke TR (1981) Canyon geometry and the nocturnal urban heat island: comparison of scale model and field observations. Int J Climatol 1:237–254. https://doi.org/10.1002/joc.3370010304
Oke TR (2004) Initial guidance to obtain representative meteorological observations at urban sites. IOM Report 81, WMO/TD no. 1250, Geneva, p 47
Papathoma-Köhle M, Promper C, Bojariu R, Cica R, Sik A, Perge K, László P, Balázs Czikora E, Dumitrescu A, Turcus C, Birsan MV, Velea L, Glade T (2016a) A common methodology for risk assessment and mapping for South-East Europe: an application for heat wave risk in Romania. Nat Hazards 82:S89–S109. https://doi.org/10.1007/s11069-016-2291-3
Papathoma-Köhle M, Promper C, Glade T (2016b) A common methodology for risk assessment and mapping of climate change related hazards-implications for climate change adaptation policies. Climate 4:8. https://doi.org/10.3390/cli4010008
Perge K, Sik A, László P, Balázs Czikora E (2014) GIS best practices—technical guide for risk mapping. Budapest, SEERISK project, p 104
Savić S, Marković V, Šećerov I, Pavić D, Arsenović D, Milošević D, Dolinaj D, Nagy I, Pantelić M (2018) Heat wave risk assessment and mapping in urban areas: case study for a midsized Central European city, Novi Sad (Serbia). Nat Hazards. https://doi.org/10.1007/s11069-017-3160-4
Šećerov I, Savić S, Milošević D, Marković V, Bajšanski I (2015) Development of an automated urban climate monitoring system in Novi Sad (Serbia). Geographica Pannonica 19:174–183
SEERISK (2014) Guideline of climate change adaptation and risk assessment in the Danube macro-region. National Directorate General for Disaster Management, Hungary, p 103
Stewart ID, Oke TR (2012) Local Climate Zones for urban temperature studies. B Am Meteorol Soc 93:1879–1900. https://doi.org/10.1175/BAMS-D-11-00019.1
Wilhelmi OV, Hayden MH (2010) Connecting people and place: a new framework for reducing urban vulnerability to extreme heat. Environ Res Lett 5:1–7. https://doi.org/10.1088/1748-9326/5/1/014021
Yu W, Hu W, Mengersen K, Guo Y, Pan X, Connell D, Tong S (2011) Time course of temperature effects on cardiovascular mortality in Brisbane, Australia. Heart 97(13):1089–1093. https://doi.org/10.1136/hrt.2010.217166

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Assessment of Climate Change Impact on Water Requirements of Orchards in Bosnia and Herzegovina

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Abstract In agriculture, climate change will have the strongest impact on orcharding, due to the length of the growing season. High temperatures, droughts and more intense solar radiation could burn leaves and fruits, which would impair the quality and marketable yield. On the other hand, heavy rains, if they occur during the period of flowering and maturing, especially of cherries and berries (strawberries, blackberries, raspberries), would result in the spread of fungi, rotting of fruit and delayed picking. In this regard, the objective of the paper is to assess the extent to which climate change will affect the availability of water in traditional, rainfed orchards, as well as to promote adaptation initiatives. The CROPWAT 8.0 model was used to analyze water surplus and shortage. Input climate data pertained to a reference period and SRES climate scenarios A1B, A2 and RCP 8.5 applied to three characteristic climatic areas in Bosnia and Herzegovina. Analyses showed that water surplus would occur regularly in the colder part of the year, in each study area and by all scenarios. All study areas would also experience water shortages in summer, but with varying

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drought duration and severity. Adaptation measures are proposed for each study area and period of the year, such as the need for drainage in winter, irrigation in summer and application of new technologies for growing fruit trees.

Keywords Climate change · Orcharding · Irrigation water requirement Mitigation measures

1 Introduction

Given that agriculture is an indivisible part of the environment, anything that has an impact on nature affects agriculture as well. Any precipitation distribution, weather, or soil anomaly would affect the entire agricultural production cycle. Constantly rising mean annual temperatures have been observed in all parts of Bosnia and Herzegovina over the past 60 years, especially since the 1980s, accompanied by increasingly frequent extreme climate events, such are floods and droughts (TNC 2016). The 5th IPCC Assessment Report (IPCC 2013) singled out this region as one of the most vulnerable, where climate changes faster than the global average. The trend is expected to continue. Climate change is already pressuring vulnerable economic sectors, including agriculture. Orchards will suffer the largest impact of climate change due to the length of the growing cycle, which can last from several seasons to several decades. Fruit trees have a physiological mechanism to store assimilates in the trunk and root, to be used as needed during the year (Arndt et al. 2001; Koshita and Takahara 2004; Millard and Grelet 2010). However, severe anomalies in weather conditions, especially high temperatures and droughts, negatively impact yield quantity and quality, but also bud formation during the current season, which affects the yield in the following year. So, the impact is twofold. There is a severe problem if drought lasts for several consecutive years. Traditionally, orcharding in Bosnia and Herzegovina is rainfed. The amount and distribution of rainfall, together with the water stored in the soil, support fruit tree growing and yielding. Research conducted to date projects further climate instability in Southeast Europe, throughout the 21st century (Seneviratne et al. 2006; IPCC 2013; Jacob et al. 2014). Increasing occurrences of droughts and extreme rain and flood events in the future have been identified as major threats to agriculture in the Western Balkans (IPCC 2014; World Bank 2014). Trbić et al. (2014) and Stričević et al. (2017a) indicated that the future climate in Bosnia and Herzegovina will be warmer and drier at the end of the century, compared to the period 1961–1990, according to SRES scenarios A1B, A2 and RCP 8.5. The growing season will be longer by nearly 50 days (Stričević et al. 2017b; Ruml et al. 2012). It is therefore reasonable to expect that water use and the need for irrigation in orcharding will increase, especially if the root system or the soil is shallow. Climate change impact on agriculture in Bosnia and Herzegovina has not been studied extensively. Only a few papers refer to the impact of climate change, solely on maize and potato (Stričević 2017a, c), or provide a general review of potential threats (Zurovec et al. 2015). However, none consider orcharding. The topic has not been widely studied elsewhere either. Having this in mind, the objective of the present research is to examine whether water excess or drought will affect orcharding in the future, and to propose adaptation measure to mitigate the adverse effects.

2 Materials and Methods

2.1 Characteristics of the Study Areas

Three study areas were selected to assess water requirements of orchards: the environs of the cities of Banja Luka, Mostar and Bijeljina, as shown in Fig. 1. The most commonly grown types of fruit trees were obtained from a statistical bulletin (http://www.rzs.rs.ba) and a land use inventory (Group of Authors 2014). Plums, followed by apples, pears, cherries, peaches, walnuts and grapes, are the most represented fruit types. Peaches and apricots are grown more in Mostar than in Banja Luka and Bijeljina, whereas plums are less common. Based on the water requirement, these fruits belong to the same group of the trees (Allen et al. 1998). Most of the orchards are rainfed, except new plantations in very limited areas. Grapevines are grown only around Mostar (Table 1).

Climate variability differs among the locations (Trbić et al. 2016). The climate in Banja Luka and Bijeljina is moderately continental, but with significant differences in the amount and distribution of rainfall. The climate in the Mostar area is Mediterranean. The main climatic parameters, such as mean annual air temperature (Tmean) and precipitation (P), are shown in Table 2 for two distinct time periods (TNC 2016). It has already been observed that air temperature increased by 1 °C over the last decade, whereas the amount of precipitation remained nearly the same.

The growing season for fruit in Banja Luka and Bijeljina starts between the 90th and the 125th day of the year (DOY) and complete senescence occurs from 288 to 335 DOY. In Mostar, the growing season starts earlier, from 62 to 86 DOY, and maturity and senescence also occur earlier—by 311 DOY (Phenological Statistical Yearbooks).

The soil in Banja Luka is predominantly Kastanozem (deep brown acidic soil), whose water holding capacity is about 200 mm/m of depth. The soil in Bijeljina (Meadow soil, Eugley soil) was formed in the valleys of rivers, where meadow vegetation is predominant. The soil texture is loamy to loam-gleyey, with a high retention capacity (more than 250 mm/m) and favorable chemical and physical properties. In Mostar, there are various types of soils (terra rossa, eutric cambisol, kalkokambisol, regosol), and the holding capacity varies from 50 mm to more than 200 mm/m in places where the soil is deep (Group of Authors 2014; Group of Authors 1975). Drought is the most severe and soonest to be manifested in shallow soils, with a low water holding capacity.

Fig. 1 Study areas (*Source* https://en.wikipedia.org/wiki/Bosnia_and_Herzegovina)

Table 1 Most commonly grown fruit trees in the study areas

Study area	Banja Luka	Bijeljina	Mostar
Apples, Cherries, Pears (ACP)	+	+	+
Plums, Peaches, Apricots (PPA)	+	+	+
Walnuts	+	+	+
Grapevines	–	–	+

Table 2 Climate parameters of the study areas

	1961–2014		2001–2014	
Study area	Tmean (°C)	Pmean (mm)	Tmean (°C)	Pmean (mm)
Banja Luka	11.2	1042	12.2	1054
Bijeljina	11.4	760	12.4	781
Mostar	14.3	1499	15.7	1527

2.2 Model Parameters and Input Data

The FAO CROPWAT (v.8.0) model was used to simulate crop water requirements and irrigation depth. This model was chosen because it is based on the water balance and proven in many studies that project crop requirements in various countries (Hoekstra and Hung 2002). It is user-friendly and able to estimate the effects of climate-related parameters, such as precipitation and air temperature in historical, present or future agro-climatic conditions. Water excess was calculated using the water balance equation for the cold part of the year (October–March).

For analysis of climate conditions in the reference period (1971–2000), monthly average data were obtained from meteorological stations in Banja Luka, Bijeljina and Mostar (Hydro-meteorological services). Two regional climate models were used for future climate, under different IPCC climate change scenarios. EBU-POM (Eta Belgrade University—Princeton Ocean Model) was integrated under IPCC SREC scenarios A1B and A2 (Djurdjevic and Rajkovic 2008; Gualdi et al. 2008), while NMMB (Non-hydrostatic Multi-scale Model on the B grid) was forced with IPCC scenario RCP 8.5 (Djurdjevic and Krzic 2013; Djurdjevic et al. 2013). Simulations under A1B and A2 were with a horizontal resolution of about 25 km, whereas that under RCP 8.5 was 8 km. Three time slices in the future were chosen for all scenarios, centered on the 2020s (2011–2040), 2050s (2041–2070) and 2080s (2071–2100).

The beginning of the growing season was run when T_{mean} was ≥10 °C for seven consecutive days. The end of the season was assumed at T_{mean} ≤ 10 °C for seven or more consecutive days. The results matched the dates reported in phenological yearbooks, for all study areas.

3 Results and Discussion

The beginning and end of the growing season of all the studied fruit types were almost the same in one study area (Table 3). Any differences were attributable more to the cultivars within the fruit type (early or late ripening). The growing season starts 4 to 8 days earlier, according to RCP 8.5 and A2 in the 2020s, compared to the reference period, whereas a ± one day difference was obtained from A1B, for all study areas. The dates are consistent with those recorded in the statistical phenological yearbooks. In the 2050s, the growing season will start 10–15 days earlier in Banja Luka and Bijeljina, according to all scenarios, and in Mostar 13–15 days earlier according to RCP 8.5 and A2 and as many as 26 days earlier according to A1B. In the 2080 s, the growing season will start the earliest according to RCP 8.5, by 33 days in all study areas. Based on A1B and A2, this will be between 21 and 26 days, with the exception of Mostar according to A2, where the growing season is expected to start 35 days earlier and thus be extended by as many days.

The end of the season will move toward late autumn but remain in the already observed range, which is around 335 DOY. In general, in the 2020s the end of the

Table 3 Beginning and end of growing season of fruit trees

		Banja Luka		Bijeljina		Mostar	
Scenario	Period	Start	End	Start	End	Start	End
RCP 8.5	**1971–2000**	103.2	309.6	97.0	312.6	85.2	334.7
	2011–2040	96.6	319.4	89.3	320.5	73.3	337.6
	2041–2070	89.0	330.7	83.8	330.9	62.5	353.3
	2071–2100	70.1	347.9	66.9	345.6	43.6	362.3
A1B	**1971–2000**	108.7	310.4	102.6	313.7	86.8	339.1
	2011–2040	109.2	311.4	101.4	315.6	85.8	342.4
	2041–2070	93.9	316.5	91.7	317.8	59.6	345.0
	2071–2100	85.2	329.0	84.5	325.0	60.0	345.2
A2	**1971–2000**	108.7	310.4	102.6	313.7	86.8	339.1
	2011–2040	103.9	310.8	98.6	313.8	80.1	342.2
	2041–2070	96.3	319.3	92.4	320.8	71.5	345.5
	2071–2100	82.4	339.4	81.6	330.6	51.9	357.4

season will be the same as at present, in the 2050s slightly prolonged, by 4–9 days, and in the 2080s up to 19 days longer in all study areas, according to scenarios A1B and A2. Slightly severe changes are envisaged according to scenario RCP 8.5, especially toward the end of the century. The end of the season is expected to be prolonged by as many as 39, 33 and 28 days in Banja Luka, Bijeljina and Mostar, respectively.

Similar results have been reported in neighboring countries. Namely, at the end of the century the growing season of grapevines in Serbia will start about 10 days earlier and in late autumn be 16 days longer, on average (Ruml et al. 2012). Studies carried out in Croatia on apple growth for the period from 1979 to 2009 show that the leaf-out time and blooming have occured 3–6 days earlier per decade. This phenomenon is more pronounced in hilly to mountainous areas, compared to the Mediterranean region (Krulić and Vučetić 2011), as observed in the case of Banja Luka.

The results obtained for Mostar might be indicative of an insufficiently long chilling period, which is essential for flower initiation and yielding. T_{mean} will be $\leq$10 °C for only 60 days. Further investigations of the chilling period should address mitigation measures, since timely adaptation is essential for growers of long-lived high value perennials (Luedeling 2012).

The water requirements of traditional orchards, with grass between rows, are shown in Fig. 2 for the reference period (1971–2000) and each study area. The water requirements in Bijeljina and Banja Luka are nearly the same for most fruit trees, about 880 mm (800 mm for walnuts). In Mostar, the levels are about 30 mm higher. Vineyards require the smallest amount of water, about 515 mm. Assuming a need for irrigation, the results vary significantly due to different precipitation totals and rainfall distributions throughout the growing season. The smallest quantity of irrigation water is needed in Banja Luka, and the largest in Bijeljina (Fig. 3). Vineyards generally do not need to be irrigated because the plants use water retained in the soil.

Fig. 2 Water requirements of main orchards in Banja Luka, Bijeljina and Mostar

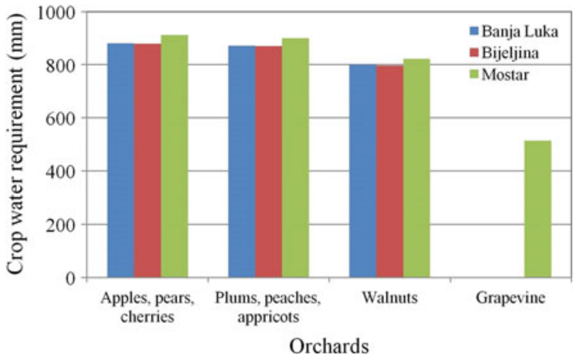
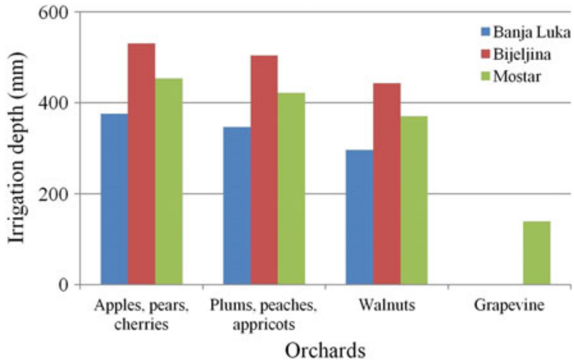


Fig. 3 Irrigation requirements of main orchards in Banja Luka, Bijeljina and Mostar



Similar values have been determined in neighboring countries. In Serbia, on two locations ET of ACP (apples, cherries and pears) will gradually increase, by 8–9% in the 2020s, 12–21% in the 2050 s and 23–31% in the 2080 s, according to scenarios A1B and A2, respectively (Stričević et al. 2017b). Comparing water requirements of grapevines to those of olives, which are analogous in like environmental conditions, similar results were obtained for Bosnia and Herzegovina, where the mid-century increment is expected to be up to 8% (Tanasijevic et al. 2014). The value was calculated assuming no changes in crop coefficients (K_c) due to variations in CO_2 concentrations, which may cause closure of stomatal conductance and a reduction in K_c. Snyder (2017) reported that "*There is little information available about how K_c values might change for tree and vine crops, but trees and vines are even more coupled to the environment, so an even bigger decrease in K_c seems plausible for the taller rougher canopies.*" He also added that "*while the evapotranspiration responses to global change seem small, the projected changes in precipitation and water storage in snowpack are large and could have devastating impacts on horticulture in some regions*".

It is important to highlight the water excess problems that normally occur during the cold part of the year, from October to March, which matches the dormancy period of the studied orchards. However, the problem also occasionally occurs in April, the

Table 4 Reference values of water excess in the study areas

Water excess (mm)	Study area		
	Banja Luka	Bijeljina	Mostar
	−349	−155	−865

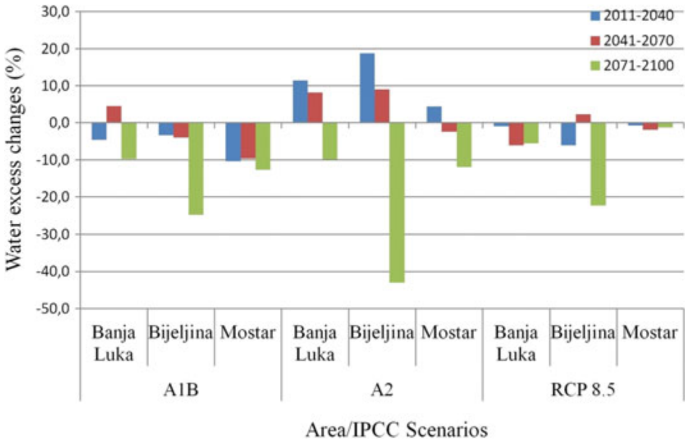


Fig. 4 Changes in water excess according to IPCC scenarios relative to the reference period (1971–2000), during the cold part of the year (October–March), by study area

month when blooming starts. Mostar suffers strongly from surplus water (Table 4), so erosion control is needed in the hilly landscape and drainage in the plains. In Banja Luka and Bijeljina, water excess usually wets land deeply and feeds groundwater, which can be a source of water during a period of drought.

Climate change conditions will mostly decrease water excess, especially in Bijeljina in the 2080s, by as much as 24, 43 and 22% according to A1B, A2 and RCP 8.5, respectively (Fig. 4). Water excess might increase in Banja Luka and Bijeljina in the 2020s and 2050s, by up to 11 and 19% according to scenario A2. All other assessments are in the range from +0.8% to −12%, which will not be significant for orchards.

The need for irrigation of ACP will increase as early as the 2020s, according to IPCC scenario A1B, by up to 17% in Banja Luka and slightly less (15%) according to scenario A2 (Fig. 5). However, contradictory results were obtained with RCP 8.5 for Banja Luka and Bijeljina. In the 2050s, the irrigation depth will increase the most in Banja Luka, by 54% and 42% according to A1B and A2, respectively, and in Mostar by up to 45% according to RCP 8.5. At a glance, it appears that Bijeljina will be the least affected in all three scenarios. In fact, Bijeljina needs the largest amount of water for irrigation (530 mm) but the increment seems small when expressed as a percentage. In Banja Luka, where the smallest amount of water is needed (376 mm), the increment is the greatest even though the amount of water is not that large. Irrigation needs will increase significantly in the 2080s, to such an extent that the

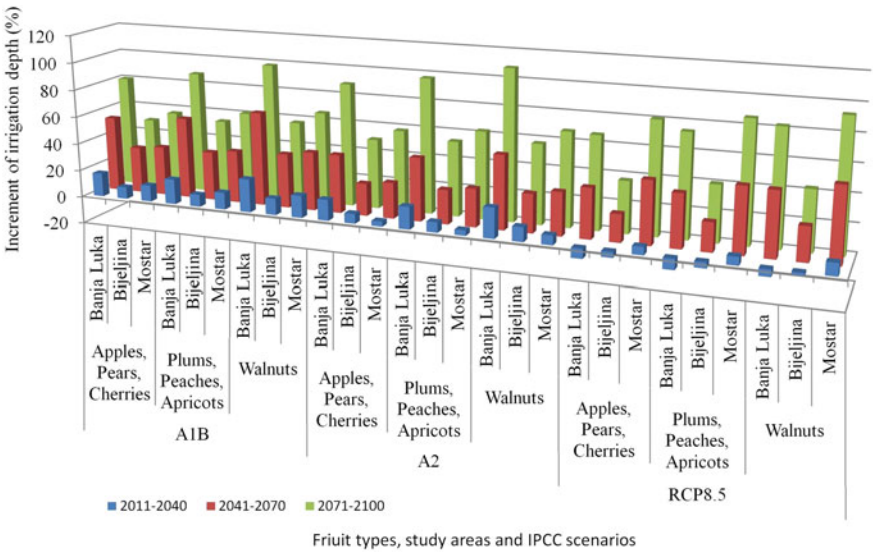


Fig. 5 Changes in irrigation depth for various fruit trees according to IPCC scenarios A1B, A2 and RCP 8.5 relative to the reference period (1971–2000) during the growing cycle by study area

possibility of rainfed orcharding might become questionable. The trend will be the same as in the 2020s, but the magnitude will differ. The increment will be up to 80% and 89% according to A1B and A2, respectively, and in Mostar up to 81% according to RCP 8.5. Bijeljina will be less affected, especially according to RCP 8.5—only 37.5%.

The changes in irrigation depth of PPA (plums, peaches, apricots), as well as walnuts, will have the same trend as in the case of APC. There is a difference only in magnitude. Namely, about 25 mm less irrigation water will be needed for PPA and 60 mm less for walnuts than for ACP but, expressed as a percentage, the irrigation depth will differ by about ±1, −0.7–4 and 3.4–8.4% in the 2020s, 2050s and 2080s, respectively. The increment in the case of walnuts will be larger compared to APC and PPA, even though less water will be required for irrigation.

Until the end of the century, water excess in vineyards will decrease according to all IPCC scenarios (Fig. 6). The largest changes will occur around mid-century (2050s). The water deficit of 140 mm in the reference period will increase to 184 mm (39%) according to A1B and by much less (10.5%) according to RCP 8.5. Scenario A2 yielded opposite results for the 2020s (Fig. 6). Around the middle of the century, the need for irrigation will decrease by 51% and 101% according to A1B and A2, but increase according to RCP 8.5 (133% increment). All scenarios showed a similar increment trend only at the end of the century, with RCP 8.5 coming up with the highest value. A water deficit of about 260 mm towards the end of century assessed by A1B and A2 indicates that grapevines could be grown in rainfed conditions in deep soils, which can retain more than 200 mm/m. The deeper the soil the more

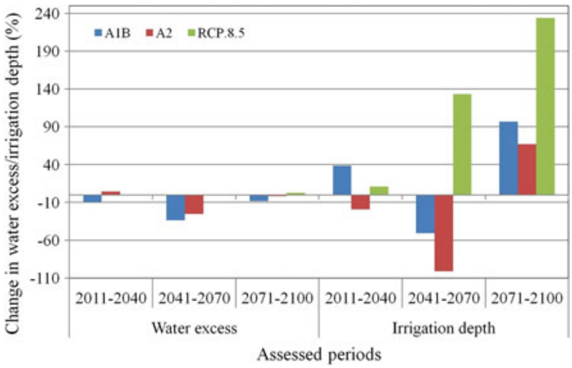


Fig. 6 Assessed water excess and water deficit for vineyards in Mostar

water is contained. If the results obtained with RCP 8.5 materialize, vineyards will need irrigation of about 440 mm.

A much larger water shortage increment was noted in the case of apples, cherries and pears in Serbia on two locations (Stričević et al. 2017b). This was due to a higher air temperature, on one hand, and lower precipitation totals than in Bosnia and Herzegovina on the other. Comprehensive research carried out by Tanasijevic et al. (2014) revealed that the need for irrigation of olive trees will increase by up to 50 mm in the 2050s, which is very similar to our results for grapevines, a plant grown in the same environmental conditions (65 mm according to A1B in the same time period).

A long growing season will require more water for fruit trees than field crops or vegetables. Some of the staple crops, such as maize and potato, would be grown in rainfed conditions (Stričević et al. 2017a, c). In rainfed farming, an earlier sowing date would help avoid both heat and water stress in the most sensitive phenological stage of growth. Unfortunately, perennial fruit trees are exposed to drought in summer and/or water logging in winter or spring, such that mitigation measures should be implemented. Orcharding practices for new apple cultivars need to address, among other things, root system maintenance at a depth of 0.3–0.5 m, which promotes efficient water and nutrient uptake from the most fertile part of the soil. This approach requires irrigation and fertigation, even in areas where fruit has been traditionally rainfed. However, considering that irrigation is a very complex agro-technical measure, it cannot be applied to all soil types (soil prone to erosion, over-logging, salinity) or in areas of water scarcity. One of the preferred options from a water management perspective is an orchard without grass. In this option, the need for irrigation could decrease by 20–25%, compared to orchards with grass. This management practice would be more effective in plains, or slightly hilly area, where there is no threat of water erosion. In areas where soils are stable, grass could be grown in strips, to both protect the soil from erosion and save water. Water saving and protection from intense solar radiation, anti-hail nets or other shading techniques should be considered, such as spraying with a kaolin suspension to create a film over the leaves. The use of water would be decreased significantly, as a result of reduced radiation, heat and wind speed and increased relative humidity. Iglesias and Alegre (2006) recorded a slight increase in relative humidity below an anti-hail net. They found an increase of 2–6% in relative humidity and at the same time a reduction in evapotranspiration of 11%, which is associated with lower wind speeds. A study conducted in Serbia (Prokopljevic et al. 2012) reported that the demand for irrigation water could be reduced by 20% in the rainy season and up to 40% in dry climate conditions. Such an approach will be more urgently needed in the Mostar area.

4 Conclusion

Orcharding in Bosnia and Herzegovina is traditionally rainfed. Water deficit is compensated by the water stored in the soil. Climate change will not have a great effect on the water demand of fruit trees at the beginning of the century. Throughout the century, especially at the very end, the need for irrigation will significantly increase according to all the studied IPCC scenarios, even for vineyards according to RCP 8.5. Greater changes are expected under scenarios A1B than A2. The smallest change will occur in the Banja Luka and Bijeljina areas under scenario RCP 8.5 and in the Mostar area under A2. Since irrigation is not applicable everywhere (i.e. soil prone to erosion), the severity of agricultural drought will be a future research challenge, especially in orcharding due to a two-year impact on yield, in order to understand the threat of climate change in that regard. To investigate this, valid results from long-term experimental trials are needed. Research of this kind is highly complex and has not been conducted extensively anywhere in the world.

Water excess will be almost in the usual range, assuming the standard variation observed in the reference period. Mitigation measures for climate change should remain as at present: well-functioning drainage system in all study areas, followed by the introduction of irrigation, where applicable, along with altered growing technologies, assuming heat and anti-hail protection and other water saving practices. This assessment did not consider the cool part of the year, which is important for yielding of perennials, especially in areas with mild winters such as Mostar. Future research might focus on that topic as well.

References

Allen RG, Pereira LS, Raes D, Smith M (1998) Crop evapotranspiration-Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. FAO, Rome. 300(9):D05109

Arndt SK, Clifford SC, Wanek W, Jones HG, Popp M (2001) Physiological and morphological adaptations of the fruit tree *Ziziphus rotundifolia* in response to progressive drought stress. Tree Physiol 21(11):705–715

Djurdjevic V, Krzic A (2013) Analysis of the downscaled ERA40 reanalysis performed with the NMMB model, Project: A structured network for integration of climate knowledge into policy and territorial planning—ORIENTGATE, WP3 Mapping and Harmonising Data & Downscaling. http://www.seevccc.rs/ORIENTGATE/Dwnsc-ERA40-NMMB.pdf. Accessed on 30 Dec 2017

Djurdjevic V, Rajkovic B (2008) Verification of a coupled atmosphere-ocean model using satellite observations over the Adriatic Sea. Anns Geophys 26(7):1935–1954

Djurdjevic V, Janjic Z, Pejanovic G, Vasic R, Rajkovic B, Djordjevic M, Vujadinovic M, Vukovic A Lompar M (2013) NCEP's multi-scale NMMB model in the hydrometeorological service of Serbia: experiences and recent model developments. In: EGU General Assembly, geophysical research abstracts, vol 15, Vienna, Apr 2013 (EGU2013-8217), pp 7–12

Group of Authors (1975) Pedological map of Yugoslavia 1:50000, Soil section of Banjaluka 1. Bureau of Agropedology. Ed. Institute of Agricultural Research, Sarajevo, Bosnia and Hercegovina, Serbian language origin

Group of Authors (2014) Soil inventory and its use in the Hercegovina region. Ed USAID, Mostar, BiH Serbian language origin

Gualdi S, Rajkovic B, Djurdjevic V, Castellari S, Scoccimarro E, Navarra A, Dacic M (2008) Simulations of climate change in the Mediterranean area, Final Scientific Report. http://www.earth-prints.org/bitstream/2122/4675/1/SINTAFinalScienceReportOctober2008.pdf. Accessed on Nov 2017

Hoekstra AY, Hung PQ (2002) Virtual water trade. A quantification of virtual water flows between nations in relation to international crop trade, vol 12. Value of water research report series, no 11. IHE Delft, The Netherlands, p 166

http://rhmzrs.com/assets/images/meteorologija/klimatologija/Final_11.pdf. Accessed on 17 Dec 2017

http://www.fhmzbih.gov.ba/podaci/klima/godisnjak/G2016.pdf. Accessed on 17 Dec 2017

Iglesias I, Alegre C (2006) The effect of anti-hail nets on fruit protection, radiation, temperature, quality and profitability of 'Mondial Gala' apples. J App Hortic 8(2):91–100

IPCC (2013) 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, UK and New York, USA, p 1535, https://doi.org/10.1017/cbo9781107415324

IPCC (2014) Climate change 2014: Impacts, adaptation and vulnerability. Part A: Global and sectoral aspects. contribution of Working Group II to the fifth assessment report of the intergovernmental panel on climate change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Billir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Geniova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, USA, p 1132

Jacob D, Petersen J, Eggert B, Alias A, Christensen OB, Bouwer LM, Braun A, Colette A, Déqué M, Georgievski G, Georgopoulou E (2014) EURO-CORDEX: new high-resolution climate change projections for European impact research. Reg Environ Change 14(2):563–578

Koshita Y, Takahara T (2004) Effect of water stress on flower-bud formation and plant hormone content of satsuma mandarin (Citrus unshiu Marc.). Sci Hortic-Amsterdam 99(3):301–307

Krulić B, Vučetić V (2011) Phenological phases and winter dormancy of apple in Croatia. Hrvatski meteorološki časopis, 46:35–43 Croatian language origin

Luedeling E (2012) Climate change impacts on winter chill for temperate fruit and nut production: a review. Sci Hortic-Amsterdam 144:218–229

Millard P, Grelet GA (2010) Nitrogen storage and remobilization by trees: ecophysiological relevance in a changing world. Tree Physiol 30(9):1083–1095

Phenology Statistical Yearbooks, http://rhmzrs.com/ and https://www.fhmzbih.gov.ba/. Accessed on 24 Dec 2017

Prokopljević D, Stričević R, Miletaški B (2012) Impact of antihail network on evapotranspiration of apple orchard in Čelarevo. In Savetovanje Melioracije (12) (Ed). Faculty of Agriculture, Novi Sad, University of Novi Sad, pp 1–7. Serbian language origin

Ruml M, Vuković A, Vujadinović M, Djurdjević V, Ranković-Vasić Z, Atanacković Z, Sivčev B, Marković N, Matijašević S, Petrović N (2012) On the use of regional climate models: implications of climate change for viticulture in Serbia. Agric Forest Meteorol 158:53–62
Seneviratne IS, Lüthi D, Litschi M, Schär C (2006) Land–atmosphere coupling and climate change in Europe. Nature 443:205–209
Snyder RL (2017) Climate change impacts on water use in horticulture. Horticulturae 3(2):27
Stocke, TF, Qin D. Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V Midgley PM (eds) (2013) IPCC climate change: the physical science basis. contribution of Working Group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York, USA, p 1535, https://doi.org/10.1017/cbo9781107415324
Stričević R, Stojaković N, Vujadinovic-Mandic M, Todorovic M (2017a) Impact of climate change on yield, irrigation requirement and water productivity of maize cultivated under moderate continental climate of Bosnia and Herzegovina. J Agric Sci 1–13. https://doi.org/10.1017/s0021859617000557
Stričević R, Srđević Z, Vujadinović-Mandić M, Srđević B (2017b) Sustainable water management and water footprint concept: application in fruit growing. Vodoprivreda 49(288–290):1–8
Stričević R, Trbić G, Vujadinović M, Cupać R, Đurović N, Ćosić M (2017c) Impact of climate change on potato yield grown in different climatic zone in Bosnia and Herzegovina. In: VIII international scientific Agriculture Symposium “AGROSYM 2017”, Jahorina 5–8 Oct 2017 (Ed). Faculty of Agriculture, University of Istočno Sarajevo, B&H; Faculty of Agriculture, University of Belgrade, Serbia, CIHEAM-IAMB Bari, Italy Book of Proceedings pp 596–601. http://www.agrosym.rs.ba/agrosym/agrosym_2017/BOOK_OF_PROCEEDINGS_2017_FINAL.pdf
Tanasijevic L, Todorovic M, Pereira LS, Pizzigalli C, Lionello P (2014) Impacts of climate change on olive crop evapotranspiration and irrigation requirements in the Mediterranean region. Agric Water Manage 144:54–68
TNC (2016)—Third national report and second two-year report of greenhouse gas emission in Bosnia and Herzegovina within the framework of UN convention of climate change file:///E:/Svi_podaci/korisnik/Documents/Medjunarodni%20projekti/UNDP_BiH/TNC%20Report%20%20LAT.pdf. Accessed on 29 Dec 2017
Trbić G, Đurđević V, Bajić D, Cupać R, Vukmir G, Popov T (2014) Climate change and adaptation options in Bosnia and Herzegovina—Case study in agriculture. In: The international conference “ADAPT to CLIMATE”, Nicosia, Cyprus, 27–28 Mar 2014
Trbić G, Bajić D, Djurdjević V, Crnogorac C, Popov T, Dekić R, Petrasević AV, Rajčević V (2016) The Impact of climate change on the modification of bioclimatic conditions in Bosnia and Herzegovina. Environ Sci 1:176–182
World Bank (2014) Turn down the heat: confronting the new climate normal. World Bank, Washington DC, USA, p 320
Zurovec O, Vedeld PO, Sitaula BK (2015) Agricultural sector of Bosnia and Herzegovina and climate change—Challenges and opportunities. Agriculture 5(2):245–266

Effects of Changes in Extreme Climate Events on Key Sectors in Bosnia and Herzegovina and Adaptation Options

Tatjana Popov, Slobodan Gnjato and Goran Trbić

Abstract Changes in the extreme climate indices during the 1961–2016 periods across Bosnia and Herzegovina and theirs effects on key sectors are examined. Daily data on minimum and maximum temperatures and precipitation from four meteorological stations located in different parts of the territory were used for calculation in the RClimDex (1.0) software a set of 27 temperature and precipitation indices defined by the ETCCDI. The climate change assessment covered trend analysis and analysis of changes in parameters of the extreme value theory distributions (location, shape and scale). Both Tmax and Tmin displayed significant upward trends (0.4 and 0.3 °C per decade, respectively). Significant upward tendency was determined for warm temperature indices, whereas cold ones displayed downward trends. The highest trend values (>5 days per decade) were obtained for warm indices: TN90p, TX90p, WSDI, SU25 and SU30. Further, the results indicate that the distributions of both maximum and minimum temperatures shifted towards higher values in the latter period. Consistent with the warming trend, warm indices also shifted towards higher values, whereas the opposite was determined for cold ones. Precipitation indices displayed trends mixed in sign, but insignificant. Moreover, no significant changes in their distributions were determined. However, the upward trends in RX1day, RX5day, R95p and R99p indicate changes towards more intense precipitation. Effects of the observed changes on key sectors in Bosnia and Herzegovina: agriculture, forestry, energetic (hydropower) and tourism were then examined. Climate change has strongly affected yields, fire frequency, energy production and consumption, suitability of destinations for tourism development, etc. Adaptation

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options were discussed in order to reduce vulnerability and increase resilience of these very important sectors for sustainable development of Bosnia and Herzegovina.

Keywords Extreme climate indices · Effects of climate change
Adaptation options · Bosnia and herzegovina

1 Introduction

Global warming is a result of globally widespread changes in mean temperatures, but also changes in frequency, intensity, duration and spatial distribution of extreme climate events (particularly temperature and precipitation extremes) (IPCC 2014a). Studies at different spatial scales, ranging from the local and regional to the global ones, determined trends in extreme temperature indices consistent with the warming of the climate system—warm temperature extremes (e.g. warm days, warm nights, tropical nights, summer days, warm spell duration index) displayed mostly significant upward tendencies, whereas cold temperature extremes (cold days, cold nights, frost days, cold spell duration index) showed downward trends (but somewhat less pronounced) (Alexander et al. 2006; Donat et al. 2013; Morak et al. 2013). The maximum and minimum values of daily maximum and minimum temperatures have increased since the second half of the 20th century (Alexander et al. 2006; Donat et al. 2013), which resulted in a lengthening of the growing season in majority of regions over the Northern Hemisphere mid-latitudes (Frich et al. 2002). Global scale studies showed that trends in extreme precipitation displayed less spatially coherent patterns of change that were mainly insignificant (IPCC 2014a; Donat et al. 2013). However, majority of extreme precipitation indices (e.g. RX5day, R10mm, R95p and SDII) displayed significant changes towards more intense precipitation at least in some regions (Donat et al. 2013).

Trends in extreme temperature indices consistent with the global warming were reported by previous studies all over the Southeast Europe region, in Bosnia and Herzegovina (Popov et al. 2018), Serbia (Unkašević and Tošić 2013; Malinovic-Milicevic et al. 2016), Croatia (Branković et al. 2013), Romania (Dumitrescu et al. 2015), Bulgaria (Alexandrov et al. 2004), Montenegro (Burić et al. 2014), Greece (Kioutsioukis et al. 2010), etc. On the other hand, weak, predominantly insignificant and spatially incoherent trends in precipitation extremes were detected in these regions (Popov et al. 2017; Unkašević and Tošić 2011; Gajić-Čapka et al. 2015; Kioutsioukis et al. 2010; Croitoru et al. 2016; Burić et al. 2015).

Impacts of extreme climate events, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of numerous ecosystems and human systems all over the world to current climate variability (ecosystems alteration, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality) (IPCC 2014b). There is a growing need for analysis of climate change effects on the key economic sectors, since such impact assessment studies were not frequent in the Southeast Europe and particularly in Bosnia and Herzegovina.

This study represents a continuation of research on climate change in Bosnia and Herzegovina and its impacts on key economic sectors in Bosnia and Herzegovina. While some earlier studies (Popov et al. 2017, 2018) have already addressed the issues of changes in climate extremes, the effects of observed climate change on key economic sectors in Bosnia and Herzegovina such as agriculture, forestry, energetics and tourism are poorly documented. In order to overcome the existing gaps in knowledge, the main goal of this study is to analyze changes in extreme climate indices during the 1961–2016 periods and to discuss potential effects of the determined patterns of change on key economic sectors in Bosnia and Herzegovina.

2 Data and Methods

Analysis of extreme climate indices in Bosnia and Herzegovina during the 1961–2016 periods was performed based on climatological data sets of daily maximum temperatures (Tmax), daily minimum temperatures (Tmin) and daily precipitation (R) from four meteorological stations covering all three macromorphological regions: Sanski Most (SM), Banjaluka (BL), Sarajevo (SA) and Mostar (MO) (Fig. 1). Climatic data were provided by the Federal Hydrometeorological Institute Sarajevo and the Republic Hydrometeorological Service of the Republic of Srpska. In the observed period, there were not interruptions in measurements (except at SM station during the November and December 1992 and November 1996). Basic data quality control performed in RClimDex software found some outliers that were checked.

During the observed 1961–2016 periods, both Tmax and Tmin displayed significant upward trends annually and seasonally (only insignificant in some areas in autumn). Annual Tmax and Tmin increased by 0.3–0.6 °C per decade and 0.3 °C per decade (only at BL station 0.5 °C per decade), respectively. The upward trend was present throughout the year, but most prominent in summer season (0.5–0.7 °C per decade and 0.4–0.6 °C per decade, respectively) and then in winter and spring. Unlike the coherent temperature trends, annual and seasonal precipitation displayed trends mixed in sign, but insignificant.

Based on input variables data, a set of 27 extreme temperature and precipitation indices (averaged for Bosnia and Herzegovina) recommended by the CCl/CLIVAR Expert Team for Climate Change Detection and Indices was calculated for the analysis of climate extremes variability over this area. Definitions of the indices used in the study are available at http://etccdi.pacificclimate.org/list_27_indices.shtml.

The selected indices can be divided in a few different categories (Alexander et al. 2006):

- Absolute indices (TNx, TNn,TXx, TXn, PRCPTOT, RX1day, RX5day and SDII).

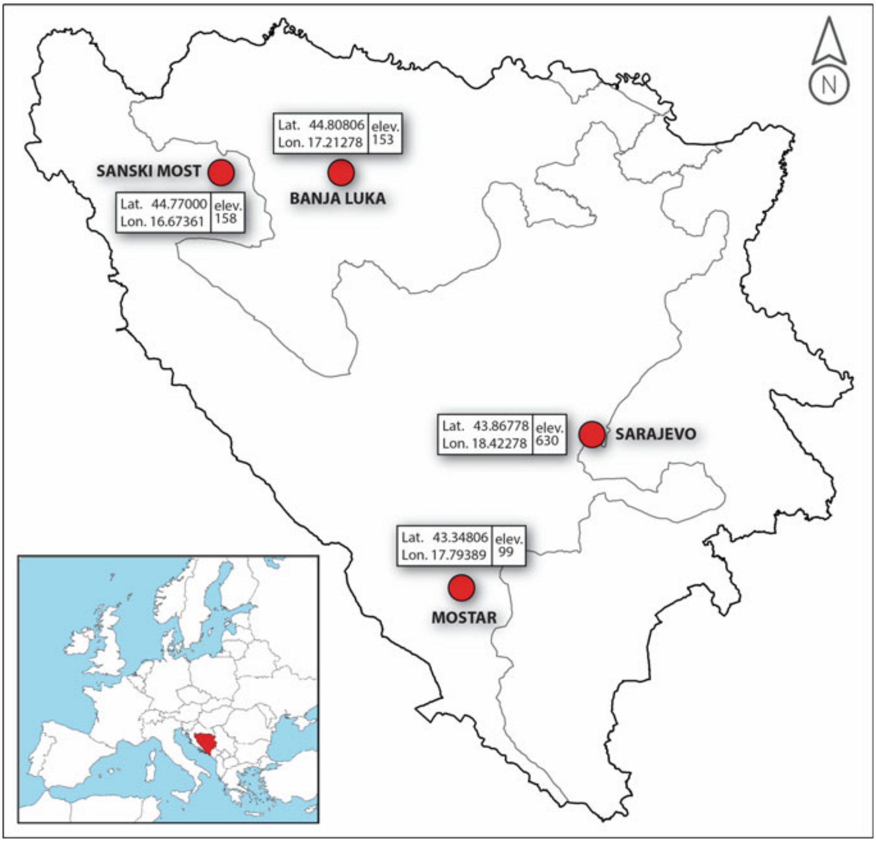

Fig. 1 Geographical location of meteorological stations used in the study

- Percentile-based indices (TN10p, TX10p, TN90p, TX90p, R95p and R99p). The 1961–1990 periods was set as reference for calculation of these indices.
- Fixed threshold-based indices defined as the number of days on which a temperature or precipitation value falls above or below a fixed threshold (FD0, ID0, SU25, SU30, TR20, R1mm, R10mm and R20mm).
- Duration-based indices defined as periods of the excessive warmth and cold periods or mild periods in the case of temperature indices or the excessive dry and wet periods in the case of precipitation indices (WSDI, CSDI, GSL, CDD and CWD).

The extreme climate indices were calculated using RClimDex (1.0) software developed at the Climate Research Division Canada (Zhang and Yang 2004). Trend slope estimate and its significance were also computed in RClimDex by linear least square method and locally weighted linear regression (Zhang and Yang 2004). Analysis of changes in extreme climate indices also covered investigation on shifts in theirs distributions. The probability density functions of indices were calculated for

Table 1 Linear trends in extreme temperature indices in 1961–2016

Index	Slope estimate	*p*-value	Slope error	R^2
TXx	0.061	0.000	0.015	24.3
TXn	0.029	0.154	0.020	3.7
TNx	0.055	0.000	0.009	41.9
TNn	0.046	0.095	0.027	5.1
TX10p	-0.127	0.000	0.023	35.9
TX90p	0.287	0.000	0.039	50.8
TN10p	-0.133	0.000	0.021	43.0
TN90p	0.332	0.000	0.036	61.5
ID0	-0.178	0.001	0.050	19.3
FD0	-0.408	0.001	0.116	18.8
SU25	0.574	0.000	0.110	33.5
SU30	0.622	0.000	0.108	38.0
TR20	0.064	0.000	0.013	31.4
WSDI	0.672	0.000	0.102	44.8
CSDI	-0.087	0.056	0.045	6.6
GSL	0.655	0.002	0.208	15.9
DTR	0.007	0.125	0.005	4.3

the two periods: 1961–1990 and 1991–2016. The two-tailed nonparametric Kolmogorov–Smirnov test, performed in XLSTAT Version 2014.5.03, was used to test significance of distribution differences between two periods. Further, changes in location, shape and scale parameters of the Generalized Extreme Value (GEV) distribution of annual maximum Tmax, Tmin and R were estimated. Maximum likelihood estimation (MLE) method was applied for this analysis. Software package for R extRemes (Gilleland and Katz 2016) was used for performing extreme value analysis. Impact assessment analysis was performed for the 1996–2016 periods based on data of the Republic of Srpska Institute of Statistics.

3 Results and Discussion

Linear trends in annual extreme temperature indices in the 1961–2016 periods are shown in Table 1.

All absolute temperature indices showed upward trends. However, the estimated trend values for maximum values of Tmax and Tmin were significant and much more prominent—TXx 0.61 °C per decade and TNx 0.55 °C per decade—than the trends in minimum values of Tmax and Tmin—TNn 0.46 °C per decade (significant only at the 90% level) and TXn 0.29 °C per decade (insignificant increase). Daily temperature range (DTR) increased negligible by the 0.07 °C per decade. Trends in percentile-based indices also confirm warming of the climate system in Bosnia and Herzegovina. Over the study area, warm nights (TN90p) and warm days (TX90p) displayed significant upward trends (3.32% or 12.1 days per decade and 2.87% or 10.5 days per decade, respectively), whereas significant downward tendencies were recorded in frequency of the cold nights (TN10p) and cold days (TX10p) (−1.33% or −4.9 days per decade and −1.27% or −4.6 days per decade, respectively). Both trends in fixed threshold-based temperature indices were also consistent with the global warming. The cold indices ID0 and FD0 displayed significant negative trends (−1.78 and −4.08 days per decade, respectively). The increase in the frequency of warm indices SU25, SU30 and TR20 (5.74, 6.22 and 0.64 days per decade, respectively) was even more pronounced and significant. In the observed period, prominent and significant positive trends in WSDI were also recorded—6.72 days per decade. Particularly rapid increase in WSDI has been recorded since the beginning of the 21st century. The average annual number of WSDI in the 2001–2016 periods was almost 5-fold compared to the 1961–1990 periods average. It should be noted that majority of most severe and long-lasting heat waves in Europe since 1950 have been registered in the 21st century (Russo et al. 2015)—for instance in summer 2003, 2007, 2012 and 2015. In contrary to the WSDI, the CSDI displayed only a weak downward trend (significant only at the 90% level) in the range of −0.87 days per decade. All the years with the highest frequency of CSDI were recorded before 1990 (in 1962–1965, 1985 and 1987). Increasing warming tendency resulted in significant extension of the growing season length (GSL)—averaged for 6.55 days per decade.

Changes in the probability density functions of both Tmax and Tmin between the 1961–1990 and the 1991–2016 periods clearly show a significant shift towards higher temperatures in latter period. This confirms the increasing warming trend after 1990s. Changes in distribution of the extreme temperature indices derived from Tmax and Tmin between two specified periods are displayed in Fig. 2. As expected, the Kolmogorov–Smirnov test results confirmed that all of the warm temperature indices significantly shifted their distributions towards higher values (except TXn, TNn and DTR), whereas the corresponding significant shift to lower values was detected for majority of cold indices (shift in ID0 was significant only at the 90% level and in CSDI insignificant due its very rare occurrence over the study area). The changes were particularly pronounced in the upper tail of the warm indices TXx, TNx, TN90p, TX90p, SU25, SU30, WSDI and GSL distributions.

The analysis of changes in GEV parameters between the two periods showed increasing values of Tmax and Tmin location parameter in latter period (Table 2). Higher scale parameter values indicate that variability of Tmax and Tmin distribution increased in latter period. The estimated 2-year, 20-year and 100-year events of both maximum Tmax and Tmin have become more common since 1990s. Negative values of shape parameter imply a bounded upper tail distribution. A negatively shaped distribution suggests that most of the values tend to occur towards the upper end of the scale, whereas increasingly fewer values occur towards the lower end.

Linear trends in annual extreme precipitation indices in the observed 1961–2016 periods are shown in Table 3. The obtained results suggest a general increase in the precipitation intensity. Moreover, growing maximum duration of both dry and

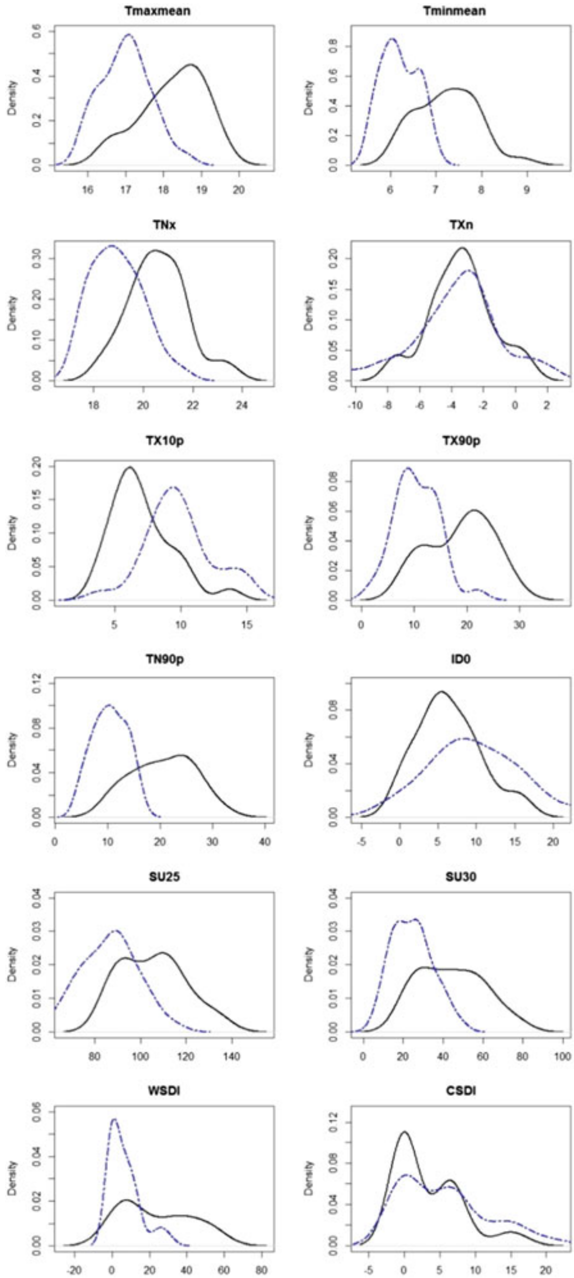

Fig. 2 Probability density functions of extreme temperature indices for the two periods: 1961–1990 (dashed line) and 1991–2016 (solid line)

Table 2 The estimated GEV parameters and return levels fitted to the annual maximum Tmax, Tmin and R in the 1961–1990 and 1991–2016 periods

Parameter	Tmax		Tmin		R	
	1961–1990	1991–2016	1961–1990	1991–2016	1961–1990	1991–2016
Location	34.81611	36.65795	18.51193	20.12777	37.74363	40.20739
Scale	1.79299	2.171086	0.892794	1.122503	7.032527	8.746319
Shape	−0.42491	−0.57817	−0.11029	−0.19993	0.085118	−0.17855
Estimated return levels						
2-year	35.42465	37.37503	18.83262	20.52447	40.36177	43.31039
20-year	37.84134	39.73882	20.77316	22.64189	61.50936	60.36918
100-year	38.43823	40.15032	21.73304	23.50412	77.3422	67.64731

wet periods indicates increasing precipitation variability. However, compared to the temperature, less spatially coherent patterns of change were registered. None of the estimated trend values (averaged for Bosnia and Herzegovina) was statistically significant. PRCPTOT (annual total of precipitation on wet days) insignificantly decreased by −3.45 mm per decade. Maximum 1-day precipitation (RX1day) and 5-day precipitation (RX5day) only slightly increased (0.37 and 0.55 mm per decade, respectively). Simple precipitation intensity index (SDII) showed a very weak upward trend over the entire territory. Although the average number of days with intense precipitation (R10mm and R20mm) was slightly reduced (−0.35 and −0.17 days per decade, respectively), the contribution from intense precipitation events to the annual total precipitation (R95p and R99p) increased (2.63 and 6.88 mm per decade, respectively). The estimated trend values of both maximum number of consecutive dry and wet days (CDD and CWD) averaged for Bosnia and Herzegovina were also low and insignificant. It should be noted that earlier more detailed analysis showed that these trends were not spatially coherent and uniform over the entire territory (trends mixed in sign occur) (Popov et al. 2017).

The Kolmogorov–Smirnov test results showed that changes in probability density functions of extreme precipitation indices (Fig. 3) between the two specified periods were not significant. However, it should be noted that distribution of heavy precipitation indices such as SDII, RX5day, R10mm, R20mm, R95p and R99p shifted to the right, to higher index values, suggesting increase in heavy precipitation events. Majority of these heavy precipitation indices displayed particularly pronounced changes in the upper tail of distribution.

Moreover, analysis of GEV distribution parameters fitted to annual maximum precipitation showed that location parameter value increased in latter period (Table 3). Higher value of distribution scale parameter shows that, in addition to intensity, the precipitation variability also increased in latter period. Changes in the probability density functions of PRCTOT and CWD are as well consistent with observed increase in inter-annual precipitation variability—the lower tail of PRCTOT distribution shifted towards drier conditions, whereas the upper tail shifted towards wetter conditions; the lower tail of CWD distribution shifted towards shorter duration of

Table 3 Linear trends in extreme precipitation indices in 1961–2016

Index	Slope estimate	*p*-value	Slope error	R^2
PRCPTOT	−0.345	0.808	1.414	0.1
RX1day	0.037	0.692	0.094	0.3
RX5day	0.055	0.718	0.150	0.2
SDII	0.005	0.346	0.005	1.7
R1mm	−0.157	0.236	0.131	2.6
R10mm	−0.035	0.580	0.062	0.6
R20mm	−0.017	0.546	0.029	0.7
R95p	0.263	0.738	0.783	0.2
R99p	0.688	0.153	0.474	3.8
CDD	−0.017	0.692	0.044	0.3
CWD	0.013	0.580	0.024	0.6

wet periods, whereas the upper tail of distribution shifted towards longer duration of wet conditions.

The observed changes in extreme climate indices have severe and diverse positive and negative effects on multiple key sectors in Bosnia and Herzegovina, such as agriculture, forestry, hydropower, energetics and tourism.

One of the positive impacts of climate change on agriculture will be extended growing season. However, negative impacts will be numerous. Extreme heat and drought stress during the crop reproductive period can be critical for its productivity (Deryng et al. 2014). Changes in the frequency and severity of extreme climatic events (e.g. heat waves, droughts, heavy and prolonged precipitation, excessive cold spells, hail storms, etc.) are expected to negatively affect crop yields and food production (including food access, utilization, and price stability) (Deryng et al. 2014; IPCC 2014b). In recent years, extreme weather events (i.e. droughts and extreme heat) have partially damaged regional crop production all over the world (national cereal production was significantly reduced by 9–10%) (Lesk et al. 2016). Crop yields show a strong dependence on temperature and available precipitation at critical stages of their development. It is projected that climate change will further exacerbate the conditions for the corn production, much more than wheat (Deryng et al. 2014).

Figure 4 shows that corn yields in Bosnia and Herzegovina are strongly related to warm temperature extremes—the significant negative correlation was determined for TXx, SU30, WSDI, DTR and TX90p. Moreover, corn yields are positively related with available precipitation, particularly during summer season (Fig. 5). Although climate change could have a positive effect on the winter crops yields due to the extended growing season, spring crops will be at risk due to high temperatures and water shortages (and drought occurrence) in summer season (Radusin et al. 2016). Increasing winter and early spring temperatures lead to greater opportunities for the pest and disease incidence (Radusin et al. 2016). An implementation measures needed for efficient adaptation of agricultural production to changing climate should

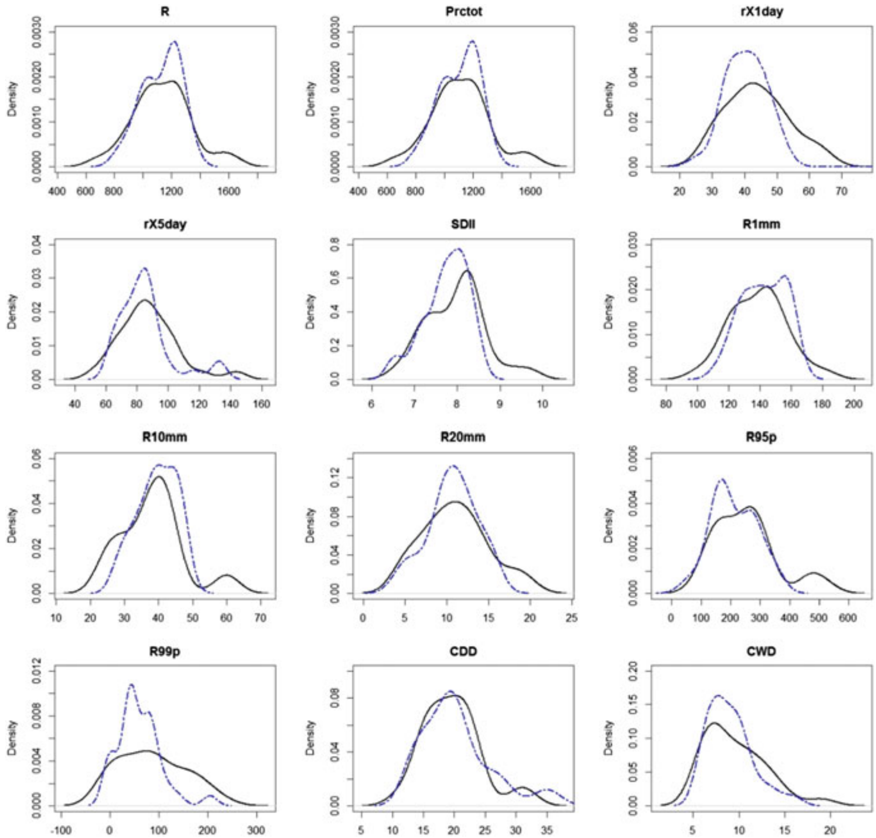

Fig. 3 Probability density functions of extreme precipitation indices for the two periods: 1961–1990 (dashed line) and 1991–2016 (solid line)

include: seasonal changes and sowing dates; different variety or species (change to a more drought- and heat adapted species; increase in winter crops); changes in water supply and irrigation system (use of artificial systems to improve water use and availability); changes in farming systems (fertilizer, tillage methods, grain drying and other field operations); research into new technologies; implementation of governmental and institutional policies and programs (FAO 2007).

Studies on forests in Europe already observed climate change effects on growth and productivity rates, phenology, composition of animal and plant communities, tree species movements and disturbances such as fires, storms, diseases, pests and invasive species (manifested in the increased frequency or unprecedented magnitude of disturbance events) (Lindner et al. 2014; Kovats et al. 2014). For instance, exceptionally large forest fires during the last decade have been associated with extreme weather conditions that exceeded the normal range of climate variability (Lindner et al. 2014). The increase of forest fires is particularly anticipated over Mediterranean

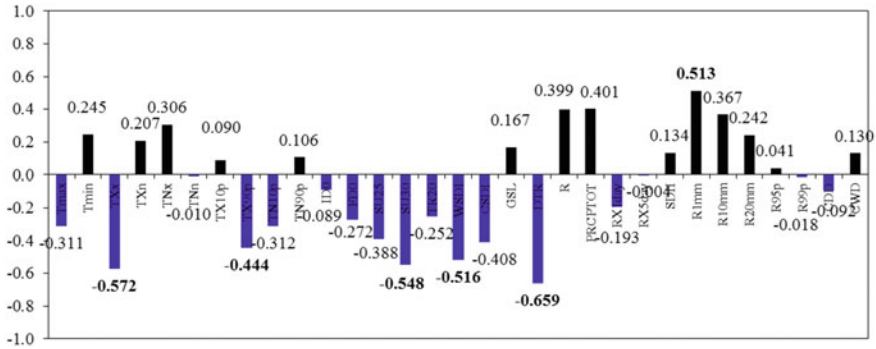

Fig. 4 Pearson correlation coefficient between extreme climate indices and corn yields in the Republic of Srpska in 1996–2016 (values in bold are significant at the $p < 0.05$ level)

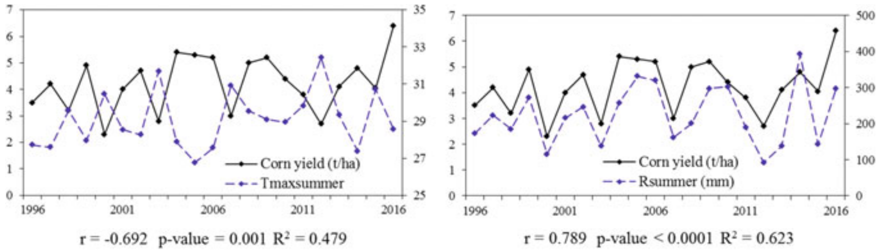

Fig. 5 Pearson correlation coefficient between summer Tmax and R and corn yields in the Republic of Srpska in 1996–2016

region. In the 1998–2016 periods, the upward tendency in total burned forest areas, in the range of 233.64 ha per year, is recorded in the Republic Srpska. The largest burned forest area over this territory was recorded during the years with extreme weather conditions—i.e. in years with intense and long-lasting heat waves and drought occurrence (2012, 2011, 2007, 2003 and 2000) (Fig. 6). Figure 7 illustrates that increasing occurrence of forest fires and larger burned areas are associated with the extremely high frequency of warm temperature indices (e.g. SU30, SU25, TX90p, WSDI and TXx). In contrast, the relationship with the precipitation is negative—i.e. the least burned forest areas were recorded in years with highest R, PRCPTOT, R1mm and CWD.

All these influences (climate change, vermin, pathogens and fires) may, in a long term, cause lower productivity and poorer health status of forests in Bosnia and Herzegovina (Radusin et al. 2013a). Tree mortality and forest decline due to severe drought events were already observed in forest populations in Southern Europe (Kovats et al. 2014). It is predicted that climate change would further alter the timing of species' life cycle events (phenology), species distributions will change radically, trophic networks will be affected and ecosystem functioning may be severely impaired, leading in the worst cases to species extinctions (Bellard et al. 2012). Distribution area of

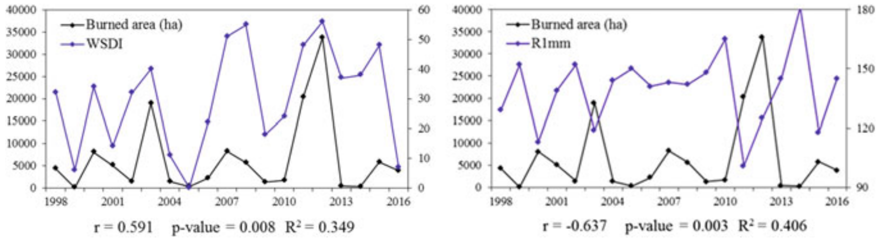

Fig. 6 Pearson correlation coefficient between WSDI and R1mm and burned forest area in the Republic of Srpska in 1998–2016

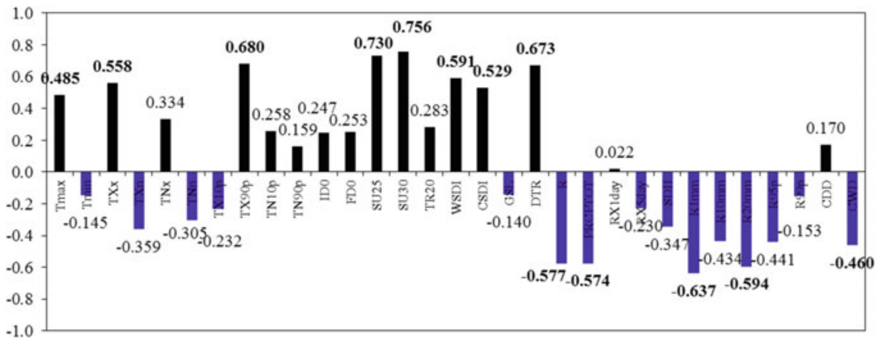

Fig. 7 Pearson correlation coefficient between extreme climate indices and burned forest area in the Republic of Srpska in 1998–2016 (values in bold are significant at the $p < 0.05$ level)

the subassociation of the Dinaric beech and fir forests in Bosnia and Herzegovina would be significantly reduced (Radusin et al. 2013a). More frequent and intense droughts could increase stress for many broad-leaved tree species, particularly in the northeastern region with lower precipitation (Radusin et al. 2013b). The beech mesophilic forests area will be significantly reduced, primarily due to the spread of different thermophilic forests and species. The increasing duration of dry periods in the future climate may lead to conditions in some parts of the territory where almost no tree species will be able to survive (Lindner et al. 2014). The most affected will be the herbaceous species with a narrow ecological valence in the highest mountainous regions above 1500 m (many of them representing Balkans endemic and relic species), which will not be able to adapt their habitats fast enough.

Adapting forests to extreme climate events will be particularly difficult because of their long life span. The basic adaptation measures have to include increasing the resilience of ecosystems, establishing monitoring system for the climate change impact on biodiversity assessment, expanding protected areas network, forest fire protection system enhancement, building capacity for integrated forest management etc. (Radusin et al. 2013b).

The energy sector is also potentially vulnerable to climate change, particularly due to reduction in river flows caused by increasing temperatures and decreasing precipitation in summer. Hydropower production is likely to decrease, whereas thermal power production will decrease during summer (Kovats et al. 2014). Lower water quantities will cause reduced energy generation—during the last decade, the hydropower production was the lowest in years with the occurrence of heat waves and droughts (e.g. in 2012, 2011 and 2007)—about 20% lower than the decadal average (RZS 2017). Space heating demand is likely to decrease, whereas cooling demand will increase (Kovats et al. 2014). In addition, flood risk and flood related damage have become more frequent and spatially cover larger areas.

The climate change would have serious implications for both spatial and temporal redistribution of tourism activities (Amelung et al. 2007). Climate change will particularly adversely affect ski tourism areas in low-altitude sites, especially where artificial snowmaking and other adaptation options are limited (Kovats et al. 2014). Climate change, accompanied by reduced snowfall, reduced duration of snow cover, increased average and especially daily winter temperatures, will have an increasing negative impact on winter tourist centers in Bosnia and Herzegovina. Following data illustrate that economic viability of this tourist activity is highly dependent on the snowfall inter-annual variability and snow cover duration and climatic conditions. At Jahorina Mountain during the ski season 2012/2013, with 126 skiing days, there were 150.380 skiers, whereas during the next season, with half the number skiing of days, a total number of skiers was 7-fold lower (Lazarević et al. 2014 as cited in Radusin et al. 2016). In order to adapt winter tourism activities to observed changes in climate condition, one of the necessary measures has to be artificial snowmaking that may prolong the activity in some ski resorts. However, its implementation has physical and economic limitations, especially in small-sized and low-altitude ski stations (such are all resorts in Bosnia and Herzegovina), whereas on the other hand significantly increases water and energy consumption (Kovats et al. 2014). Further, shifts to higher altitudes, operational/technical measures, and year-round tourist activities (which is one of the benefits of improved climatic conditions in warmer and drier summer season) will be necessary to compensate these adverse impacts (Kovats et al. 2014). City tourism might also be affected by changing climate due to high increase in summer temperatures and increasing frequency of heat waves occurrence.

4 Conclusion

A significant increase in frequency, intensity or duration of hot extremes was detected during the observed 1961–2016 periods over the entire Bosnia and Herzegovina territory, whereas the cold extremes have shown a downward tendency. However, both trends indicate warming of the climate system. Upward trends in heavy precipitation indices suggest changes towards more intense precipitation in Bosnia and Herzegovina (although, majority of the estimated trends were not significant). The analysis showed that the observed changes in extreme climate events had strong impact on agriculture production, forestry (forest fires regime), energy production, demand and supply and winter tourism in Bosnia and Herzegovina. The main research limitation is that the impact assessment study was carried out for the period since the 1990s, given that the data for the previous period were not available for analysis. However, analysis covered the period when climate change was most pronounced (the end of the 20th century and the beginning of the 21st century). The future research should be focused on projecting future changes in extreme climate indices and further, more complex impact assessment studies, i.e. the analysis of possible impacts of the observed changes in the extreme climate events on key economic sectors, but also on natural systems. In the future, climate change is projected to be a powerful stressor on natural and human ecosystems. Hence, the study on implementation of efficient strategies for adaptation and mitigation to climate change will be also necessary. IPCC have already discussed adaptation needs and options, but also adaptation constraints and limits (IPCC 2014b). Although the possibilities on adaptation of key economic sectors to climate changes in Bosnia and Herzegovina are evident, certain limitations (technical and technological, legislative, financial and limitations in education and research) are nevertheless present (Trbić et al. 2018) and should be considered. Adaptation options for key economic sectors in Bosnia and Herzegovina were defined in *Climate change adaptation and low emission development strategy for Bosnia and Herzegovina*, which implementation should reduce vulnerability of these sectors due to climate change by minimizing its negative impacts, increase resilience, and take advantage of opportunities brought by climate change (Radusin et al. 2013b). In order to fulfill defined goals, these guidelines have to be incorporated into sector policies and development strategies.

References

Alexander LV, Zhang X, Peterson TC, Caesar J, Gleason B, Klein Tank AMG, Haylock M, Collins D, Trewin B, Rahimzadeh F, Tagipour A, Rupa Kumar K, Revadekar J, Griffiths G, Vincent L, Stephenson DB, Burn J, Aguilar E, Brunet M, Taylor M, New M, Zhai P, Rusticucci M, Vazquez-Aguirre JL (2006) Global observed changes in daily climate extremes of temperature and precipitation. J Geophys Res Atmos. 111:D05109

Alexandrov V, Schneider M, Koleva E, Moisselin JM (2004) Climate variability and change in Bulgaria during the 20th century. Theor Appl Climatol 79(3–4):133–149

Amelung B, Nicholls S, Viner D (2007) Implications of global climate change for tourism flows and seasonality. JTR 45(3):285–296

Bellard C, Bertelsmeier C, Leadley P, Thuiller W, Courchamp F (2012) Impacts of climate change on the future of biodiversity. Ecol Lett 15(4):365–377

Branković Č, Cindrić K, Gajić-Čapka M, Güttler I, Pandžić K, Patarčić M, Srnec L, Tomašević I, Vučetić V, Zaninović K (2013) Sixth national communication of the Republic of Croatia under the United Nation Framework Convention on the Climate Change (UNFCCC) Selected Sections in Chapters: 7. Climate change impacts and adaptation measures 8. Research, systematic observation and monitoring. Meteorological and hydrological service of Croatia, Zagreb

Burić D, Luković J, Bajat B, Kilibarda M, Živković N (2015) Recent trends in daily rainfall extremes over Montenegro (1951–2010). Nat Hazards Earth Syst Sci 15:2069–2077

Burić D, Luković J, Ducić V, Dragojlović J, Doderović M (2014) Recent trends in daily temperature extremes over southern Montenegro (1951–2010). Nat Hazards Earth Syst Sci 14(1):67–72

Croitoru AE, Piticar A, Burada DC (2016) Changes in precipitation extremes in Romania. Quat Int. 415:325–335

Deryng D, Conway D, Ramankutty N, Price J, Warren R (2014) Global crop yield response to extreme heat stress under multiple climate change futures. Environ Res Lett 9(3):4011

Donat MG, Alexander LV, Yang H, Durre I, Vose R, Dunn RJH, Willett KM, Aguilar E, Brunet M, Caesar J, Hewitson B, Jack C, Klein Tank AMG, Kruger AC, Marengo J, Peterson TC, Renom M, Oria Rojas C, Rusticucci M, Salinger J, Elrayah AS, Sekele SS, Srivastava AK, Trewin B, Villarroel C, Vincent LA, Zhai P, Zhang X, Kitching S (2013) Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: the Hadex2 dataset. J Geophys Res Atmos. 118:2098–2118

Dumitrescu A, Bojariu R, Birsan MV, Marin L, Manea A (2015) Recent climatic changes in Romania from observational data (1961–2013). Theor Appl Climatol 122(1–2):111–119

FAO (2007) Adaptation to climate change in agriculture, forestry and fisheries: perspective, framework and priorities. Food and Agriculture Organization of the United Nations, Rome

Frich P, Alexander LV, Della-Marta P, Gleason B, Haylock M, Klein Tank AMG, Peterson T (2002) Observed coherent changes in climatic extremes during the second half of the twentieth century. Clim Res 19(3):193–212

Gajić-Čapka M, Cindrić K, Pasarić Z (2015) Trends in precipitation indices in Croatia, 1961–2010. Theor Appl Climatol 121(1–2):167–177

Gilleland E, Katz RW (2016) extRemes 2.0: an extreme value analysis package in R. J Stat Softw 72(8):1–39

IPCC (2014a) Climate change 2014: synthesis report. In: Core Writing Team, Pachauri RK, Meyer LA (eds) Contribution of Working Groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change. IPCC, Geneva

IPCC (2014b) Summary for policymakers. In: Climate change 2014: impacts, adaptation, and vulnerability. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge and New York

Kioutsioukis I, Melas D, Zerefos C (2010) Statistical assessment of changes in climate extremes over Greece (1955–2002). Int J Climatol 30(11):1723–1737

Kovats RS, Valentini R, Bouwer LM, Georgopoulou E, Jacob D, Martin E, Rounsevell M, Soussana JF (2014) Europe. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) (2014) Climate Change 2014: impacts, adaptation, and vulnerability, Part B: regional aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (1267–1326). Cambridge University Press, Cambridge

Lesk C, Rowhani P, Ramankutty N (2016) Influence of extreme weather disasters on global crop production. Nature 529:84–87

Lindner M, Fitzgerald JB, Zimmermann NE, Reyer C, Delzon S, van der Maaten E, Schelhaas MJ, Lasch P, Eggers J, van der Maaten-Theunissen M, Suckow F, Psomas A, Poulter B, Hanewinkel M (2014) Climate change and European forests: What do we know, what are the uncertainties, and what are the implications for forest management? J Environ Manage 146:69–83

Malinovic-Milicevic S, Radovanovic MM, Stanojevic G, Milovanovic B (2016) Recent changes in Serbian climate extreme indices from 1961 to 2010. Theor Appl Climatol 124(3):1089–1098

Morak S, Hegerl GC, Christidis N (2013) Detectable changes in the frequency of temperature extremes. J Clim 26(5):1561–1574

Popov T, Gnjato S, Trbić G, Ivanišević M (2017) Trends in extreme daily precipitation indices in Bosnia and Herzegovina. Collect Pap—Fac Geogr Univ Belgrade 65(1):5–24

Popov T, Gnjato S, Trbić G, Ivanišević M (2018) Recent trends in extreme temperature indices in Bosnia and Herzegovina. Carpath J Earth Env 13(1):211–224

Radusin S, Medić V, Cero M, Abdurahmanović I, Avdić S et al (2016) Third national communication and second biennial update report on greenhouse gas emissions of Bosnia and Herzegovina under the United Nations framework convention on climate change. UNDP, Sarajevo

Radusin S, Oprašić S, Cero M, Abdurahmanović I, Vukmir G et al (2013a) Climate change adaptation and low emission development strategy for Bosnia and Herzegovina. UNDP, Banjaluka

Radusin S, Oprašić S, Cero M, Abdurahmanović I, Vukmir G, Avdić S, Cupać R et al (2013b) Second national communication of Bosnia and Herzegovina under the United Nations framework convention on climate change. UNDP, Banjaluka

Republika Srpska Institute of Statistics (RZS) (2009, 2014, 2017) Statistical Yearbook of Republika Srpska. Republika Srpska Institute of Statistics, Banjaluka

Russo S, Sillmann J, Fischer EM (2015) Top ten European heat waves since 1950 and their occurrence in the coming decades. Environ Res Lett 10(12):124003

Trbić G, Bajic D, Djurdjevic V, Ducic V, Cupac R, Markez Đ, Vukmir G, Dekić R, Popov T (2018) Limits to adaptation on climate change in Bosnia and Herzegovina: insights and experiences. In: Leal Filho W, Nalau J (eds) (2018) Limits to climate change adaptation (245–259). Climate Change Management, Springer, Cham

Unkašević M, Tošić I (2011) A statistical analysis of the daily precipitation over Serbia: trends and indices. Theor Appl Climatol 106(1–2):69–78

Unkašević M, Tošić I (2013) Trends in temperature indices over Serbia: relationships to large-scale circulation patterns. Int J Climatol 33(15):3152–3161

Zhang X, Yang F (2004) RClimDex (1.0) user manual. Climate Research Branch Environment Canada, Downsview

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Promoting Adaptation Within Urban Planning: Case Study of the General Regulation Plan of the City of Požarevac

Tijana Crnčević, Ana Niković and Božidar Manić

Abstract This paper, by presenting the case study of the General Regulation Plan, provides an overview of the potentials and limitations of the planning system regarding adaptation in the context of urban planning in the Republic of Serbia. The spatial coverage of the Plan includes the central/urban and peri-urban area of the city of Požarevac, within which various land uses are represented. In addition to housing, commercial and industrial facilities, green infrastructure, as well as other land uses, agriculture is also presented. Taking into consideration the specificity of the Plan area, the paper presents measures that promote adaptation, with special emphasis on the green infrastructure, the water system, energy efficiency and the urban structure. Thus, one of the measures promoted by this Plan is the reservation of the space for raising fast-growing forests, building green roofs and walls and as well developing and expanding of the water drainage system network. In accordance with the current legal and planning basis, within the conclusions that this work stresses is that, even in an incomplete legal and planning framework, there are real possibilities for the inclusion of adaptive measures in the process of urban planning.

Keywords Adaptation · Urban planning · Climate change · Green infrastructure
Požarevac

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1 Introduction

Accepting climate change as a global phenomenon results in needs for new strategic frameworks, as well for the continual innovation of actual policies and plans. Accordingly, global documents—agreements, strategies, declarations, in addition to achieving sustainable development, define the need for building resilient infrastructure and creating resilient cities (European Commission (EC) 2013; United Nations 2015). Unlike spatial planning, which has a key role in controlling the development of renewable energy sources and other low-carbon technologies, at the level of urban planning, the construction and design of infrastructure play a key role in minimizing the risks of climate change to the environment and population (ECCP 2006a, b). Adaptation[1] and mitigation[2] have been recognized as the primary measures to combat climate change, where adaptation is seen as a key measure and, in this sense, it is advocated that adaptation measures should be incorporated into planning at all levels (Stern Review 2006). In this respect, recognizing that the role of planning in the context of climate change, inter alia, includes proactive interventions through plans, the need to establish adaptation to climate change as a key objective of (spatial) planning is indicated (Davoudi 2009; ESPACE Project 2007).

Respecting the need for action, the EU defined an *Adaptation Strategy* that promotes three key objectives: the adoption of adaptation strategies, adaptation within vulnerable sectors (cohesion policy, agriculture, fisheries), more resilient infrastructure in Europe, insurance against natural and man-made disasters and better informed decision-making (European Commission (EC) 2013). This strategy has significant support within the *Covenant of Mayors for Climate and Energy*, initiated and established in 2008 (Covenant of Mayors for Climate and Energy (CMCE) 2018). This agreement promotes a voluntary, bottom-up approach and gathers 7755 local regional authorities. In 2015, a new goal was established that aims at reducing CO_2 emissions, while intensifying adaptation to climate change.

The contemporary planning framework integrates climate change and adaptation into national policies as (1) a special part in national adaptation strategies (Austria, United Kingdom, Italy); (2) mainstreamed throughout the national adaptation strategy (Bulgaria, Denmark, France, Turkey); or (3) urban issues mainstreamed thematically into—Building and construction (Finland, Spain, Turkey), Spatial planning (Czech Republic, Finland, Germany, Portugal, Spain, Switzerland, Turkey), Health (Belgium, Czech Republic, Finland, Germany, Portugal, Spain, Switzerland), Transport (Belgium, Czech Republic, Finland, Portugal, Spain), Disaster risk management (Czech Republic, Portugal, Turkey) and Water management (Netherlands, Portugal, Turkey) (European Environment Agency (EEA) 2016).

[1] Adaptation considers the "adjustment in natural or *human systems* in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Intergovernmental Panel on Climate Change (IPPC) 2007).

[2] Mitigation considers "an *anthropogenic* intervention to reduce the anthropogenic forcing of the *climate system*; it includes strategies to reduce *greenhouse gas sources* and emissions and enhancing *greenhouse gas sinks*" (Intergovernmental Panel on Climate Change (IPPC) 2007).

Europe has seen "varying changes in temperature and rainfall" (Kovats et al. 2014: 1270) across the continent with already recorded winter floods, summer droughts and summer heat waves (Fay et al. 2010). Climate projections anticipate increases in high temperature extremes and precipitation, as well as meteorological droughts without changes in wind speed (Kovats et al. 2014). Even with the recognized high capacity in Europe for adaptation compared to other parts of the world, the region of Eastern Europe, together with Asia, has already been identified as having an "'adaptation deficit' which can only increase with the projected climate changes" as "the region's vulnerability is dominated by non-climatic factors, including socioeconomic and environmental issues" (Fay et al. 2010: XIX). Particular stress is made on the vulnerability of the populations within urban areas to the impacts of climate change due to the high density of the inhabitants within cities (Ibid.).

The Republic of Serbia in the last decade has been faced with the impacts of climate change, such as an increase in the duration of heat waves, followed by a lack of significant increase in the length of the vegetation period, as well as strong and extreme precipitation and a decrease in the number of frosty and icy days (RS, Ministarstvo zivotne sredine 2017). In line with global trends and EU policy, the Republic of Serbia has adopted and signed all relevant international agreements, providing a legal framework for the implementation of the contemporary framework regarding the issues of climate change. The changes in climate conditions, as well as the introduction and innovation of the current framework also establish new conditions for urban planning. Serbia's towns are faced with many challenges of market-led urban transformations where some substantial values of urban spaces are jeopardized and must be protected through the planning framework. A common problem is 'filling the space'—usurpation of all available open spaces in the towns and converting them into building plots (Marić et al. 2013; Marić et al. 2010). That has a negative impact on the potential to implement measures of adaption to climate changes. Taking this into consideration, the paper aims to give an overview of the potentials and limitations of the planning system regarding adaptation in the context of urban planning in the Republic of Serbia by presenting the selected case study—the Plan of general regulation of the city of Požarevac.

2 Methodology

The research is based on background analysis and review of the relevant literature, as well as on the techniques of document analysis, i.e. the collection and analysis of contemporary approaches/frameworks defined by policies, plans or programmes that promote adaptation in urban environments. The obtained analytical framework is then used to analyze a selected case study/the Plan of general regulation of the city of Požarevac. Although adaptation has not been recognized within the current framework in Serbia, the paper indicates the potentials and limitations of the planning system regarding adaptation in the context of urban planning in the Republic of Serbia.

3 Case Study: The City of Požarevac

In accordance with the current Law on Planning and Construction (2009–2014), for every urban settlement in Serbia the obligation of developing general regulation plans for all constitutive parts of the settlement is proscribed. The Institute of Architecture and Urban and Spatial Planning of Serbia has developed six general regulation plans (GRPs) that cover the entire urban buildable area of the city of Požarevac—referred to as “Požarevac 1”, “Požarevac 2”, “Požarevac 3”, “Požarevac 4”, “Požarevac 5” and “Požarevac 6”. According to the Law, these entities are based on the planning documentation at a higher level—the Master Plan of Požarevac (2014).

In this paper the adaptation measures within the planning process for GRP “Požarevac 1” (Institute of Architecture and Urban & Spatial Planning (IAUS) 2017a, draft version[3]) and GRP “Požarevac 4” (IAUS 2017b draft version) are outlined. These two plans are indicative because the entity “Požarevac 1” encompasses the inner city centre characterised by very high building density with a consequent insufficiency of open and green spaces/green infrastructure. The entity “Požarevac 4” is mainly determined by its strong spatial elements—the entrance roads to the city—important streets which connect the city centre with its surroundings and include portions of the state roads. According to the Master Plan, along these major axes, commercial and business uses are planned that would help to better integrate all parts of the city. In these development strategies, green infrastructure should be included to ensure the future balance between built and open/green spaces. The planning procedures are still in progress. The plan is in its final phase with adoption expected in the second half of 2018.

The General Regulation Plan “Požarevac 1” encompasses the largest part of the continuously built and populated area of Požarevac (around 900 ha), including the entire central city zone. Most of the population of the city of Požarevac lives in this area, which also contains the largest part of building stock. Dominant uses are: residential, commercial, public services and communal infrastructure areas, with mixed-use areas in the city centre. The basic goals of this Plan are to determine the rules of regulation, construction and protection, which improve the quality of housing, urban green areas, public services and infrastructure systems, and the protection of cultural heritage. The emphasis is on the rational use and protection of space with a realistic view of further development needs.

The area encompassed by the boundary of the General Regulation Plan “Požarevac 4” is divided into several spatial entities with the following dominant uses: a penitentiary-correctional facility complex, multifamily housing, individual housing, agricultural areas with rural housing, communal and infrastructure areas and structures. The main aims of developing GRP 4 are spatial and urban regulation, building, protection and the improvement of land. The special aims are re-cultivation and sanitation of the existing landfills, especially the illegal ones, planning the location for

[3]The draft version of the plan is a legal step in the procedure of the plan adoption and represents the phase of the fully elaborated graphic and textual parts of the plan to be processed by the administrative bodies.

the waste transfer station, extending the area of the existing cemetery, improving street and infrastructure systems, the protection and development of new green areas and protective greenery.

3.1 Overview of the Current State Within Planning in the Context of Climate Change in Republic of Serbia

The emphasis within the region of Europe is not only on the varying impacts of climate change but also on varying capacity due to "limited evidence of adaptation planning in rural development or land use planning" (Intergovernmenatl Panel on Climate Change (IPCC) 2014: 1273). Regarding climate change, the Republic of Serbia, in line with European integration, is a signatory of international documents that direct sustainable development and promote climate change issues—*the Paris Agreement,*[4] *the United Nations Framework Convention on Climate Change* (UNFCCC), *the Kyoto Protocol, the United Nations International Strategy for Disaster Reduction* (UNISDR) and, as well, at the level of the European Union the *European Climate Change Programme* together with *The European Emissions Trading Scheme* (ETS), *White paper on Adapting to Climate Change, The EU Adaptation Strategy* and others. As was stated, the "national policy framework … is in a process of revision, with the EU and global framework …where within related regulations covering climate change and DRR, the response is slightly slower and still needs coordination and harmonization, not only within the national framework (i.e. vertical coordination), but also within the legal framework (horizontal adjustments)" (Crnčević and Lovren-Orlović 2018: 117). Taking into account the current planning framework,[5] it should be noted, as was stated, that this framework "foresees the inclusion of climate change issues, primarily by representing the use of renewable energy, energy efficiency, prevention and protection against natural disasters, elimination of climate change causes, the conservation and sustainable use of natural resources and, in particular, the promotion of the ecological network NATURA 2000" (Crnčević et al. 2016: 167). Further, an analysis of the Spatial Plan of the Danube corridor through Serbia, taking into consideration the Plan coverage, indicates that the Plan promotes measures for the establishment of rules for land use in vulnerable areas, for flood protection, preservation of protected water areas, maintenance and restoration of

[4]*The Paris Agreement* was adopted in December 2015, at the 21st Conference of the Parties of the UNFCCC. To date, 194 countries have signed and 141 have ratified *The Paris Agreement* (United Nations 2018).

[5]The Law on the Spatial Plan of the Republic of Serbia 2010–2014–2021 (Official Gazette RS No. 88/10), Law on Planning and Construction (Official gazette of RS No. 79/09, 81/09-correction, 64/10-US, 24/11, 121/12, 42/13-US, 50/13-US, 98/13-US, 132/14 and 145/14), Law on Strategic Environmental Assessment (Official gazette of RS No. 88/2010), Law on Environmental Impact Assessment (Official gazette of RS No. 135/2004.36/2009), Law on Environmental Protection (Official gazette of RS No. 135/2004), Law on Emergency Situations (Official gazette RS No. 111/09, 92/11, 93/12), Law on Nature Protection (Official gazette. RS No. 36/2009, 88/2010) etc.

wetlands and riverbeds habitat networking (Ibid.). However, regarding adaptation capacity, "development of a system for adaptation is still not recognized as a priority", where the main limitations can be seen "in the fields of impact research and implementation of the planning instruments" (Ibid.: 167).

Taking this into account, the main potentials could be outlined because such data about risk zones are already integrated into the data on climate change, and current practice indirectly does take into account climate change issues through the promotion of measures such as the planning of ecological corridors and network habitats, measures for ecosystem protection, the increase of protected areas and the defining of the protective regime (Bazik and Dželebdžic 2011; Crnčević 2013; Crnčević et al. 2016). However, to achieve a proactive role, it is necessary to have data to identify and map risk areas, to map vulnerable areas and to integrate climate change scenarios into the process of evaluating risks and risk management, as these measures are seen as the "basis for future adaptation" (Crnčević et al. 2016:175).

Taking into consideration that, as was noted, "adaptation strategies vary from sector to sector, community to community and place to place" (Alam et al. 2018), according to the report *Urban adaptation to climate change in Europe 2016—Transforming cities in a changing climate* (European Environment Agency (EEA) 2016), two approaches are recognized that deal with adaptation. *Coping* considers "responding to damage arising from a disaster and recovery afterwards" while *incremental adaptation* builds on "existing adaptation measures and known solutions by improving these, bit by bit, and increasing their capacity to avoid any damage under a future level of risk" (Ibid.:7). Besides these approaches, it is also recognized that transformative adaptation follows a broader and systematic approach, because "it addresses the root causes" as "vulnerability to climate change is often a result of human actions such as setting in risk prone areas, inadequate building design…."(Ibid.: 8). As was noted, "all three approaches have their justification" and making a decision among them depends on the city refereeing the social, economic and other circumstances, where "transformative adaptation is broader and systematic" as "it addresses the root causes of vulnerability" (Ibid.: 23). In accordance with the *Second National Communication of the Republic of Serbia to the UN Framework Convention on Climate Change*, adaptive measures are foreseen within the field of agriculture, forestry, health and hydrology and water resources and, as has been indicated, the implementation of adaptive measures in the field of agriculture has already begun (investments in irrigation systems, changes in agricultural crops and their varieties, reduction of soil cultivation and improvement of soil structure and others) (Republika Srbija (RS), Ministarstvo životne sredine 2017).

The results of an overview of the existing literature in Serbia within the field of planning indicates that the issue of climate change/adaptation is present in both the foreign frameworks and experiences and in the national frameworks, which also point out the limitations and possibilities for implementing adaptation measures. This issue is also present in the planned adaptation measures of selected case studies within the current practice of spatial and urban planning (see more in Niković et al. 2013; Marić et al. 2013; Mihajlović 2013; Pucar et al. 2016; Crnčević et al. 2011; Crnčević 2013; Crnčević et al. 2016; Marić et al. 2015). Therefore, aiming to obtain comprehensive insight into the potential and limitations within urban planning and taking into consideration measures within the *Second National Communication of the Republic of Serbia to the UN Framework Convention on Climate Change* and, as well, the contemporary framework regarding planning and adaptation, the adaptation within urban planning in Serbia for the Požarevac Plan has been analyzed according to the adaptation measures that were outlined within the project "Future Cities".[6] In addition, according to these analyses, structural adaptation measures within the green infrastructure, water system, energy efficiency and mitigation and urban structure have been considered (Table 2).

3.2 Achieving Adaptation: Overview of the Adaptive Measures Within the Plan

The immediate legal and planning framework for the General Regulation Plan of the city of Požarevac also includes, as is outlined in Table 1, the Decision on making Plans and Strategic environmental assessments (SEA) where the scope for the Plan is outlined in more detail. It should be stressed that this framework was analysed according to the presence of the key words: adaptation and climate change, together with related measures for mitigation and adaptation as outlined previously (the use of renewable energy, energy efficiency, prevention and protection against natural disasters, elimination of climate change causes, conservation and sustainable use of natural resources and, in particular, promotion of the ecological network NATURA 2000). However, as can be seen, regarding the capacity for adaptation outlined in Table 1, although adaptation is not directly presented, adaptation is indirectly promoted through the planning framework within planned measures.

The area within the boundary of the General Regulation Plan "Požarevac 1" consists of three main urban entities (Fig. 1). The first—inner city centre—comprises most of the mixed-use city area, including the main commercial, cultural, educational and public services. Most of the medium- and high-density housing is also in this urban entity. The second one—the wider city centre—consists of the rest of the medium- and high-density housing, some of the accompanying areas, especially commercial services, and has a large share of low-density housing. The third entity—the urban tissue outside the city centre—mainly consists of low-density housing. In this part of Požarevac are also: a hospital, cemetery, sports centre, the protected park "Čačalica" and some special purpose areas, as well as unbuilt agricultural, abandoned or unused areas.

In accordance with the legal and planning framework within the subject area, different types of green areas are planned as an integral part of a unique system—the green infrastructure. Within the scope of the Plan are represented: (1) independent urban green areas: (a) parks (City Park, Sunny Park, a park in front of the SUP and

[6] According to the EU—Interreg IVB-project, "Future Cities—urban networks to face climate change" http://www.future-cities.eu/.

Table 1 Legal and planning framework for Požarevac GRP: overview of the adaptation capacities

Legal framework	**Adaptation**
Law on Planning and Construction (Official gazette of RS No. 79/09, 81/09-correction, 64/10-US, 24/11, 121/12, 42/13-US, 50/13-US, 98/13-US, 132/14 and 145/14)	Does not include adaptation or adaptation measures not included; climate change issues included by promoting energy efficiency and rational use of non-renewable natural resources and renewable energy sources
Rulebook on the content, method and procedure for spatial and urban planning documents (Official gazette of RS, No. 64/15)	Do not include adaptation; climate change issues presented indirectly through the detailed defining scope of the spatial and urban plans covered
Decision on making Plan and Strategic environmental assessments for the GRP "*Požarevac* 1" ("Official gazette of city of Požarevac" No. 8/15) *Decision on making Plan and Strategic environmental assessments for the GRP "Požarevac 2*" ("Official gazette of city of Požarevac" No. 8/15)	Do not include adaptation; climate change issues presented indirectly through promoting goals of improving infrastructure systems, protection and developing green areas, supporting public interests in using space. Also through the Decision of elaborating the SEA, the importance of developing measures of protection of the living environment, natural values and providing sustainable development
Planning framework	**Adaptation**
Master plan of the city of Požarevac ("Official gazette of the city of Požarevac" No. 13/14), *Spatial Plan of the city of Požarevac* ("Official gazette of city of Poažarevac" No. 10/12), *Spatial Plan of the area of special purposes Kostolac coal basin* ("Official gazette of RS" No. 1/13), *Regional spatial plan for the area of Podunavlje and Braničevski district* (Official gazette of RS No. 8/15)	Do not include adaptation. Indirectly promote climate change issues by supporting mitigation and adaptation measures (increasing of protected areas, development of ecological networks, protection of ecosystems etc.)

a children's park in Moša Pijade Street); (b) city park forest—[park forest Čačalica (24 ha) and Tulba (8 ha)]; squares—(Oslobodjenja, Radomira Vujovića, Pionirski trg (traffic square), (d) piazzas (J. Šerbanović Street and M. Pijade Street, at the corner of Leninova and V. Dulića) (2) integrated green areas: (a) public greenery and greenery of public buildings and services (flat areas in open blocks, sports and recreation, tourist and recreation centres, (c) greenery for other purposes: integrated green areas of production complexes and individual dwellings, healthcare facilities; (3) connecting green areas: avenues and protective greenery along the roads.

The Plan does establish the conditions for building green walls within the regulation of public areas. Further, the Plan specifies that the walls must be built with modular technology—to be made of special cassettes where the supporting structure serves as a basis for the growth and development of different plants (ornamental grasses, flower beds, perennials). Also, regarding green roofs, within areas with commercial content, the Plan recommends to green the flat roofs of structures with a minimum 30 cm of the soil substrate, as well as to green the surface above the under-

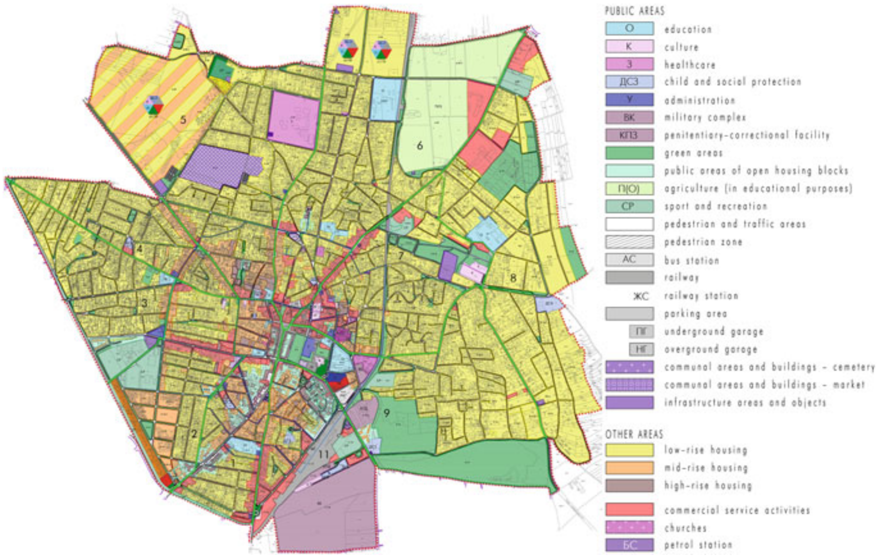

Fig. 1 General Regulation Plan 'Požarevac 1'—the Planned Use Chart

ground garage (and level with a zero angle of the terrain). In relation to existing conditions, green infrastructure covers a total 39 ha, compared to the 67 ha planned. It is necessary to note that, within this balance, the green areas within the integrated green areas as well the planned green walls and roofs are not included. Green roofs are included indirectly. For example, for a particular zone 40% of greenery is required on a plot, or 30% if it has a green roof.

The area encompassed by the boundary of the General Regulation Plan "Požarevac 4" consists of six planned spatial and ambient entities (Fig. 2). The first entity ('KPZ') comprises the penitentiary-correctional facility "Zabela" with accompanying industrial and commercial facilities. Also included in this entity are areas with multifamily housing, infrastructural objects, sports and recreation, agriculture with rural housing and traffic. Three entities (P1, P2, P3) are mainly characterized by agricultural areas with rural housing. All of them also include industrial and commercial uses, green areas and traffic corridors. In one of them, a waste transfer station is planned, while in another the new cemetery and an area of a possible archeological site is planned. The remaining two entities (G1, G2) have been marked as the "entrance direction to the city" because the physical structure—individual housing—has mainly developed along the important streets that connects the city centre with the city surroundings. Beside housing, these two entities contain agricultural areas with rural housing, green areas, sports and recreation, industrial and commercial uses, and traffic corridors.

Different types of green areas are planned as an integral part of a unique system, as follows: (1) independent urban green areas: (a) parks (at Metkor Place and near Dunav Street), (b) squares (near Metkor and at the corner of the streets Zmaj Jovina

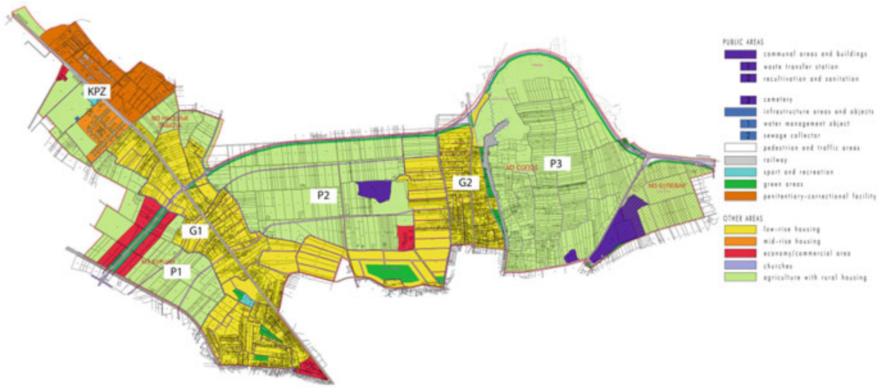

Fig. 2 General Regulation Plan 'Požarevac 4'—the Planned Use Chart

and Bate Bulića (2) integrated green areas: (a) public greenery and greenery of public buildings and services (flat areas in open blocks, sports and recreation, tourist and recreation centres), (c) greenery of other purposes: integrated green areas of production complexes and individual dwellings; (3) connecting green areas: protective greenery along the roads.

Regarding green roofs, this unit also considers building within the commercial content under the same conditions, while green walls are not planned. Further, the formation of a protective belt of greenery along the national route DP 1B 34 is planned to function as protection against noise, dust and ash, a minimum width of 20 m. For the planned green belt, the Plan proposes the formation of energy plantations of the willow (*Salix Viminalis*), as an alternative solution for a long-term supply of clean energy.

Significant new green areas are envisaged in the area encompassed by the boundary of the General Regulation Plan "Požarevac 1", with an increase of over 70% compared to the existing situation. Several new squares are planned, in order to increase the quality and availability of green spaces as well as their quantity, and ramify the green infrastructure network. Transforming the corridor of the old industrial railway line into a green line that would connect the city centre with the surrounding environment is also planned. The rules for planning and designing green roofs and green walls are provided. Measures are foreseen to extend the network of the water drainage system network and introduce elements of still water into the urban space. GRP "Požarevac 1" also provides guidelines and recommendations for using renewable energy and increasing energy efficiency.

In the case of GDP "Požarevac 4", the standard of green areas has been highly improved through the measures given through the plan (Table 2). Although the main part of the planned area in its existing state is occupied by greenery, we cannot include it in the city's green infrastructure—of 887.92 ha in total, 61.62% is agricultural land and 6% is other undeveloped areas. The only exception is green areas in the blocks of multifamily housing in the "KPZ" entity. Because all agricultural land is planned

Table 2 Adaptation within the General regulation plan for the city of Požarevac

Type of measure	Existing		Planned	
	Požarevac 1	Požarevac 4	Požarevac 1	Požarevac 4
Green roofs	/	/	Greening of flat roofs of objects and surfaces above the underground garages	
Green walls	/	/	Recommended within the regulation of public areas.	/
Green open spaces	39 ha	Green open spaces are not included within land use	67 ha	21.17 ha
Water retention	Yes, two	/	Two new ones are planned	/
Water drainage	Water drainage system is insufficient and does not cover the whole territory		Developing and expanding of the water drainage system network is planned	
Urban water spaces-flowing	/	/	/	/
Urban water spaces-standing	/	/	One of the retentions will be used as an open water element—a pond	/
Increase energy efficiency	Not enough data. According to expert judgement, the energy efficiency level is low and unsatisfactory		Guidelines, recommendations and measures for increasing the energy efficiency are given in the Plan	
Renewable energy	/		Guidelines, recommendations and measures for renewable energy use are given in the Plan	Guidelines, recommendations and measures for renewable energy use are given in the Plan; formation of energy plantations

(continued)

Table 2 (continued)

Type of measure	Existing		Planned	
	Požarevac 1	Požarevac 4	Požarevac 1	Požarevac 4
Urban setting	The urban matrix of Požarevac and its street network are extremely irregular, most closely related to the monocentric radial type. Radial directions spread extensively from the centre, forming the basic structure of this matrix, which is filled with irregular, spontaneously formed urban tissue. Concentric, i.e., transversal directions are not sufficiently developed	The physical structure is mainly developed along the two main roads which connects the city centre with the outskirts. The other residential parts have an incompletely developed street and infrastructure network	Improving urban matrices—regulating existing and implementing new streets with infrastructure, accompanied with greenery	
Urban texture	Heterogenous, with less than 5% of green areas	Domination of open, undeveloped areas and agricultural land. In built-up areas, low-rise, individual housing with auxiliary structures on the plot	Forming new green areas (almost doubling the existing areas); e.g. reserving private vacant plots in the middle of existing neighbourhoods	Forming new green areas; reserving private vacant plots in the middle of existing neighbourhoods

to be converted into urban buildable land, it is important to point to the measures to be implemented in developing these areas, especially in terms of preserving quality open and green spaces. On the other hand, through the regulation of built-up areas of the plan with individual housing, the reserved green areas on the vacant plots are planned with the aim to improve the urban setting and urban texture. Private property within these plots could cause a problem in implementation. Because the Master Plan of Požarevac, as well as the GDP 4, envisages stronger connections between the city centre and its outskirts, the green infrastructure takes this role too.

4 Conclusions

Taking into account the climate change issue and the promotion of adaptation, Serbia has been continuously working on improving both its legal and planning frameworks. It should be stressed that a main limitation is that appropriate support is missing in the context of the promotion of adaptation as a primary goal or as an integral part of the strategies or within sectorial urban thematic issues. However, a main potential is, as has been noted, that adaptation is present in spatial and urban planning in Serbia. As previous research and the case study presented here indicate, climate change issues, together with mitigation and adaptation are included by indirectly promoting the goals of improving infrastructure systems, protecting and developing green areas, and supporting the public interest in space use.

Based on the results of the analysis of the General Regulation Plan of the City of Požarevac, it can be noted that even in the low regulative and planning capacity regarding adaptation, the Plan is achieving significant results in its promotion. Taking into account spatial coverage, overcoming the noted limitations of the city of Požarevac is accomplished with a "bottom–up" approach, through promotions measures at the local/urban level within green structures, the water system, energy efficiency and the urban structure. The adoption and implementation of these measures will result in a significant contribution towards making the city of Požarevac more resilient while the results and experience gained will make a significant contribution not only within the current practice of urban planning but also in the formation of an empirical base.

Future prospects within urban planning are anticipated by promoting this bottom-up approach, while the development and adoption of the *National Climate Change Strategy* together with the *Action plan* (expected in 2019) will make an important contribution in establishing the needed strategic framework to combat climate change and promote adaptation.

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References

Alam GMM, Alam K, Mushtaq S, Khatun MN, Leal Filho W (2018) Strategies and barriers to adaptation of Hazard-Prone rural households in Bangladesh. In: Leal Filho W, Nalau J (eds) Limits to climate change adaptation. Climate change management. Springer, Cham, pp 11–24

Bazik D, Dželebdžić O (2011) Climate change adaptation—a new role of Spatial Planning—(the case of Danube Area in Serbia) (Prilagođavanje klimatskim promenama - nova uloga prostornog planiranja. (primer Podunavlja u Srbiji)). In: Uticaj klimatskih promena na planiranje i projektovanje, Arhitektonski fakultet Univerziteta u Beogradu, Beograd, pp 66–84 (in Serbian)

Crnčević T (2013) Planiranje i zaštita prirode, prirodnih vrednosti i predela u kontekstu klimatskih promena u Republici Srbiji – prilog razvoju metodološkog okvira, Posebna izdanja br. 72, IAUS, Beograd (in Serbian)

Crnčević T, Lovren-Orlović V (2018) Displacement and climate change: improving planning policy and increasing community resilience. Int J Clim Change Strat Manage 10(1):105–120

Crnčević T, Marić I, Josimović B (2011) Strategic environmental assessment and climate change in the Republic of Serbia—support to development and adjustment process. SPATIUM 26:14–19

Crnčević T, Dželebdžić O, Milijić S (2016) Planning and climate change: a case study on the spatial plan of the Danube Corridor through Serbia. In: Leal Filho W, Adamson K, Dunk R, Azeiteiro U, Illingworth S, Alves F (eds) Implementing climate change adaptation in cities and communities. Climate change management. Springer, Cham, pp 161–177

Covenant of Mayors for Climate and Energy (CMCE), http://www.covenantofmayors.eu/IMG/pdf/covenantofmayors_text_en.pdf. Accessed 18 Mar 2018

Davoudi S (2009) Framing the role of spatial planning in climate change. Electronic working paper no. 43. http://www.ncl.ac.uk/media/wwwnclacuk/globalurbanresearchunit/files/electronicworkingpapers/ewp43.pdf. Accessed: 20 Sept 2017

ESPACE Project (2007) Planning in a changing climate: the strategy & supporting evidence CD-ROM, putting adaptation at the heart of spatial planning. http://www.espace-project.org/part1/publications/ESPACE%20Stategy%20Final.pdf. Accessed 20 Aug 2017

European Commission (EC) (2013) European Union strategy on adaptation to climate change. https://ec.europa.eu/clima/sites/clima/files/docs/eu_strategy_en.pdf. Accessed 10 Sept 2017

European Climate Change Programme (ECCP), Working Group II Impacts and Adaptation (2006a) Regional Planning, Energy and Public Infrastructure and Structural Funds Sectoral Report. (a) https://ec.europa.eu/clima/sites/clima/files/eccp/second/stakeholder/docs/regional_en.pdf. Accessed 20 Nov 2017

European Climate Change Programme (ECCP), Working Group II Impacts and Adaptation (2006b) Urban Planning and Construction Sectoral Report. (b). https://ec.europa.eu/clima/sites/clima/files/eccp/second/stakeholder/docs/urbanplanning_en.pdf. Accessed: 20 Nov 2017

European Environment Agency (EEA) (2016) Urban adaptation to climate change in Europe 2016, transforming cities in a changing climate. Publications Office of the European Union, Luxemburg. https://doi.org/10.2800/021466

Fay M, Block RI, Ebinger J (2010) Adapting to climate change in Eastern Europe and Central Asia. The International Bank for Reconstruction and Development/The World Bank, Washington

Intergovernmenatl Panel on Climate Change (IPCC) (2014) Climate change 2014. In: Barros VR, CB Field, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Impacts, adaptation and vulnerability. Part B: regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Intergovernmental Panel on Climate Change (IPPC) (2007) IPPC Fourth Assessment Report: Climate Change 2007. https://www.ipcc.ch/publications_and_data/ar4/wg2/en/annexessglossary-a-d.html. Accessed 20 Sept 2017

Institute of Architecture and Urban & Spatial Planning (IAUS) (2017a) General Regulation Plan "Požarevac 1" (draft version), Belgrade

Institute of Architecture and Urban & Spatial Planning (IAUS) (2017b) General Regulation Plan "Požarevac 4" (draft version), Belgrade

Kovats RS, Valentini R, Bouwer LM, Georgopoulou E, Jacob D, Martin E, Rounsevell M, Soussana JF (2014) Europe. In: Barros VR, CB Field, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 1267–1326

Law on Planning and Construction (Zakon o planiranju i izgradnji) (Official gazette of RS No. 79/09, 81/09-correction, 64/10-US, 24/11, 121/12, 42/13-US, 50/13-US, 98/13-US, 132/14 and 145/14) (in Serbian)

Marić, I, Niković, A, Manić, B (2010) Transformation of the New Belgrade urban tissue: filling the space instead of interpolation. Spatium International Review 22:47–56

Marić I, Niković A, Manić B (2013) Enhancement of urban structure with the aim of reducing the impacts of climate change on the example of Belgrade. In: Vujošević M, Milijić S (eds) Proceedings of the 2nd international scientific conference "Regional Development, Spatial Planning and Strategic Governance—RESPAG 2013" (pp 823–851). IAUS, Belgrade. Marić I, Niković A, Manić B (2010) Transformation of New Belgrade Urban Tissue: filling the space instead of interpolation. SPATIUM, vol 22, pp 47–56

Marić I, Crnčević T, Cvejić J (2015) Green infrastructure planning for cooling urban communities: overview of the cotemporary approaches with special reference to Serbian experiences. SPATIUM 33:55–61

Master Plan of Požarevac (2014) Spatial Plan of the city of Požarevac (Official gazette of city of Požarevac No. 10/12)

Master plan of the city of Požarevac (Generalni urbanistički plan Požarevca), "Official gazette of the city of Požarevac" no. 13/14 (in Serbian)

Mihajlović M (2013) Mogućnost inkoporacije klimatski odgovornog planiranja i promene dosadašnje percepcije razvoja beogradskog priobalja – na primeru projekta Danijela Libeskinda za luku Beograd (Possibilities of incorporating climate planning and changing hitherto perceptions of development of Belgrade waterfront—based on the Daniel Libeskind's solution of the Port of Belgrade). In: Pucar M, Dimitrijević B, Marić I (eds) Klimatske promene I izgrađeni proctor, politika i praksa u Škotskoj i Srbiji (Climate change and the built environment, policies and practice in Scotland and Serbia), Posebna izdanja br. 70 (Special issue 70), IAUS, Beograd, Glasgow Caledonian University, pp 330–345 (in Serbian)

Niković A, Manić B, Marić I (2013) Mogućnosti primene mera prilagođavanja klimatskim promenama pri projektovanju i planiranju užeg centra Beograda i integrisanja u strategije održivog razvoja. In: Pucar M, Dimitrijević B, Marić I (eds) Klimatske promene I izgrađeni prostor, politika i praksa u Škotskoj i Srbiji (Climate change and the built environment, policies and practice in Scotland and Serbia), Posebna izdanja br. 70 (Special issue 70), IAUS, Beograd, Glasgow Caledonian University, pp 386–390 (in Serbian)

Odluka o izradi plana generalne regulacije "Požarevac 1" i "Požarevac 4" ("Službeni glasnik grada Požarevca", br. 8/2015) Decision on the elaboration of the General Regulation Plan "Požarevac 1" and "Požarevac 4" ("Official Gazette of the City of Požarevac", No. 8/2015) (in Serbian)

Pucar M, Kovačević B, Simonović Alfirević S (2016) Model razvoja kulturno istorijskog spomen kompleksa Brankovina i predlog mera zaštite od klimatskih promena (Model for the development of the cultural historical memorial complex Brankovina and proposal of measures for the protection against climate change). In: Pucar M, Nenković Riznić M (eds) Prostorni, ekološki, energetski i društveni aspekti razvoja naselja i klimatske promene, Posebna izdanja br. 78, IAUS, Beograd, pp 165–192 (in Serbian)

Regional Spatial Plan for the area of Podunavlje and Braničevski district (Official gazette of RS No. 8/15)

Republika Srbija (RS), Ministarstvo zivotne sredine (2017) Drugi nacionalni izveštaj R. Srbije prema Okvirnoj konvenciji UN o promeni klime (Second National Communication of the Republic of Serbia to the UN framework convention on climate change), http://www.klimatskepromene.rs/wp-content/uploads/2017/12/Drugi-izvestaj-o-promeni-klime-SNC_Srbija.pdf

Rulebook on the content, method and procedure for spatial and urban planning documents (Official gazette of RS No.64/15)

Spatial Plan of the arera of special purposes Kostolac coal basin (Official gazette of RS No. 1/13)

Stern Review (2006) The economics of climate change, http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf. Accessed 20 Nov 2017

United Nations (2015) Resolution adopted by the General Assembly on 25 September 2015, http://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf. Accessed 25 Nov 2017

United Nations, Paris Agreement, http://unfccc.int/paris_agreement/items/9444.php. Accessed 25 Jan 2018

Hail as a Natural Disaster in Bosnia and Herzegovina

Tihomir Dejanovic, Goran Trbić and Tatjana Popov

Abstract The increased frequency and intensity of hail occurrence is one of the negative consequences of climate change in Bosnia and Herzegovina. The monitoring system of the hail occurrence, as well as the suppression from the hailstorms damages, is best organized in the northern part of the country, which represents largest and most important region of crops and fruit production. Activities on hail suppression have been implemented in Bosnia and Herzegovina since 1970. The main aim of the paper is to perfom a complex analysis of the hail occurrence in Bosnia and Herzegovina in the 2000–2017 periods, based on data from meteorological stations Banja Luka, Bijeljina, Mrakovica, Gradiška, Srbac, Derventa, Doboj and Prijedor, and 203 anti-hail stations. The temporal and spatial distribution of the hail occurrence over the study area, and their interdependence with climate change will be determined. It is particularly important to emphasize that during the last two decades prominent climate change have been observed over the study area, which caused higher atmosphere lability and increased frequency of occurrence, as well as intensity of the phenomenon. The paper also discusses the extreme hailstorm event on June 25, 2014, when the northern part of Bosnia and Herzegovina was affected by supercell cumulonimbus. Further, the potential impacts on the agricultural sector and adaptation options were investigated.

Keywords Hail · Climate change · Bosnia and Herzegovina · Adaptation Agriculture

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1 Introduction

Research on the hail phenomenon and suppression issues have been intensified during the last two decades. In the scientific literature can be found papers addressing this issue in Serbia (Ćurić and Janc 2016), France, Romania (Burcea et al. 2016), Germany (Mohr and Kunz 2013; Puskeiler et al. 2016), Turkey (Kahraman et al. 2016), Mongolia (Lkhamjav et al. 2017), Molodova (Potapov et al. 2007) etc. However, in spite of that, issues of hail occurrence and suppression are not addressed sufficiently in the IPCC reports. In the Fourth report of the first workgroup (The physical science basis), the hail issues were discussed within the analysis of thunders and tornadoes, giving information related primarily to the USA (IPCC, AR4-WGI 2007). In the IPCC Fifth report, information about the hail occurrence was given for Germany (Hartmann et al. 2013). For the Eastern Europe and Western Balkans region, there was no information on hail issues in the previous IPCC reports. The most important information about the hail issues for the South Europe region can be found in Sanchez et al. (2017). It can be expected that in the IPCC Sixth report the hail issues in the Eastern Europe region will be more discussed, given that during the last five years many scientific research have been published (e.g. papers cited earlier in the text).

Bosnia and Herzegovina is located in geographical latitudes where frequent thunderstorms with hail occurrence occur. The hailstorms bring severe damages to the economy (especially agriculture), and to movable and immovable property in Bosnia and Herzegovina.

Research on the hail, as one of the most common natural disasters in Bosnia and Herzegovina, has gained increasing significance over the last few decades, due to the apparent climate change. Climate change is primarily manifested in the increasing air temperatures and the disturbance of the pluviometric regimen and the increased atmosphere lability (instability) (Trbić et al. 2018). The strong relationship between climate change and occurrence of hailstorms suggests that if increasing air temperature scenario is achieved that would directly lead to the greater atmosphere instability and to the higher frequency and intensity processes. In addition, the pluvioregime disorder, in which the rainfall occurs in a few days and with more intense precipitation, acts in the same direction (Second National Communication Bosnia and Herzegovina under UNFCCC www.unfccc.ba).

The research of the climatic element of the appearance of the hail in a certain geographical area requires appropriate analyzes of other climatic elements as well as their cause-and-effect relationships.

The northern part of Bosnia and Herzegovina territory represents the most important arable land area in the country. As such, it was recognized in the former SFR Yugoslavia, when in this area at the beginning of the 1970s started organized hail suppression activities, primarily in order to protect agricultural production as one of the strategic industries (Dejanović 2009). The mentioned activities are still carried out over the area of 10,602 km^2, covering a territory of 26 local administrations—24 in the Republika Srpska entity, 1 in Federation of Bosnia and Herzegovina entity and the Brčko District as a special form of local government in Bosnia and Herzegovina. The activities of anthropogenic modification of the weather in order to reduce damages from the hailstorms are carried out under the jurisdiction of the Ministry of Agriculture, Forestry and Water Management of the Republic of Srpska, through the Public Company "The Hail Prevention Company of the Republic of Srpska". The hail suppression system has been improved by the Soviet methodology, i.e. the introduction of silver iodide (AgI). Over the northern part of Bosnia and Herzegovina, i.e. in its 26 local administrations, 220 missile launchers have been deployed.

A complex analysis of the hail occurrence in Bosnia and Herzegovina is based on the reports from aforementioned 220 locations, in the northern part of Bosnia and Herzegovina. Moreover, data from meteorological stations Banja Luka, Bijeljina, Mrakovica, Gradiška, Srbac, Derventa, Doboj and Prijedor, and 203 anti-hail stations were used for the analysis. The 2000–2017 periods was set for the analysis and observations are carried out at the aforementioned 10,602 km^2 in the northern part of Bosnia and Herzegovina.

2 Physical-Geographical Characteristics of the Northern Part of Bosnia and Herzegovina

2.1 Geographical Location

The northern part of Bosnia and Herzegovina is located in the central part of the northern temperate belt, between the subtropical belt of the high air pressure and subpolar belt of low air pressure (Trbić 2010) (Fig. 1).

The study area is located at the contact between two large physiognomic regions—the Pannonian lowlands in the north and the mountainous rim area in the south. The Dinaric Mountains greatly prevent the Mediterranean influences from the south, and considerably modify the influence of air masses coming from the Atlantic (which have the most important impact on pluviometric regime in this area).

2.2 Climate Features

The climate of the northern part of Bosnia and Herzegovina is determined by the main climatic factors: geographical position, geological composition, relief and proximity of the Adriatic Sea. Thus, the study area climate, but also the climate of Southern and Central Europe in general, is strongly dictated by the global atmospheric circulation and air masses flows over the Bosnia and Herzegovina throughout the year or in some seasons. However, regional and local climatic factors modify the airmass influence to a considerable extent and determine climatic and topoclimatic specificities. A

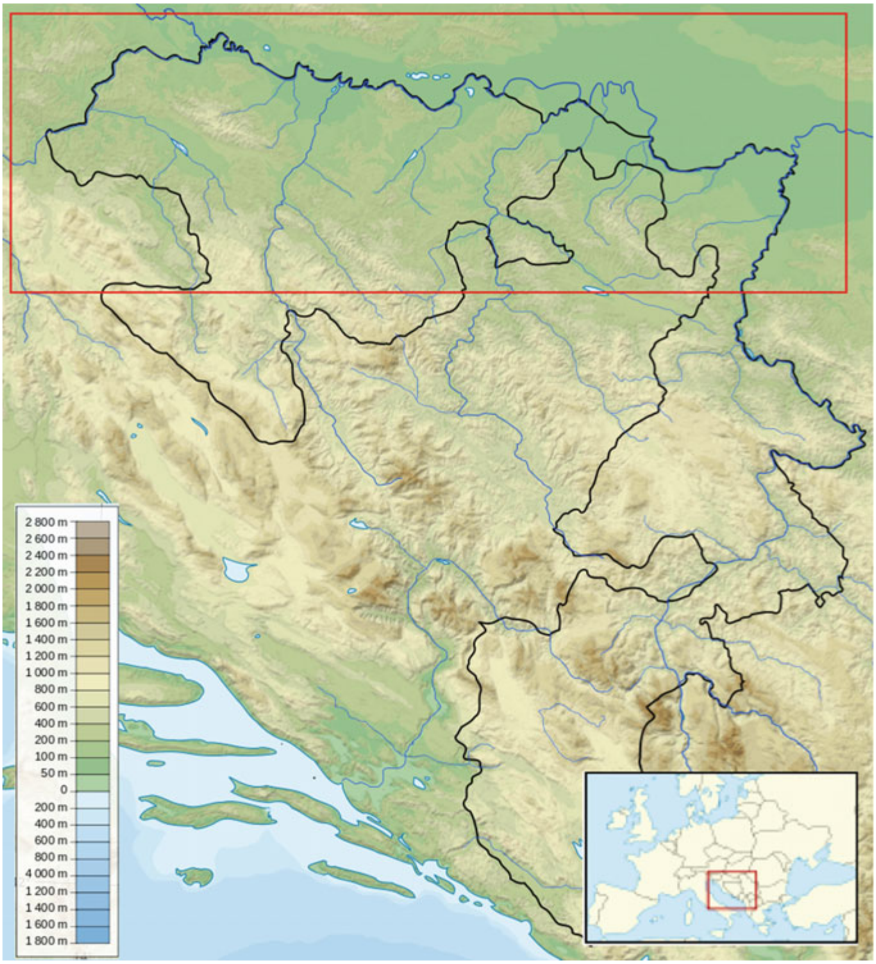

Fig. 1 Geographic location of the study area

temperate continental climate is the characteristic of northern part of Bosnia and Herzegovina (Trbić 2010).

Data on hail events and other climatic elements were collected for the 2000–2017 periods from meteorological stations Banja Luka, Bijeljina, Derventa, Doboj, Mrakovica, Gradiška, Prijedor and Srbac. Data were provided by the Republic Hydrometeorological Service of the Republic of Srpska (Table 1 and Fig. 2).

Table 1 Geographical location of meteorological stations used in the study

Meteorological station	h (m)	ϕ	λ
Banja Luka	153	44° 09′N	17° 15′E
Bijeljina	90	44° 46′N	19° 16′E
Derventa	122	44° 59′N	17° 55′E
Doboj	146	44° 44′N	18° 16′E
Gradiška	92	45° 09′N	17° 16′E
Mrakovica	806	45° 00′N	16° 54′E
Prijedor	141	44° 98′N	16° 72′E
Srbac	102	45° 10′N	17° 52′E

Source Republic Hydrometeorological Service of the Republic of Srpska

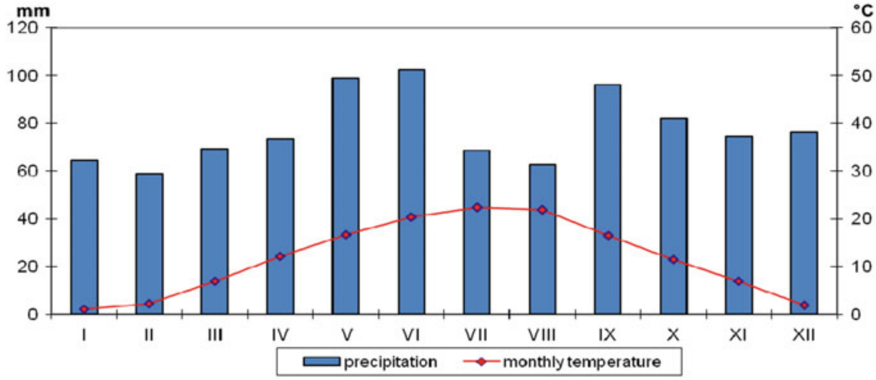

Fig. 2 Climadiagram for the northeastern region of Bosnia and Herzegovina in the 2000–2017 periods

In late spring, early summer and autumn (in May, June and September), the observed area is predominantly exposed to the cyclone from Atlantic. In this time of the year, the highest monthly precipitation amounts are recorded. According to Van Veber, during the late spring and early summer, the Sava River valley bring large amounts of precipitation in the form of rain. In summer, this area is predominantly under the influence of the Azores anticyclone, which conditions warm and clear weather and a low precipitation. Significant penetrations of warm air masses from the south (i.e. from Sahara and Mediterranean area) condition a very warm and dry weather over the study area. Summer is characterized by local depressions, formed due to sudden overheating of the soil surface, which cause showery precipitation, but also hailstorms, which adversely affect the crops (i.e. partly and completely destroying them). Local modifying influence of the mountains is manifested in the creation of local depression and temperature inversions.

2.3 Climate Change in Bosnia and Herzegovina

In the Second national report of Bosnia and Herzegovina in accordance with the United Nations Framework Convention (June 2013), recent climate change trends in Bosnia and Herzegovina are given based on the comparative analysis of the 1981–2010 periods compared to the reference 1961–1990 periods. The observed increase in annual temperature was in the range of 0.4–0.8 °C, whereas the growing period temperature increase was even 1 °C. In this period, the decrease in annual number of days with precipitation greater than 1 mm was observed, whereas the annual number of days with intense precipitation increased—therefore, the pluviometric regime is disturbed (Source: Second National Report of B&H to the UNFCCC www.unfccc.ba).

3 The Hail Occurrence Over the Northern Part of Bosnia and Herzegovina

Cumulonimbus (Cb) are formed in an unstable atmosphere. The atmosphere is in unstable equilibrium state when the thermal gradient is greater than the adiabatic gradient. In an unstable atmosphere, there are vertical ascending air currents, which is most often the case in cyclones. The formation of nimbostratus (Ns) and cumulonimbus (Cb), and the precipitation of precipitation from these clouds, are directly related to visible and audible electrical discharge in the atmosphere (Young KC 1993) (Fig. 3).

The stresses in the cumulonimbus, leading to the strong lightning discharge, are undoubtedly the result of condensation of water vapor or its products. Atmospheric disorders can be divided into thermal and frontal. Thermal accidents occur due to the overheating of ground air masses over the land surface in hot summer days, and are the consequence of the daily temperature flux. Frontal accidents occur on a cold air front. The penetration of cold and humid air over overheated shore conditions a pronounced instability and a strong development of convective cloudiness. Such frontal cumulonimbus often develops to the tropopause, and even beyond it, especially in the afternoon, followed by thunderstorms, rainshowers and storm winds. The hail occurrence is most common in the narrow zone of the front where the strongest frontal dynamics occurs. The hail occurrence is also higher in the zone behind the front than in front of the front, which is explained by the development of the altitude valley and the cyclone in the cold mass behind the front. The 69% of the frontal disasters in the observed area occurs in the May-June periods (Stričević 1982).

Fig. 3 The area of the northern part of Bosnia and Herzegovina area covered by the hail suppression system (10,602 km^2) (Documentation and material of the RS Hail Prevention Company for the 2000–2017 periods)

The hail is a phenomenon characteristic for the warmer part of the year. Based on phenomenon occurrence, it is determined that hailstorm season lasts from April 15 to October 15.

Activities on suppression of this atmospheric natural disaster in the present-day northern part of Bosnia and Herzegovina started in 1970. Based on the available data, the most accurate analysis of hail occurrence can be made precisely for this area.

Table 2 Mean altitude of isotherms based on the atmospheric catheter, for days with the occurrence of a degree of danger objections to the northern part of B&H in the 2000–2017 periods

Month	0	−4	−6	−10	−12	−14	−28
April	2.7	3.3	3.6	4.3	4.5	4.7	6.9
May	3.0	3.6	4.0	4.6	4.9	5.2	7.6
June	3.4	4.1	4.3	5.0	5.3	5.7	7.7
July	3.8	4.4	4.8	5.4	5.8	6.2	7.9
August	3.7	4.3	4.8	5.4	5.7	6.3	7.8
September	3.6	4.2	4.6	5.1	5.6	5.9	7.7
October	3.6	4.0	4.4	4.9	5.3	5.7	7.6

Source Documentation and material of the RS Hail Prevention Company for the 2000–2017 periods

3.1 Characteristics of the Atmosphere in Days with the Phenomenon

The level of cloudiness, in practice, is determined by radar measurements, while the height of the isotherm is determined by the atmospheric catheter in given terms. At the beginning of spring season, with increasing daytime temperatures, the atmosphere begins to heat up, which results in the isothermic rising trend. The conditions for the atmosphere lability and the occurrence of atmospheric disasters are created by the inflow of humid air (Table 2).

The atmosphere temperature is the most important cause of the atmospheric lability, and its seasonal increase (from half to mid-summer) and daily increase (in the afternoon) is different. The seasonal atmosphere temperature increase is the best illustrated by the isotherm height. The second factor of the atmosphere lability is the increased presence of moisture in the air. In most cases, it is conditioned by the movement of humid air masses from the Atlantic and the Mediterranean. In the analyzed 2000–2017 periods, in days with the occurrence of gradient cumulonimbus, height of isotherm −28 °C ranged from a minimum of 6.9 km (in April) to a maximum of 7.9 km (in July). It can be assumed that all cumulonimbus, which exceeded this isotherm, already contain hail grains. In days with the occurrence of the hail, the mean height of the cumulonimbus exceeded the mean height of the isotherm −28 °C but it is indicative that the upward streams in the atmosphere are the strongest in the warmest months, leading to the highest mean altitudes of cumulonimbus in July. In addition to the seasonal warming of the atmosphere the greatest lability of the atmosphere in the afternoon and afternoon hours, is when the atmosphere due to daily warming, The presence of moisture further destabilizes. In the vegetation season (April–October) 76% of the weather is in the period from 12 to 24 h (Dejanović 2015).

Table 3 Mean and absolute maximum altitude of cumulonimbus above the northern part of B&H, in the 2000–2017 periods

Month	Cb height		
	Mean	Mean in days with the hail	Absolute maximum
April	9.4	10.0	16.0
May	11.5	12.2	16.3
June	12.6	13.2	18.0
July	12.9	13.9	17.0
August	12.2	13.0	17.5
September	11.3	12.6	13.5
October	12.1	–	12.6

Source Documentation and material of the RS Hail Prevention Company, for the 2000–2017 periods

3.2 Height of Cumulonimbus (Cb)

The physical characteristics of cumulonimbus (Cb) over the study area, i.e. its height (mean and maximum) are determined by radar measurements. Mean height for all of the observed cumulonimbus, mean cumulonimbus height in days with the hail occurrence and the absolute maximum altitude is determined on monthly level for the 2000–2017 periods (Dejanović 2015). Over the northern part of Bosnia and Herzegovina, the average height of these clouds increases from April until the end of July, and then it begins to decrease—similar changes are determined for the isotherm height (Table 3).

It is evident that the mean cumulonimbus heights in days with the hail occurrence are higher than the mean heights in general (including the cumulonimbuses that did not cause the hailstorms). In absolute maximum altitudes, the strength and energy of the process is definitely taken as the factor of their reach, but also the relief orography and the type of substrate on the path along which cumulonimbus moves. Transitions over orographic obstacles give an additional height to cumulonimbus. If the orographic barrier is rich in watercourses and forest vegetation with strong evapotranspiration, which is the case over the study area, additional moisture in the atmosphere occurs. It is noteworthy to mention that in the analyzed April–October period, cumulonimbus do not cause hailstorms only in October (Dejanović 2015). Absolutely highest radar measured cumulonimbus height over the study area in the 2000–2017 periods was recorded on June 27, 2008 (18,000 m) (Source: Documentation and material of the RS Hail Prevention Company, for the 2000–2017 periods).

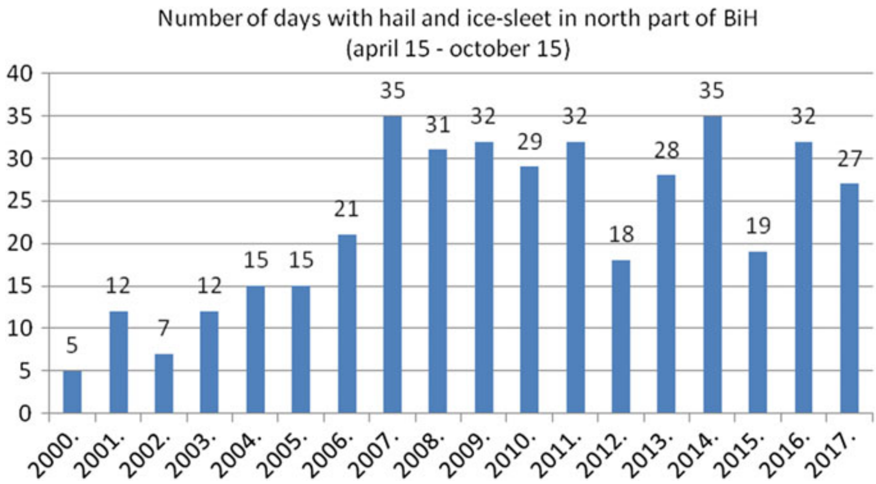

Fig. 4 Number of days with hail in B&H in the 2000–2017 periods

3.3 Frequency of the Cumulonimbus Hail Occurrence

The northern part of Bosnia and Herzegovina, in the observed 2000–2017 periods is included in the hail suppression system. According to the reports from with 220 anti hail stations, the analysis of the monthly frequency of occurrence during the warmer part of the year (April–October) was carried out. In this part of the year (April–October), over the study area 47 days with the appearance of cumulonimbus and 23 days with the occurrence of hail were observed on average. It is evident that during the analyzed 2000–2017 periods, but particularly since 2005, there has been a significant increase in the total annual number of days with the hail occurrence. Namely, until 2006 there were up to 15 days with a hail occurrence annually, since then annual number of days with a hail occurrence ranges from 18 to 35 days. The highest annual number of days with the hail occurrence over the northern part of Bosnia and Herzegovina was recorded in 2007 and 2014, when 35 such days were recorded. In 2014, the phenomenon of extremely strong gradient processes was associated with extremely long trails (of several hundreds of kilometers) and a drop in the hail grains with a diameter of more than 50 mm and with kinetic energy that created enormous damage on the ground (Source: Documentation and material of the RS Hail Prevention Company, for the 2000–2017 periods) (Figs. 4 and 5).

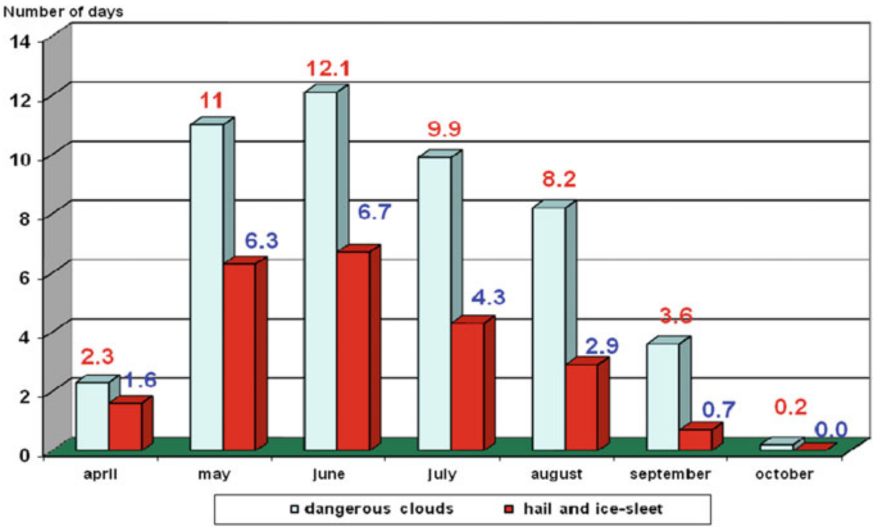

Fig. 5 The average number of days by months with cumulonimbus and hail in B&H in the 2000–2017 periods

3.4 Spatial Distribution of the Hail Occurrence

The analysis of the maximum number of days with the hail and ice-sleet occurrence in the April–October season showed that in eight local governments (which cover the largest area—5411 km^2 or 51.0% of the protected area) maximum number of days with the hail is up 15 days per year, in eleven local administrations (which cover 4038 km^2 or 38.1% of the protected area) up to 10 days per year, whereas in only seven local administrations (with an area of 1153 km^2 or 10.9% of the protected area) hail occurrence can be expected in maximum 5 days per year (Fig. 6).

The average annual number of days with the hail and ice-sleet occurrence ranges from 0.1 to 7.5 days. In 13 local administrations (which cover 7830 km^2 or 73.8% of the protected area) more than 4 days with the hail and ice-sleet occurrence is recorded annually on average (Fig. 7).

4 Consequences of the Hailstorms

Average annual gross value of total plant production in the 17 analyzed local governments of Republika Srpska in the 2006–2009 periods was 392 million Convertible Marks (BAM). Of course, in extreme weather conditions, the estimated damage is multiplied by the hail monitored. The best illustration of the stated is the example of supercell cumulonimbus from June 25, 2014. The year was a unique natural phe-

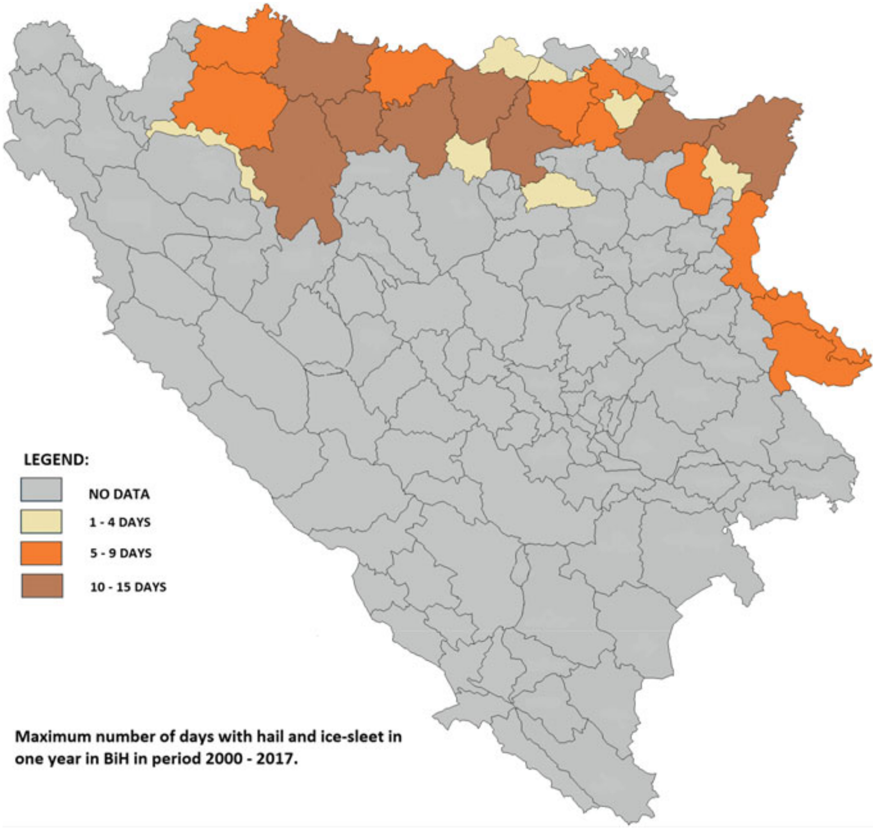

Fig. 6 Maximum annual number of days with the hail occurrence over the northern part of B&H, in the 2000–2017 periods

nomenon by the intensity of the hail's downfall and the economic phenomenon after the damage it was involved (Dejanović 2015).

Analysis of the state of the atmosphere on June 25, 2014 showed that in the afternoon, there was the development of extremely strong storms, followed by a devastating wind and hail, and intense precipitation. All prognostic parameters, for that day, from several meteorological numerical models, have shown that there were conditions for a great storm. For the first time in 2014, the European Center for the Evidence of Storm marked B&H (along with Serbia, Romania and Bulgaria) as the area with the highest level of risk in Europe. The cyclone center in the first part of the day was located on the border of Croatia and Slovenia, later in the day it moved through Hungary to Slovakia and Poland. Its movement, first caused the inflow of a high amount of moisture and warmer air from the Mediterranean region, and then in the afternoon came a cold front within this cyclone (Fig. 8).

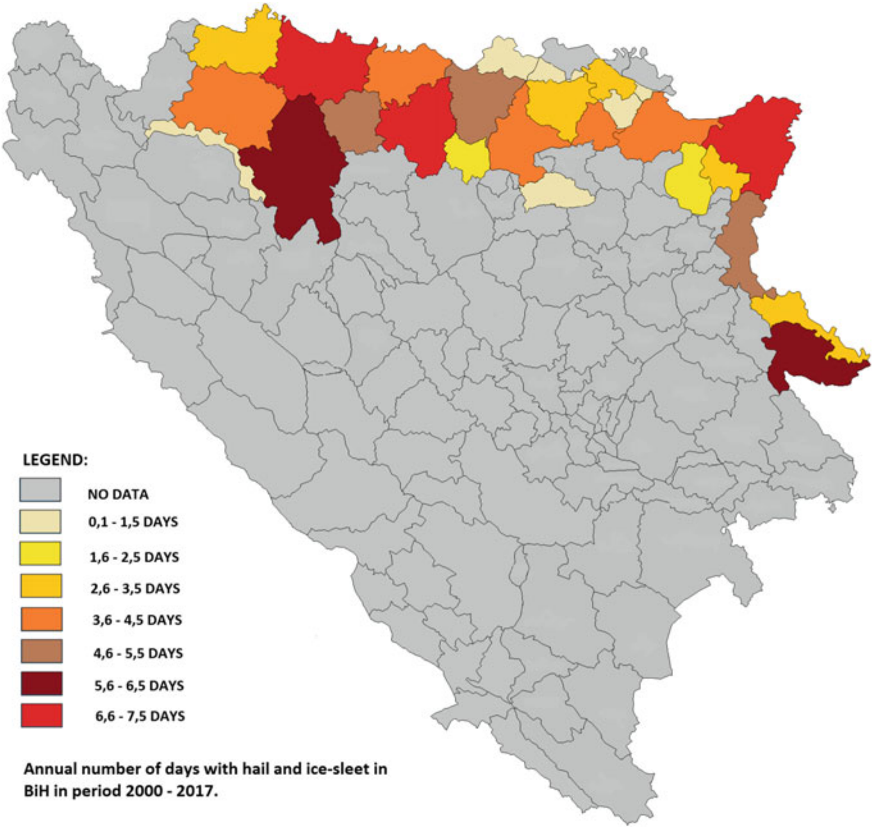

Fig. 7 Average annual number of days with hail and ice-sleet occurrence in one calendar year

A clash of warm and cold air mass caused the development of convective cloudiness along the frontal line, and therefore cloudiness on satellite images and sky seemed to be "cut off" (Fig. 9).

During the period of instability, radar followed 10 stronger processes over B&H and surrounding areas. Thunderstorm came from the west and quickly moved towards the east of Bosnia and Herzegovina. Extremely strong supercellular process was formed around 14 o'clock in Croatia, in particular in the Una River area. This process developed for about 30 min and strengthened until it entered the northern part of Bosnia and Herzegovina, in the municipality of Kozarska Dubica. Radar images showed the maximum possible reflection rate (figure), the physical height of the cloud top was over 15 km high, that is, above the tropopause, and the speed of movement was up to 100 km/h (Source: Documentation and material of the RS Hail Prevention Company, for the 2000–2017 periods) (Fig. 10).

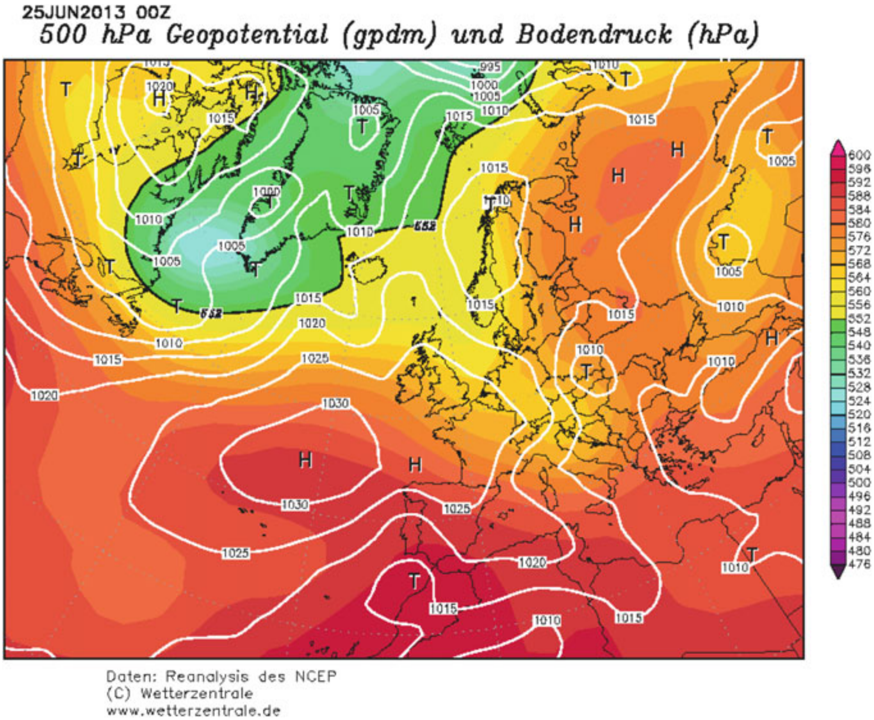

Fig. 8 Geopotential to 500 hectopascals on June 25, 2014

In addition to the storm, the processes also produced extremely large amount of rain. At Gradiska meteorological station, in less than 5 min, 24 mm (l/m^2) of rainfall were recorded (Source: Documentation and material of the RS Hail Prevention Company, for the 2000–2017 periods) (Fig. 11).

The route supercell cumulonimbus passed through covered defended territory from Kozarska Dubica in the west to Bijeljina in the east. The same stormy process continued to inflict damage further in the east in the Serbia (Fig. 12).

Along the route of cumulonimbus movement (about 200 km), in the central part in a width of up to 4 km, a hail of size from walnut to hen eggs (about 4 cm). The hail was followed by stormy winds and extreme rainfall, which further increased the damage. Because of the high velocity of movement, the process failed to act with a larger input of silver iodide (AgI) and gave a maximum radar reflection along the route, meaning that the process was not substantially weakened. The greatest damage was caused along the 200 km of cumulonimbus movement route (with 4 km width), precisely over the study area, where fruit plantations in Gradiška area and other most valuable agricultural areas all the way to Bijeljina were located. In September 2014, the Local Government of Gradiška Municipal Commission for the assessment of damage in agriculture publicly disclosed that the damage from the hailstorm, which occurred

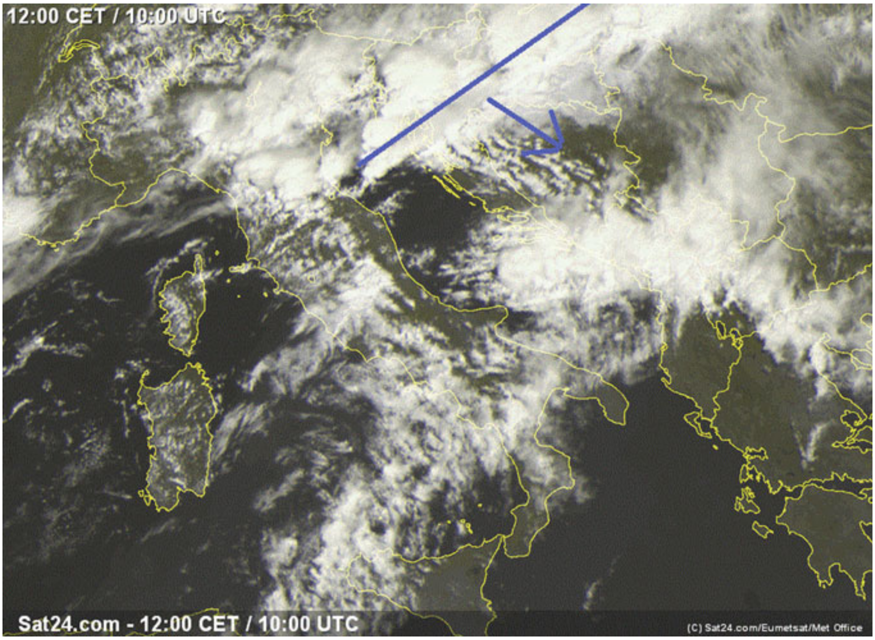

Fig. 9 Satellite Snapshot on June 25, 2014

on June 25, only in Gradiška area was 11,039,017.44 BAM. This fact tells us that the extreme storm-gradient processes over the studied northern part of Bosnia and Herzegovina, damage to agricultural production much more then previously designed on the basis of 3 and 5% of the hail of affected arable land can be significantly higher. We will use the published results of Gradiška Municipal Commission for the damages assessment and statistical data to illustrate how much damage we can expect from the extreme hail events over the study area (Figs. 13 and 14).

By adding the parameters, the territory affected by the hail 7.9% in the earlier model, it is concluded that the damage from the hail, in extreme cases, only in the area of 17 local governments in the northern part of the RS, during only one disaster, can reach up to 30,978,531 convertible marks (Fig. 15).

It is suggested that with the further development of agricultural production (that is with increasing yields or cultivation of more viable cultures), and with the current average number and intensity of gradient processes, the damages caused by the hailstorms over the observed area will increase in the future (Figs. 16 and 17).

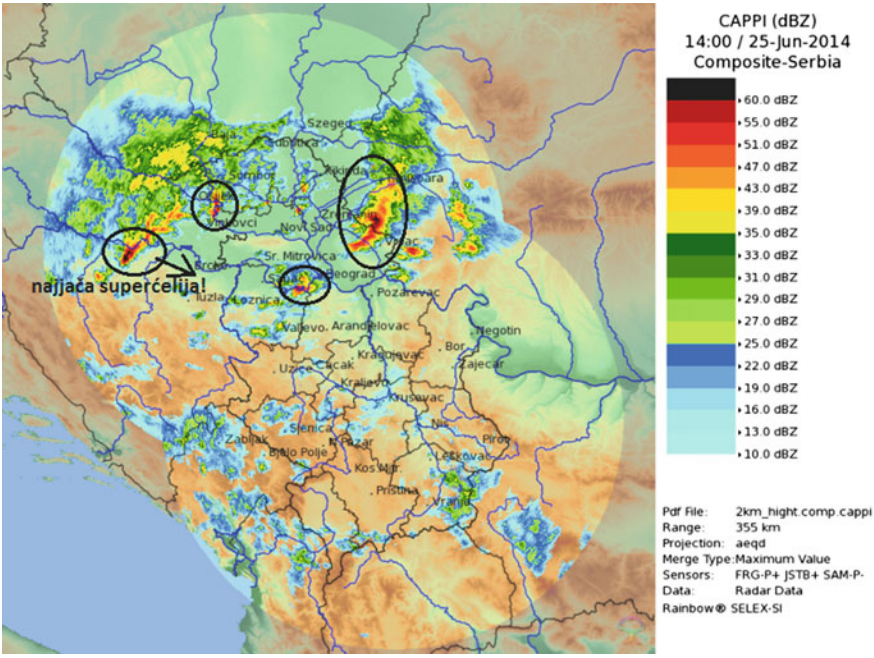

Fig. 10 Radar Record on June 25, 2014 at 14 o'clock

5 Conclusion

The occurrence of hail, as a natural disaster, in Bosnia and Herzegovina and the surrounding countries is a common during the warmer part of the year. During the analyzed period, it is noticeable that the recent climate change manifested in increasing temperature trend (global warming) has to a greater frequency and intensity of gradient processes over the northern part of Bosnia and Herzegovina territory. It was determined that in the warmer part of the year (April–October), in the northern part of Bosnia and Herzegovina, 47 days with the cumulonimbus occurrence were recorded annually on average, out of which in 23 days on average the hail occurred. It is evident that during the analyzed 2000–2017 periods, more precisely since 2005, there has been a significant increase in the total number of days with the hail occurrence. The extradition number of 35 days with the town and cohort in the northern part of Bosnia and Herzegovina occurred in 2007 and 2014. For 2014, the phenomenon of extremely strong gradient processes is associated with the exceptionally long trails (hundreds of kilometers) of the city falling by over 50 mm and with kinetic energy that created enormous damage on the ground. The most frequent route from which the gradient cumulonimbus enters the area of the northern part of Bosnia and Herzegovina is southwest. In the period April–October, 76% of the weather is in the period from 12 to 24 h. The analysis of radar measurements was established that starting from

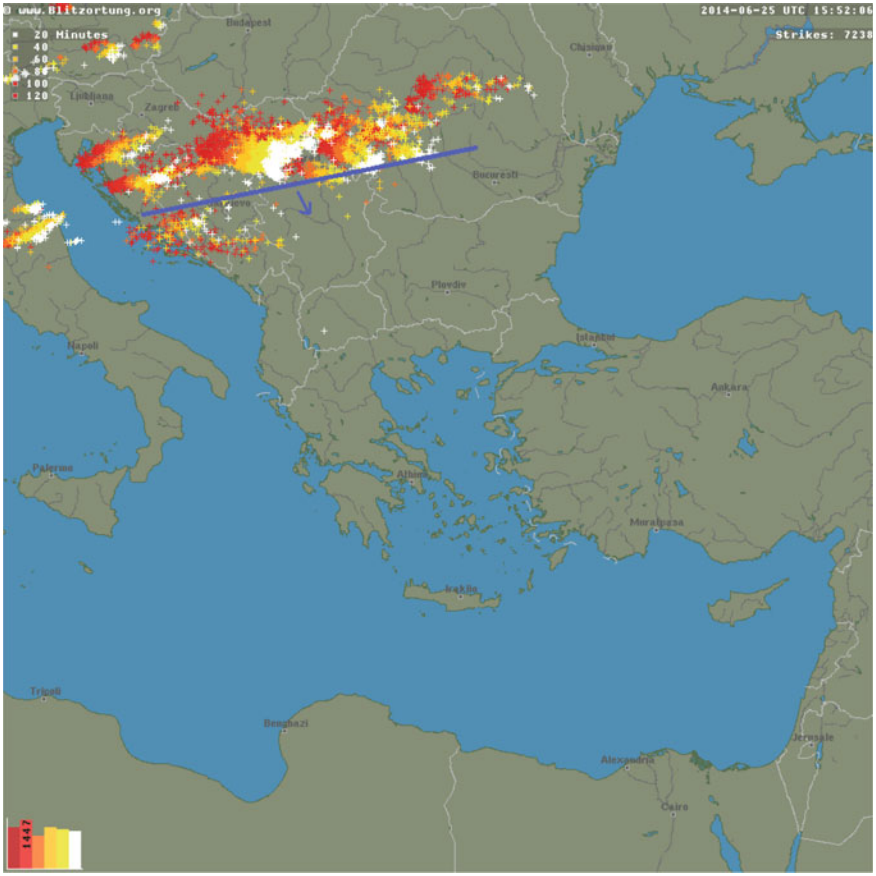

Fig. 11 Software processed image of thunderbolts on June 25, 2014 at 16 o'clock

April, by the end of July, the mean height of the cumulonimbus grow and then begin to decrease, similar to the movement of the isotherm height. It is also evident that the mean altitudes of the clouds in the days with the city and co-habitation are more than the overall mean heights of all treated cumulonimbus. Based on the analyzes conducted for the period 2000–2017. In some months, it is evident that the largest number of days with the town and cohort in June (6.7 days) and in May (6.3 days).

One of the key constraints is the lack of adequate papers and literature dealing with the problems of the hail in Bosnia and Herzegovina. Against hail prevention, it is not impregnated throughout the territory of B&H, therefore, the focus of the research was on the part of the northern territory where there is monitoring and where the actions against the rockets are being carried out. As the trend of increasing the number of days with the appearance of the hail, conditioned by climate change, it is necessary to expand the monitoring and fight against the city throughout the territory of Bosnia and Herzegovina. It is also necessary to strengthen capacities and cooperation with

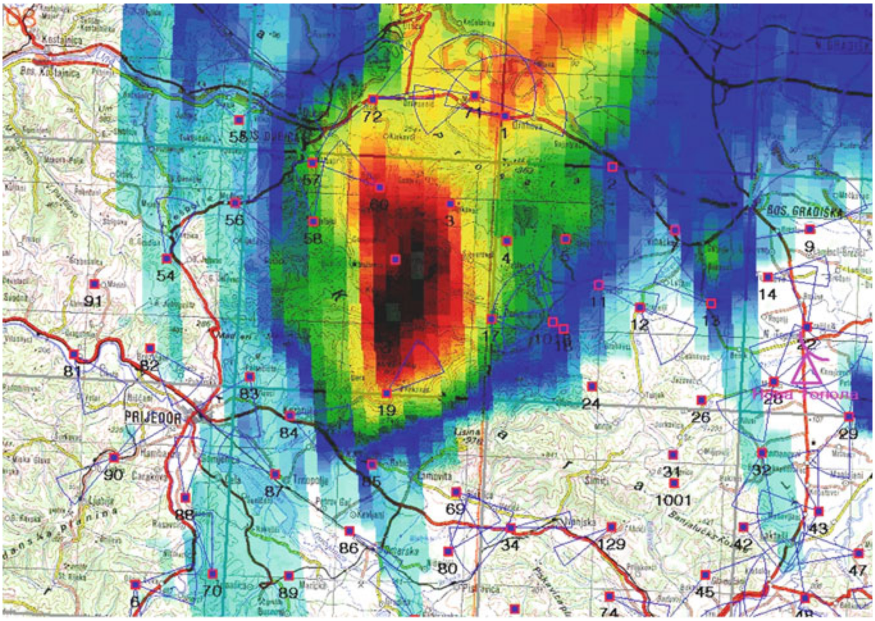

Fig. 12 Software processed radar image, transferred to a geographical background (plane), showing supercellular process on June 25 2014 at the moment of entering the study area near Kozarska Dubica

Fig. 13 Size and shapes of the hail on the cumulonimbus route on June 25, 2014

researchers from the region. This is especially important because more and more cumulative emergence of cumulonimbus involves much larger territory and, as a rule, brings damage to the surrounding countries. These are primarily Serbia and Croatia. It is also necessary to raise public awareness of the problems caused by the city and the way and possibilities of preventing damage.

Fig. 14 The village of Jablanica (Gradiška)—hail damage to an apple tree on June 25, 2014

Fig. 15 The village of Jablanica (Gradiska)—hail damage to an peach tree on June 25, 2014

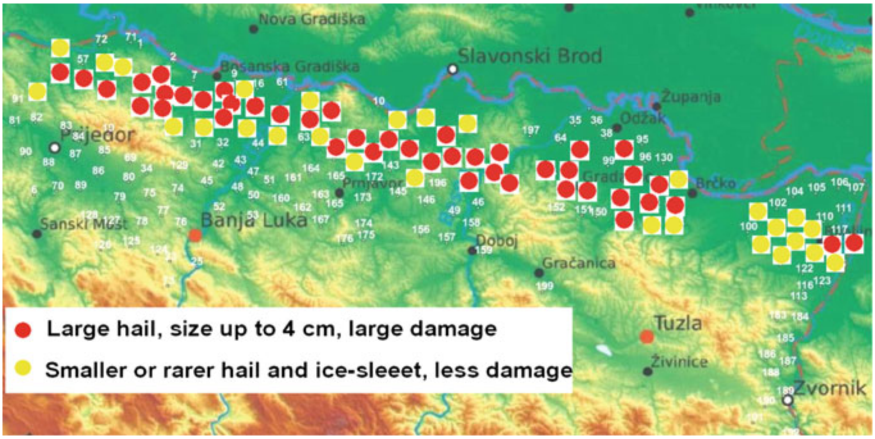

Fig. 16 The route of extreme storm-gradient disaster on June 25, 2014

Fig. 17 South Brčko District—Damage to immovable property caused by the hailstorm on June 25, 2014

References

Burcea S, Cică R, Bojariu R (2016) Hail climatology and trends in Romania: 1961–2014. Mon Weather Rev 144:4289–4299. https://doi.org/10.1175/MWR-D-16-0126.1
Ćurić M, Janc D (2016) Hail climatology in Serbia. Int J Climatol 36:3270–3279. https://doi.org/10.1002/joc.4554
Dejanović T (2009) Istorijski osvrt na borbu protiv grada u Republici Srpskoj, Značenja br. 66, Narodna biblioteka Doboj, Doboj
Dejanović T (2015) Grad kao elementarna nepogoda u sjevernom dijelu Republike Srpske, Magistarski rad, Prirodno-matematički fakultet, Univerzitet u Banjoj Luci
Hartmann DL, Klein Tank AMG, Rusticucci M, Alexander LV, Brönnimann S, Charabi Y, Dentener FJ, Dlugokencky EJ, Easterling DR, Kaplan A, Soden BJ, Thorne PW, Wild M, Zhai PM (2013) Observations: atmosphere and surface. In: 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, UK and New York, USA. https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter02_FINAL.pdf
IPCC (2007) Climate change 2007: the physical science basis. Contribution of Working Group I to the fourth assessment report of the intergovernmental panel on climate change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK and New York, USA, 996 pp
Kahraman A, Tilev-Tanriover Ş, Kadioglu M, Schultz DM, Markowski PM (2016) Severe hail climatology of Turkey. Mon Weather Rev 144:337–346. https://doi.org/10.1175/MWR-D-15-0337.1
Lkhamjav J, Jin HG, Lee H et al (2017) A hail climatology in Mongolia. Asia-Pacific J Atmos Sci 53:501. https://doi.org/10.1007/s13143-017-0052-1
Mohr S, Kunz M (2013) Recent trends and variabilities of convective parameters relevant for hail events in Germany and Europe. In: 6th European conference on severe storms 2011. Palma de Mallorca, Spain, 1 Apr 2013 Atmos Res 123:211–28. https://doi.org/10.1016/j.atmosres.2012.05.016
Potapov E, Burundukov G, Garaba I, Petrov V (2007) Hail modification in the Republic of Moldova. Russ Meteorol Hydrol 32:360–365. https://doi.org/10.3103/S1068373907060027
Puskeiler M, Kunz M, Schmidberger M (2016) Hail statistics for Germany derived from single-polarization radar data. Atmos Res 178–179:459–470. https://doi.org/10.1016/j.atmosres.2016.04.014 ISSN 0169-8095
Sanchez JL et al (2017) Are meteorological conditions favoring hail precipitation change in Southern Europe? Analysis of the period 1948–2015. Atmos Res 198:1. https://doi.org/10.1016/j.atmosres.2017.08.003
Stričević N (1982) Čestine pojave grada u zavisnosti od rastojanja atmosferskih frontova, Glasnik Protivgradne zaštite, Str.29–31, RHMZ Srbije, Beograd Statistički godišnjak SFRJ, Beograd 1988
The Second National Communication (SNC) of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change (UNFCCC) (2013) UNDP Bosnia and Heryegovina. http://www.ba.undp.org/content/bosnia_and_herzegovina/en/home/library/environment_energy/sncbih-2013.html
Trbić G et al (2018) Limits to adaptation on climate change in Bosnia and Herzegovina: insights and experiences. In: Leal Filho W, Nalau J (eds) Limits to climate change adaptation. Climate change management. Springer, Cham. https://doi.org/10.1007/978-3-319-64599-5_14
Trbić G (2010) Ekoklimatska rejonizacija Peripanonskog oboda Republike Srpske, Geografsko društvo RS, Banja Luka
Young KC (1993) Microphysical processes in clouds, Oxford University Press, Oxford, USA, 448 pp. ISBN-13: 9780195075632

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Aggravated Occupational Heat Stress Recognition and Mitigation in Slovenia

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Abstract Global warming is strongly reflected in an increase in the number of hot days and, consequently, heat waves—their occurrence over a wider time frame, their duration, intensity and frequency. Changed characteristics were studied at two locations in Slovenia, confirming the increase. The problem of heat stress, health risks and labor productivity loss experienced by workers is well studied in hot locations, but not enough in Europe. Heat stress relies on both environmental and individual factors and it is important to understand how the general public and workers perceive heat risk, since this information may be helpful in preparing or updating heat stress mitigation strategies. Two studies were conducted in Slovenia in the frame of the Horizon 2020 Heat-Shield project, the first analyzing already experienced heat stress symptoms and health issues, productivity loss and self-initiative measures among workers in various sectors (N = 687), and the second investigating workers' knowledge of heat stress, its impact and preventive measures (N = 117). Workplace temperature in a large majority of cases was considered not suitable, negative heat stress impacts were recognized and already experienced. The results of the two studies show the importance of the problem, which is expected to worsen due to climate change, making mitigation of heat stress an unavoidable issue.

Keywords Heat stress · Climate change · Occupational health · Mitigation Workers

1 Introduction

Summertime episodes with extremely high air temperatures, lasting for several days or longer, are often referred to as "heat waves" (Lau and Nath 2012). They are addressed as climatic events, an anomaly of temperature (Pascal et al. 2013) that is short-term and uncomfortable (Zuo et al. 2015). Defining a heat wave is in general a

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problem that is difficult to resolve, involving a choice of thresholds, minimum duration, and possibly various variables (Robinson 2001). Pascal et al. (2013) concluded that the use of the high percentile of the meteorological indicators' distribution would be a good option for defining thresholds when no study of the temperature-mortality relationship has been done.

According to IPCC (2014), the frequency of extreme meteorological events is projected to increase in the future. In Central and Eastern Europe, projected changes in temperature extremes result from changes in both the mean and the shape of probability distributions (Schär et al. 2004). In the Carpathian Region, heat wave events have shown a general increase in the period 1961–2010, in terms of intensity, duration and severity (Spinoni et al. 2015). Extended heatwaves will become more common with rising global mean temperatures and could occur in any country in Europe (Russo et al. 2015). For example, in Eastern Europe, including the European part of Russia, summer 2010 was exceptionally hot and, additionally, eastern European countries have lower adaptive capacity in general than western or northern European countries (IPCC 2014). Morabito et al. (2017) presented study results supporting a call for heat-related mitigation and adaptation strategies, in order to counteract the effects of heat waves in most EU capitals, with priority given to southeastern cities. In addition to the increase in temperature, the population is aging (Pascal et al. 2013). Although the impacts of climate change and heat on public health, the environment and human activities are quite well documented, this cannot be said of the impact on the working population (Adam-Poupart et al. 2013), especially in Europe. Occupational heat stress can be directly associated with productivity losses (Ioannou et al. 2017; Nybo et al. 2017), so the need to analyze heat waves and their impact on workers is even stronger (UNDP 2016; Nybo et al. 2017). Studies of workers in heat conditions in Europe have only recently started in the frame of the Heat-Shield project (Ioannou et al. 2017; Piil et al. 2017; Pogačar et al. 2017): it is becoming clear that heat is already a problem for European workers in agriculture, industry and other sectors.

Heat impacts on workers' health and productivity can be direct or indirect. In general, exposure to high environmental temperatures causes an increase in body temperature; an increase of body temperature from 38 to 39 °C increases the risk of exhaustion and symptoms of heat stress occur (Adam-Poupart et al. 2013). Heat stroke mainly occurs when the body temperature reaches 40 or 41 °C (LoVecchio et al. 2007). Indirect impacts mean higher risks of injuries due to reduced attention and fatigue. Physical discomfort may cause a change of emotional state, such as inexplicable anger leading to a lower level of work safety (Tawatsupa et al. 2010). Dehydration can cause reduced cognitive, visual and motoric abilities, short-term memory and attention (Adam-Poupart et al. 2013).

The aim of this research was first to examine the occurrence of heat waves in Slovenia leading to aggravated occupational heat stress and, secondly, to analyze the state of heat stress recognition and self-mitigation among workers in Slovenia. It can serve as an example for other European countries with similar climate and working conditions.

2 Methods and Material

2.1 Heat Wave Analysis

A new general definition of heat wave has been in use in Slovenia since 2017 (before there was no common definition), defining three different thresholds of daily average temperature, depending on the climate of the area (classification in Kozjek et al. 2017): for a wet or moderate climate in a hilly region the threshold is 22 °C, for the subcontinental region 24 °C, and for the submediterranean region 25 °C. Thresholds approximately correspond to the 96th percentile for the period 2006–2015 or to the 97th percentile for the period 1986–2015. A heat wave occurs if the threshold is reached on at least three consecutive days. The definition was confirmed in agreement with the Slovenian Environment Agency, University of Ljubljana, National Institute of Public Health and other contributors. An analysis of heat waves was carried out for meteorological stations in Bilje and Celje (in the vicinity of part of two surveys), based on the aforementioned heat wave regulations. Average daily air temperature data were collected from the archive of the Slovenian Environment Agency. Heatmaps were modeled in Python programming language, days with higher temperatures are colored darker on these maps.

2.2 Surveys Among Workers

The first survey was conducted in the summer and autumn of 2016 among 687 workers, investigating their workplace (Fig. 1) heat load, heat stress symptoms and health problems experienced, and preventive measures taken within the company or by themselves. There were 400 workers from industry (factory producing rear automotive lights) near Celje, 230 farmers (not necessarily full time), and 57 tourist guides, both of the latter from all over Slovenia. Men prevailed among farmers (62%), and women in the other two sectors (65% in industry, 52% among tourist guides). One-fifth of all workers were above 50 years old .

The second survey was conducted in the summer of 2017 among 117 workers working in hot conditions inside (industry: 45 workers) or outside (agriculture: 29, construction: 19, tourism: 18, transport: 6; Fig. 2). Workers were asked about their knowledge of heat stress warnings, symptoms, and their own sensitivity. Among them, 30% were older than 50 years. Answers were analyzed using SPSS tools for statistical analysis.

Fig. 1 Workplace in factory near Celje, and a typical working place for a tourist guide in Ljubljana, where part of the first survey was conducted

Fig. 2 Outside workplace in agriculture (Bilje) and construction site (Ljubljana), where part of the second survey was conducted

3 Results and Discussion

3.1 Heat Wave Presentation for Bilje and Celje

The analysis of heat waves in the period 1981–2015 (Fig. 3) shows the distinctive characteristics of both locations: Bilje in southwestern Slovenia in the submediterranean region, and Celje in northeastern Slovenia in the continental region. Although the threshold for a heat wave is set 1 °C higher in Bilje, the prevalence of heat waves in all their characteristics in comparison with Celje is impossible to overlook. However, it is even clearer in Celje that the frequency of heat waves is increasing. Since 1998 there has been at least one heat wave every year except 2009 and 2014; before that, years with heat waves were very rare (1988, 1992, 1993, 1994). It can be seen in both locations that heat waves have started to occur earlier in recent years, from the beginning of June and, especially in Bilje, they occur even in late August (and September—not shown in the Figure). Heat waves are becoming longer and more intense—reaching higher air temperatures.

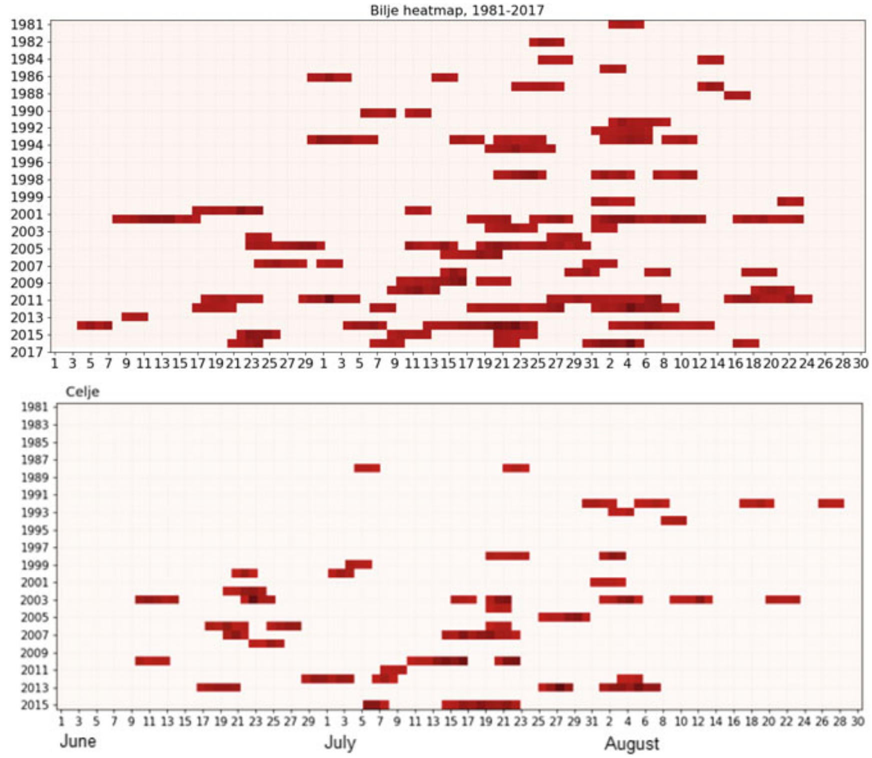

Fig. 3 Heat wave map for Bilje (upper) and Celje (lower) stations from 1 June to 31 August in the 1981–2015 period (days of heat wave are colored, higher temperatures are darker)

These findings are in agreement with those of the Slovenian Environment Agency (ARSO 2017), where analyses of climate change in Slovenia show a statistically significant increase in mean air temperature and the number of hot days. According to Kuglitsch et al. (2010), the intensity, length and number of heat waves in the eastern Mediterranean have increased by a factor of 6–8 since the 1960s.

3.2 Heat Stress Impact in Various Workplaces

The first survey showed that thermal comfort was worst in the factory. Working conditions during heat waves were very hot for 45% employees, and hot for 20%. Working temperatures could be as high as 35 °C. Working outside during heat waves felt very hot for 27% and hot for 36% of agricultural workers. Negative impacts of heat stress in current conditions were already reported, with no significant differences related to the age of workers. The impact on well-being and concentration was most perceived

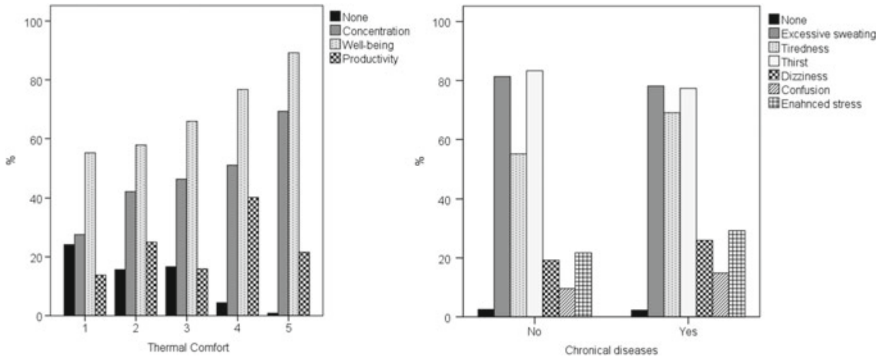

Fig. 4 Left: negative impact of heat stress at workplace in relation to thermal comfort (1—neither warm nor cool, 2—slightly warm, 3—warm, 4—hot, 5—very hot; productivity only assessed by farmers); right: perceived symptoms of heat stress during work in summertime in relation to workers with and without a chronic disease

by industrial workers (more than 75 and 67%, respectively), followed by tourist guides (72 and 44%, respectively), and farmers (68 and 34%, respectively). Negative impact on productivity was only assessed by farmers (experienced by 68%), since workers in industry have to maintain norms and productivity is difficult to define for tourist guides. However, 17% of tourist guides described their working abilities during heat waves to be reduced by more than 30%. Workplace heat causing significant labor loss was confirmed in Europe for grape-pickers in Cyprus (Ioannou et al. 2017). The more uncomfortable the workers were at their workplace, the higher the noticeable impact of heat waves (Fig. 4 left). The connection is quite straightforward, except for the impact on productivity, which was obviously not easy to assess for agricultural workers. Piil et al. (2017) showed that heat per se has little impact on simple motor or cognitive test performance but complex motor performance is impaired, especially when multiple tasks are combined.

Symptoms of heat stress were perceived by the great majority, especially milder symptoms such as thirst (79%), excessive sweating (79%) and tiredness (65%), and in a smaller proportion enhanced stress (27%), dizziness (24%) and confusion (13%). Only 2% of all workers stated that they had not perceived any kind of heat stress symptoms. There were no statistically significant differences between younger and older workers, but most symptoms were more pronounced among women than men. Having a chronic disease appears to make workers more sensitive to tiredness, dizziness, confusion and enhanced stress (Fig. 4 right). Further work at high temperatures without additional measures to mitigate heat stress can lead from basic heat stress symptoms to more serious heat-induced health problems. The most prevalent symptoms already experienced by workers were exhaustion (57%) and headache (53%) and, to a much smaller extent, nausea or vomiting (17%), prickly heat (12%), fainting (7%), muscle cramps (5%) and heat cramps (1%), while only one person had suffered

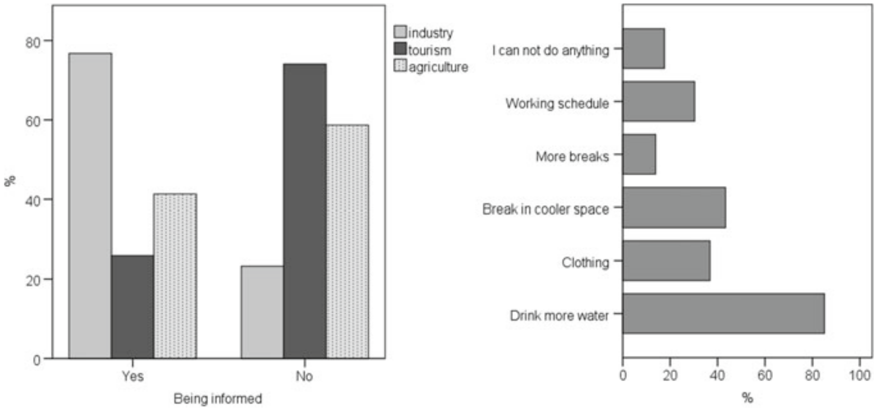

Fig. 5 Left: Answers of workers to the question of whether they had been informed about heat stress impacts; right: how they could reduce exposure to heat stress (option 'more breaks' was not available for industry)

heat stroke. Chronic diseases have the highest impact on heat-induced headache and nausea or vomiting.

Even though problems due to heat stress obviously exist, information on heat stress impacts and possible measures at the workplace are not easy to find. The highest share of workers informed about heat stress was in the factory (77%). Awareness was much lower among farmers (41%) and tourist guides (26%), since they both work as self-employed (Fig. 5 left). On the other hand, despite being poorly informed, workers try their best to protect themselves when they start to feel the first heat stress symptoms that they can recognize on their own. There were no statistically significant differences between men and women, nor younger and older workers about taking precautionary measures. Eighteen percent of workers claim that they cannot do anything to reduce heat stress (Fig. 5 right). Factory workers have the duty to follow regulations in terms of clothing, working schedule and number of breaks. Only small variations are allowed. Workers in agriculture can be most flexible about the working schedule, but there are still some tasks that cannot be rescheduled. The majority of workers try to drink more water (85%). Increased fluid intake was also the most frequently reported protective measure in other observational studies (Cuesta et al. 2017; Van Loenhout and Guha-Sapir 2016).

In the first study, 37% of workers did not feel that heat stress has been getting worse in recent years. The others recognized changes and related them to climate change (42%), their own aging (15%) and/or change of their workplace (11%). In the second study, workers were more convinced; 81% of them said that temperature has been increasing lately and 11% were not sure. A solid majority (89%) of those that said temperature is not increasing described themselves as not at all sensitive to heat (Fig. 6 left). On the other hand, the largest share (45%) of those who have noticed a temperature increase, feel that they are partly sensitive to heat; a similar

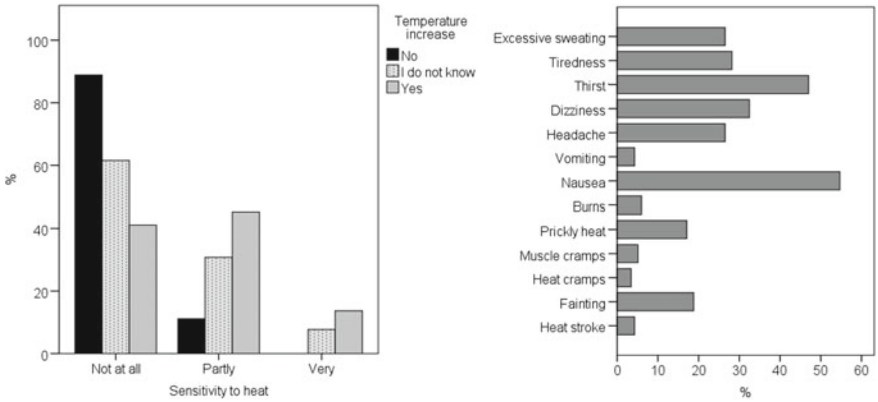

Fig. 6 Left: Opinion on temperature increase in the last years in relation to self-assessed sensitivity to heat; right: knowledge of heat stress symptoms and heat-induced diseases (no options were available, workers needed to list them)

share (41%) not at all and a minority (14%) very sensitive. Only 12% of all survey contributors described themselves as very sensitive to heat.

In the second study, knowledge was analyzed and not personal experiences. Workers had to list heat stress symptoms or heat-induced diseases without being given possible options (Fig. 6 right). The largest proportion were aware of nausea (47 and thirst (40%), followed by dizziness (27%), tiredness (24%), excessive sweating (22%) and headache (22%), fainting (16%) and prickly heat (15%). Only a few recalled vomiting, muscle and heat cramps, or heat stroke.

In the first study, mainly workers in industry were informed about heat stress prevention measures. In contrast, in the second study mainly workers from agriculture and construction sector claimed to have knowledge about them (Fig. 7 left). The highest shares of workers would think of drinking more water during heat stress at the workplace (67%), wear more appropriate clothes (44%), take a break in a cooler space (26%), try to change working schedule (16%) or take more breaks (13%). Similar results about knowledge of protective measures were found for Brussels and Amsterdam (Van Loenhout and Guha-Sapir 2016) and Lisbon and Madrid (Cuesta et al. 2017).

4 Conclusion

Heat waves are becoming more frequent, and their intensity and duration are increasing. Although the changed summer conditions were shown only for two locations in Slovenia, the same can be expected everywhere with similar climatic conditions. Aggravated occupational heat stress is an inevitable consequence of global warming, and Europe is not an exception.

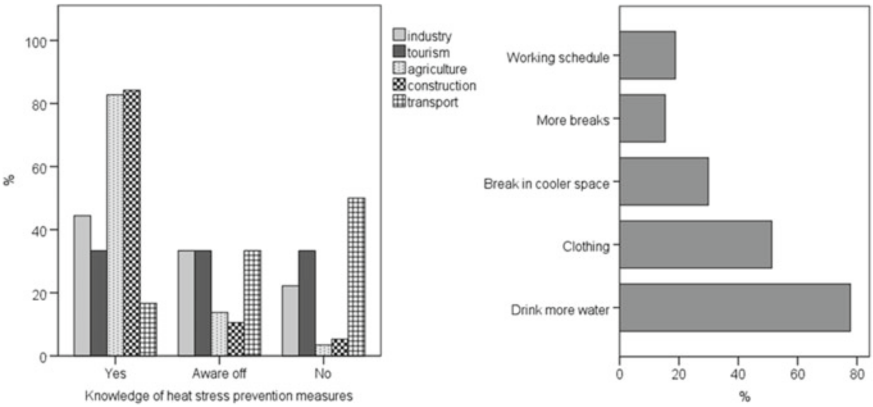

Fig. 7 Left: Knowledge of the existence and content of heat stress prevention guidelines at work; right: knowledge of possible heat stress prevention measures (no options were available, workers needed to list them)

Negative impacts of heat stress have already been reported in current conditions. The impact on well-being and concentration was most perceived by industrial workers. A large proportion perceived symptoms of heat stress and heat-induced illness, especially thirst, excessive sweating, tiredness, exhaustion and headache. Almost one-fifth of workers complained that they cannot do anything to reduce heat stress, others mainly try to drink more water. In the first study, slightly fewer than half of the workers had observed worse thermal conditions recently and related them to climate change, while in the second study almost twice as many. In the second study, in connection with heat workers were mainly aware of nausea, thirst, dizziness, tiredness, excessive sweating and headache. The highest share of workers would consider drinking more water during heat stress at the workplace, followed by wearing more appropriate clothes, and taking a break in a cooler space.

The main limitation of the second study was the small groups of workers in transport, construction and tourism included in the analysis. In the first study there was even an absence of workers in transport and construction. These are certainly very important sectors dealing with occupational heat stress and should be studied in the future. Furthermore, studies should be extended to a broader geographical area.

The first phase of the 5-year Heat-Shield project is finishing, recognizing heat wave conditions in Europe and occupational heat stress impacts, preparing projections and vulnerability maps. It is of great importance additionally to address less knowledgeable or more vulnerable groups when heat-awareness national plans are implemented. In the next phase, the Heat-Shield project will provide a warning system for individual workers, employers, companies and other stakeholders, and develop possible solutions with assessed efficiency for various sectors.

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References

Adam-Poupart A, Labreche F, Smargiassi A, Duguay P, Bosque MA, Gagne C, Zayed J (2013) Climate change and occupational health and safety in a temperate climate: potential impacts and research priorities in Quebec, Canada. Ind Health 51:68–78

ARSO (2017) Podnebna spremenljivost Slovenije (PPS project): Project reports and interactive portal on climate change in Slovenia, Slovenian Environment Agency, Ljubljana, Slovenia. http://meteo.arso.gov.si/met/sl/climate/pss-project/

Cuesta JG, Van Loenhout JAF, Conceição Colaço M, Guha-Sapir D (2017) General population knowledge about extreme heat: a cross-sectional survey in Lisbon and Madrid. Int J Environ Res Public Health 14(122). https://doi.org/10.3390/ijerph14020122

Ioannou LG, Tsoutsoubi L, Samoutis G, Kajfez Bogataj L, Kenny GP, Nybo L, Kjellstrom T, Flouris AD (2017) Time-motion analysis as a novel approach for evaluating the impact of environmental heat exposure on labor loss in agriculture workers. Temperature 4(3):330–340. https://doi.org/10.1080/23328940.2017.1338210

IPCC (2014) Climate change 2014: synthesis report. In: Core Writing Team, Pachauri RK, Meyer LA (eds) Contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 151 p

Kozjek K, Dolinar M, Skok G (2017) Objective climate classification of Slovenia. Int J Climatol 37(1):848–860. https://doi.org/10.1002/joc.5042

Kuglitsch FG, Toreti A, Xoplaki E, Della-Marta PM, Zerefos CS, Türkeş M, Luterbacher J (2010) Heat wave changes in the eastern Mediterranean since 1960. Geophys Res Lett 37(4). https://doi.org/10.1029/2009gl041841

Lau NC, Nath MJ (2012) A model study of heat waves over North America: meteorological aspects and projections for the twenty-first century. J Clim 25:4761–4784. https://doi.org/10.1175/JCLI-D-11-00575.1

LoVecchio F, Pizon AF, Berrett C, Balls A (2007) Outcomes after environmental hyperthermia. Am J Emerg Med 25(4):442–444

Morabito M, Crisci A, Messeri A, Messeri G, Betti G, Orlandini S, Raschi A, Maracchi G (2017) Increasing heatwave hazards in the Southeastern European Union capitals. Atmosphere 8(7):115. https://doi.org/10.3390/atmos8070115

Nybo L, Kjellstrom T, Flouris AD, Kajfež Bogataj L (2017) Global heating: attention is not enough; we need acute and appropriate actions. Temperature 4(3):199–201. https://doi.org/10.1080/23328940.2017.1338930

Pascal M, Wagner V, Le Tertre A, Laaidi K, Honoré C, Bénichou F, Beaudeau P (2013) Definition of temperature thresholds: the example of the French heat wave warning system. Int J Biometeorol 57(1):21–29. https://doi.org/10.1007/s00484-012-0530-1

Piil JF, Lundbye-Jensen J, Trangmar SJ, Nybo L (2017) Performance in complex motor tasks deteriorates in hyperthermic humans. Temperature 4:420–428. https://doi.org/10.1080/23328940.2017.1368877

Pogačar T, Črepinšek Z, Kajfež Bogataj L, Nybo L (2017) Comprehension of climatic and occupational heat stress amongst agricultural advisers and workers in Slovenia. Acta Agriculturae Slovenica 109(3):545–554. https://doi.org/10.14720/aas.2017.109.3.06

Robinson PJ (2001) On the definition of a heat wave. J Appl Meteorol 40:762–775. https://doi.org/10.1175/1520-0450(2001)040%3c0762:OTDOAH%3e2.0.CO;2

Russo S, Sillman J, Fischer EM (2015) Top ten European heatwaves since 1950 and their occurrence in the coming decades. Environ Res Lett 10. https://doi.org/10.1088/1748-9326/10/12/124003

Schär C, Vidale PL, Lüthi D, Frei C, Häberli C, Liniger MA, Appenzeller C (2004) The role of increasing temperature variability in European summer heatwaves. Nature 427(322):332–336. https://doi.org/10.1038/nature02300

Spinoni J, Lakatos M, Szentimrey T, Bihari Z, Szalai S, Vogt J, Antofie T (2015) Heat and cold waves trends in the Carpathian Region from 1961 to 2010. Int J Climatol 35(14):4197–4209. https://doi.org/10.1002/joc.4279

Tawatsupa B, Lim LLY, Kjellstrom T, Seubsman S, Sleigh A, The Tai Cohort Study team (2010) The association between overall health, psychological distress, and occupational heat stress among a large national cohort of 40,913 Thai workers. Glob Health Action 3:10–20

UNDP (2016) Climate change and labour: impacts of heat in the workplace. UNDP, New York, USA, 33 p. http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/tackling-challenges-of-climate-change-and-workplace-heat-for-dev.html

Van Loenhout JAF, Guha-Sapir D (2016) How resilent is the general population to heatwaves? A knowledge survey from the ENHANCE project in Brussels and Amsterdam. BMC Res Notes 9:499. https://doi.org/10.1186/s13104-016-2305-y

Zuo J, Pullen S, Palmer J, Bennetts H, Chileshe N, Ma T (2015) Impacts of heat waves and corresponding measures: a review. J Clean Prod 92:1–12. https://doi.org/10.1016/j.jclepro.2014.12.078

Impacts of Future Climate Change on Runoff in Selected Catchments of Slovakia

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Abstract In this study the authors looked at the impact of climate change on a hydrological regime and catchment runoff in selected catchments of Slovakia. Changed climate conditions, which are characterized in particular by changes in precipitation, air temperature, and potential evapotranspiration in future decades, have been predicted according to the outputs of the KNMI and MPI regional climate change models and the A1B emission scenario. Assuming these scenarios, the hydrological regime characteristics were simulated by a distributed WetSpa rainfall-runoff model parameterized for five selected river basins in a daily step by the year 2100. When compared to the current state, changes in the total runoff and its components, as well as changes in the soil moisture and the actual evapotranspiration, confirm the assumption of an increase in extremes of the runoff regime in the winter period and a decrease during the summer and autumn periods, causing possible droughts. The results of the study indicate a need for re-evaluation of the water demands and the future design of water management structures in Slovakia.

Keywords Climate change · Runoff regime changes · Slovakia

1 Introduction

Environmental changes (including land use changes and climate change) and their impact on water resources are topical issues in recent hydrological studies. The direct or indirect impacts of land use and climate change on a hydrological regime undoubtedly have contributed to problems such as drought and water scarcity, increasingly frequent flash floods, and damage caused by massive deforestation.

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Rainfall-runoff models are often used as a tool for assessing the impacts of climate change and land use changes on the hydrological cycle. While climate change modeling can be used in specific conceptual rainfall-runoff models, models with spatially-distributed parameters are needed to simulate the effect of land use changes on runoff in a river basin.

The climate and the hydrological cycle are strongly coupled with land surface and ecosystem processes, both in the sense that modifications of the water cycle significantly affect land surface properties and the functioning of ecosystems, and because vegetation and land surface changes can significantly affect the entire hydrological cycle and the climate (McFarlane et al. 1993).

Climate change caused by rising concentrations of greenhouse gases in the atmosphere may affect the hydrological cycle and the availability of water to humans, there-by affecting agriculture, forestry and other industries (Misra 2014).

Changes in the hydrological cycle may cause more floods in some areas; on the other hand, droughts can predominate in other areas, with an associated increased pressure on water supplies and irrigation systems (Blauhut et al. 2016; Freire-González et al. 2017). Therefore, it is important to be able to estimate the possible impact of climate change on water resources and develop strategies of sustainability. One of the challenges in predicting the hydrological response affected by climate change is the issue of hydrological non-stationarity (Milly et al. 2008). There are many factors that can affect hydrological stationarity. These include, for example, the response of vegetation to increased CO_2 and changes in land use and precipitation characteristics. It is therefore important to better understand the impact of non-stationarity on hydrological assessments of climate change. The possibilities of estimating or predicting the future development of river basin processes are considerably limited even though there are a number of different complex and accurate hydrological models, as well as databases of climatic, geological and hydrological data and other elements and characteristics.

Distributed hydrological models (models with spatially distributed parameters) take into account the spatial variability of atmospheric processes and the physical-geographic characteristics of river basins that control rainfall-runoff processes (Kulhavý and Kolář 2002). Physically-based and spatially-distributed hydrological models are capable of directly using geospatial information. The intense development of computer programs supports the ability to exploit the rich content of information describing the physical-geographic features of a landscape. The basis for accurate hydrological predictions is also important for access to the relevant data of rainfall and surface characteristics of a basin that transforms precipitation into runoff.

In Central Europe, many different hydrologically—distributed models have been used to simulate runoff processes under changed land use and climate conditions. Good examples of such models include: WetSpa (Valent et al. 2016; Rončák et al. 2016, 2017a, b); SWAT (Arnold et al. 1998); or MIKE SHE (Tegelhoffová 2010). This article builds on previously published papers and uses several older outputs of global and regional models, climate change scenarios, and various conceptual or distributed hydrological models in Slovakia (see, e.g., Hlavčová et al. 2008, 2015; Štefunková et al. 2013; Rončák et al. 2017a, b).

The aim of this study is to evaluate the possible impacts of climate change on the runoff regime in selected catchments, where the simulation of future changes in runoff processes are based on the outputs of the KNMI and MPI regional climate models (RCMs).

2 Study Area

For the modelling of runoff and hydrological characteristics, five pilot river basins were selected: the **Hron**—Banská Bystrica [1], **Turiec**—Martin [2], **Váh**—Liptovský Mikuláš [3], **Topľa**—Hanušovce nad Topľou [4], and **Laborec**—Humenné [5]. Their locations on Slovak territory is in Fig. 1. These basins represent rivers without any anthropogenic influences and have been subject to long-term observations of hydrological and climatological characteristics.

The basic spatial input data, such as the digital elevation model, land use map, and map of the soil types, were processed and provided by Esprit s.r.o. The time series of average daily flows, mean daily precipitation, and average daily air temperature data were provided by the Slovak Hydrometeorological Institute (SHMI) for the period 1981–2010 and were used as inputs for the modelling.

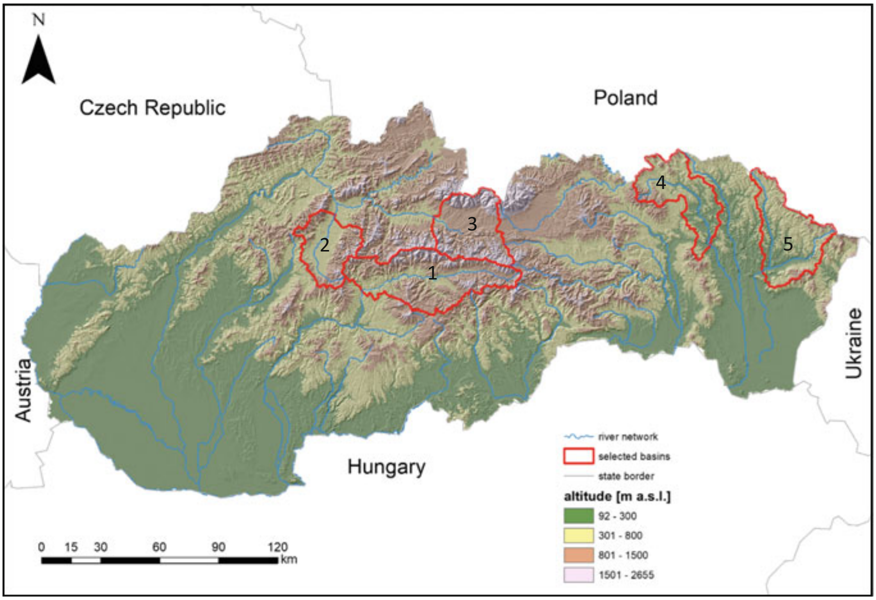

Fig. 1 The location of the selected catchments in Slovakia

3 Climate Change Scenarios

The latest climate change scenarios for the territory of Slovakia were downscaled to the selected precipitation and climate stations on the basis of outputs from climatic atmospheric models at the Department of Astronomy, Earth Physics and Meteorology at the Faculty of Mathematics, Physics and Informatics of Comenius University (Lapin et al. 2012).

In this study, the KNMI and MPI regional models (Lapin et al. 2012) were used to represent a more detailed integration of the dynamic equations of atmospheric and oceanic circulation in a network of grid points at a distance of 25 × 25 km, while the boundary conditions of the solution to the equation are taken from the outputs of the global ECHAM5 model and the SRES A1B (moderate) emission scenario. The KNMI and MPI RCMs have 19 × 10 grid points (190) in Slovakia and its surroundings with a detailed topography and an appropriate expression of all the topographic elements larger than 25 km. The outputs of the scenarios of the daily temperature and precipitation were available for the period 2010–2100.

Table 1 shows a comparison of the long-term mean monthly air temperature in °C between the period 1951–1980 and the climate change scenarios (KNMI and MPI) in the period 2071–2100 for all of Slovakia. We can observe an increase in the average air temperature in the winter months by 3 °C and in the summer season by 4 °C in the future horizon.

Figure 2 shows the differences in the long-term mean monthly air temperature in the Laborec and Váh River basins in the 2071–2100 horizon. The air temperature has a rising trend in both basins. The Laborec River basin is characterized as a lowland catchment; therefore, there is a more extreme rise in the air temperature in comparison with the mountainous Váh River basin.

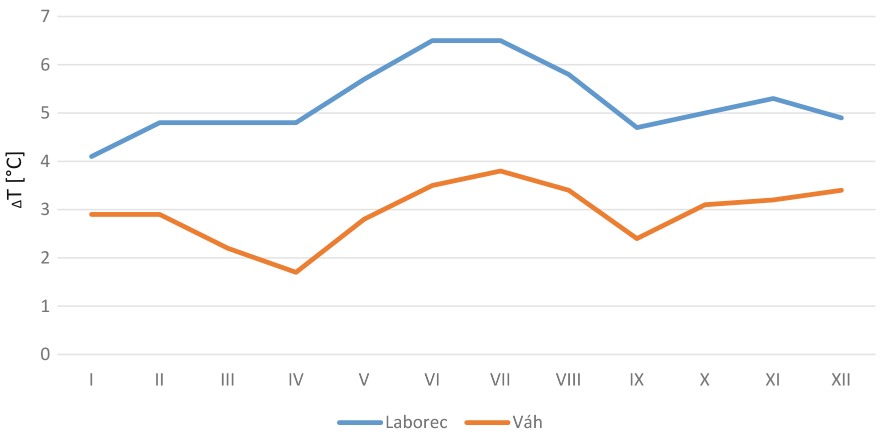

Fig. 2 Differences in the long-term mean monthly values of the air temperature in the Laborec and Váh River basins in the 2071–2100 horizon

Table 1 Long-term mean monthly values of the air temperature during the period 1951–1980 and for the future time horizon of 2071–2100 in Slovakia (Lapin et al. 2012)

Scenario	Horizon	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1951–1980		−3.8	−1.8	2.2	7.7	12.5	16.1	17.5	16.8	13	8	3	−1.5
KNMI	2071–2100	-0.6	1.6	4.9	9.8	15.6	20	21.7	20.6	15.9	11.4	6.4	2.3
MPI		−0.1	2.2	4.6	9.5	15	19.5	20.8	20.8	16.6	11.6	6.7	2.4

Table 2 Long-term mean monthly values of the areal mean monthly precipitation of the reference period (1981–2010) and the changes in their values in [%] for the future time horizons of 30 years from 2010–2100 in the selected river basins

Precipitation [mm]			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Hron	1981–2010		48.2	45.1	53.6	56.1	94	101.3	93.7	82.2	66	59.3	67.3	62.6
	KNMI	2010–2040	−3.1	3.4	0.4	−4.2	−9.2	0.8	−11.4	3.9	34.3	−2.1	4.2	20.4
		2041–2070	5.2	8.8	11.7	16.4	−0.6	−15.7	−9.5	2.9	19.4	8.5	2.5	19.9
		2071–2100	14.1	21.8	24.9	10.3	−19.9	−32.9	−22.1	−3.1	37.7	14.6	6.8	24.1
	MPI	2010–2040	−0.7	8.8	3.4	−3.6	−8.4	19.7	9.5	−3.3	25.1	−3.9	8.5	13.1
		2041–2070	7.8	6.8	16.7	21.8	−10.5	7.8	−3.7	−8.3	16.4	7.8	1.6	17.1
		2071-2100	15.5	18.1	26.2	18.3	−14.7	0.1	−10.1	−3.8	30.3	18.6	13.9	14.8
Laborec	1981–2010		50.9	45.6	46.9	58.2	83.8	98.5	105.3	76.4	80.2	56.5	58.2	64.1
	KNMI	2010–2040	−9.1	4.9	−4.7	−9.6	−14.8	9	−6.5	−0.4	23	4.9	8.1	9.3
		2041–2070	−0.2	5.4	7.9	11.8	−8.4	8.9	−15.3	−9.7	17.2	13	0	17.1
		2071–2100	9.5	14.1	13.7	5.3	−10.6	−25.3	−19.3	0.3	41.6	10	10.3	16.8
	MPI	2010–2040	−2.6	9.7	−5.7	−4.8	−9.8	−3.3	−10.7	2.8	18.8	4.5	4.7	7.5
		2041–2070	5.8	−0.3	11.2	16.1	−11.8	5.3	−7.3	−1.4	9.9	13.6	−6.6	22
		2071–2100	11.4	9.2	18.9	19.1	−11	−18.1	−29.4	−12.3	16.5	13	7.5	11.7
Topľa	1981–2010		35.8	33.8	33.5	51.7	84.1	96.4	96.1	74.9	64.1	44.1	38.1	43
	KNMI	2010–2040	−8.4	−0.7	−4.4	−7.8	−6	6.1	−3.5	−0.5	27.9	1.7	2.4	3.1
		2041–2070	−1	−0.2	4.6	12.4	−6	2.5	−9	−6.1	14.7	10.4	−2	15.3
		2071–2100	7.3	11.5	11.4	7.9	−13.4	−25.6	−19.6	0.9	50.8	10.9	4.6	17.8
	MPI	2010–2040	−1.3	9.2	−2.1	−5.6	−1.2	12.7	−4.9	12.9	6.9	1.4	1.3	1.3
		2041–2070	4.7	0.2	11.4	12.9	−8.6	10.3	−0.3	10.7	16.1	13.1	−2.1	10.2
		2071–2100	13.3	10.2	12.6	10.8	-2.1	-15.9	-19.7	5.6	12.5	9.5	4.9	8.2
Turiec	1981–2010		60.3	51.3	60.2	57.7	92.3	95.5	100.2	87.4	76.2	62.5	69.5	67.4
	KNMI	2010–2040	−3.1	0.2	−4.5	−8.5	−13.4	−4.4	−23.4	−3.9	30.1	−6.3	−1	21.9
		2041–2070	2.1	3.7	9.1	12.9	−4.1	−13.4	−21.4	0.4	14	6.2	−0.5	24.8
		2071–2100	16.5	14.4	23.7	7.8	−20.1	−33.2	−32.9	−5.5	30.1	9.5	5.8	28.6
	MPI	2010–2040	−0.5	7.1	−0.9	−5.6	−14.9	16.3	−0.2	−10.4	22.1	−7.4	1.6	11.1
		2041–2070	2.5	3.7	13.4	19.1	−13.3	9.3	−12	-10.9	13.1	4.3	−7.1	19
		2071–2100	12.7	11.8	22.5	14.1	−17	0.8	−19.5	−10.8	22.6	12.7	4.8	11.6
Váh	1981–2010		47.8	42.7	53.8	54.3	93.5	96	106.2	85.2	69.8	59.3	61.1	55.6
	KNMI	2010–2040	−3.5	0.5	−2.6	−5.5	−12	3	−16.8	5.4	33.4	−3.4	2.8	19.3
		2041–2070	3.9	4.5	8.2	13.6	−5	−12.6	−16.3	2.9	16.6	6.2	0.7	21.9
		2071–2100	13.6	16.6	21.3	8	−22.4	−30.4	−30.8	−3.7	37.3	10.9	3.3	25.7
	MPI	2010–2040	1.2	4.8	−1.7	−2.8	−11.8	17.9	6	−2.9	20	−4.9	5.1	13.2
		2041–2070	8.9	3.3	12.2	20	−14	9.9	−3.6	−5.9	13.4	8.2	−0.6	20
		2071–2100	17.2	13.7	18.8	15.1	−16.3	−2.8	−14.5	−3.9	23	14.1	10.3	17.2

Table 2 presents the long-term mean monthly values of the precipitation for the 1981–2010 reference period in the selected river basins and the changes in their values for three future time horizons till 2100 according to the KNMI and MPI regional climate change scenarios.

According to the individual climatic models as seen in Table 2, a decrease in the mean monthly precipitation in the summer period can be expected. On the other hand, the winter period should be more humid in comparison with the current conditions. The mean monthly air temperature will rise, without any exception, in the individual river basins at about the same rate. The mean monthly air temperatures will increase with the increasing time horizons.

4 The WetSpa Rainfall-Runoff Model

For simulations of runoff and other components of a hydrological balance under changed conditions, the Water and Energy Transfer between Soil, Plants and Atmosphere (WetSpa) distributed rainfall-runoff model was used. The model uses geospatially referenced data as the input for deriving the model's parameters, which include most data types supported by ArcGIS, such as coverage, shape files, grids and ASCII files. An image can be used for a reference within a view, but is not used directly by the model. The three base maps used in the model are digital maps of the topography, land use and soil types, while other digital data are optional, depending upon the data available and the purpose and accuracy requirements of the project (Wang et al. 1996).

The WetSpa model simulates runoff and river flow in a watershed in a daily time step. The availability of spatially—distributed data sets (a digital elevation model, land use, soil and radar-based precipitation data) coupled with GIS technology enables the WetSpa to perform spatially distributed calculations. The hydrological processes considered in the model are precipitation, interception, depression storage, surface runoff, infiltration, evapotranspiration, percolation, interflow, and groundwater drainage. The total water balance for each raster cell is composed of a separate water balance for the vegetated, bare-soil, open water, and impervious parts of each cell, see Fig. 3. The model predicts discharges in any location of the channel network and the spatial distribution of hydrological characteristics.

Digital maps of the topography, land use and soil types are the three base maps used in the model. Daily precipitation totals and the average daily values for the air temperature from spot measurements were used as hydro-meteorological data in the model too. The Thiessen polygon method was used for the interpolation of the rainfall data. The flow data consisted of the average daily flows at the outlet profile.

The use of rainfall-runoff models comes with a few problems which are predominantly linked with the vast simplification of an otherwise complex system of runoff creation, the quality of the input data or the model´s calibration, and the finding of the optimal set of parameters. Therefore, calibration of the parameters is one of the most important parts of hydrological modelling. The calibration of the model requires the identification of a set of parameters which will provide the best possible agreement between the measured and simulated parameters of the hydrological model in accordance with the selected criteria. Various agreement criteria were used during the calibration of the models for expressing any differences between the observed and

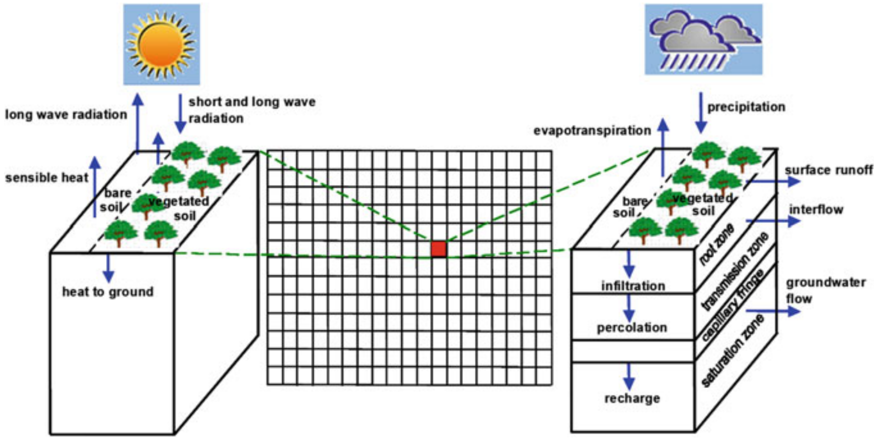

Fig. 3 WetSpa model structure

modelled data. The calibration period was from 1981–1995. Twelve parameters for which a range of admissible values were set were optimized. The Nash—Sutcliffe coefficient was chosen as the dominant criterion in this work.

5 Impacts of Climate Change on a Runoff Regime

Using the parameters of the calibrated WetSpa model and the outputs from the KNMI and MPI climate scenarios, the simulation of flows in the selected basins outlets for the future time periods until the year 2100 was made. The 30-year period from 1981 to 2010 was chosen as the reference period.

The future changes in runoff due to climate change were evaluated by comparing the simulated average daily flows and their statistical characteristics for the current state and the modelled scenarios; they are presented in Table 3.

From the results of the scenarios of the long-term mean monthly flows presented in the future horizons and comparing them to the reference period 1981–2010, we can state that change in the monthly discharge regime in all the catchments analysed could be expected. Also, the evidence of an increase in the long-term runoff can be seen; it has a linear relationship with the increase in mean precipitation in the future in these catchments. The Hron River basin will manifest an increase in average monthly discharges, especially during the autumn and winter months. This will be valid for both scenarios and all the horizons (except for the horizon 2025 in the MPI climate scenario). According to the KNMI scenario, the runoff may achieve a 100% increase in January and February in the last horizon. This could be due to higher temperatures and earlier snowmelt in this region. But we can see that due to climate change, the runoff will react in the opposite way in the summer period. According

Table 3 Simulated long-term mean monthly runoff in [mm] using the parameters from the 1981–1995 calibration period and their changes in [%] for the three future time horizons of 30 years from 2010–2100 in the selected river basins

River basins	Scenario	Horizon	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Q annual [mm]
Hron	1981–2010 [mm]		26.7	26.3	54.0	71.7	50.2	38.9	29.3	24.0	21.5	25.3	31.6	29.6	429
	KNMI [%]	2010–2040	27	56	2	−11	−7	−19	−2	0	42	39	11	26	462
		2041–2070	77	90	20	0	3	−12	−26	−7	16	41	4	52	501
		2071–2100	104	112	36	1	−23	−38	−40	−40	2	32	28	86	501
	MPI [%]	2010–2040	−22	−5	−2	27	31	27	43	19	53	42	12	−4	508
		2041–2070	67	95	14	1	−5	−5	−14	−26	−10	14	4	38	479
		2071–2100	65	81	24	28	5	−8	−14	−30	1	69	39	62	537
Laborec	1981–2010 [mm]		30.0	34.9	57.0	50.2	31.6	22.6	21.7	13.7	16.8	19.5	26.3	30.7	355
	KNMI [%]	2010–2040	14	24	−15	−27	−26	−13	13	12	60	48	15	17	367
		2041–2070	42	42	−11	−13	−9	30	−17	−14	36	39	−13	28	386
		2071–2100	63	49	−2	−13	−19	−24	−24	−27	36	28	15	52	394
	MPI [%]	2010–2040	−10	11	−10	9	−7	−18	−21	14	41	49	7	−3	362
		2041–2070	30	46	−4	3	0	−1	−22	−8	14	50	−16	11	384
		2071–2100	45	33	−3	7	−1	−32	−45	−41	−29	13	0	22	363
Topľa	1981–2010 [mm]		16.0	21.1	38.8	33.6	25.0	21.0	16.6	12.3	11.3	10.5	12.0	14.4	232
	KNMI [%]	2010-2040	8	16	−19	−26	−20	−13	35	21	104	79	20	13	245
		2041-2070	41	46	−18	0	−5	1	−6	−9	29	82	9	23	255
		2071–2100	102	69	4	1	−18	−33	−19	−31	68	93	41	82	281
	MPI [%]	2010–2040	−22	17	−6	19	−7	4	12	35	36	48	14	−11	251
		2041–2070	32	59	−6	19	9	6	−13	9	64	85	21	28	279
		2071–2100	54	51	4	11	7	−32	−38	−15	−8	41	10	31	253
Turiec	1981–2010 [mm]		29.4	31.0	62.2	77.3	49.9	34.9	27.7	23.1	26.4	27.2	30.3	28.5	448
	KNMI [%]	2010–2040	40	66	1	−34	−32	−37	−27	−36	−4	8	−4	33	419
		2041–2070	80	84	4	−24	−19	−26	−40	−30	−23	8	−9	51	452
		2071–2100	105	98	18	−18	−33	−44	−56	−59	−36	−5	7	78	458
	MPI [%]	2010–2040	−11	34	−1	−8	−12	−9	3	−18	6	12	−1	2	441
		2041–2070	44	75	2	−11	−12	−9	−23	−37	−27	−1	−11	24	449
		2071–2100	75	71	8	−12	−21	−25	−32	−46	−35	19	11	52	462
Váh	1981–2010 [mm]		16.3	14.7	32.8	76.4	84.1	53.6	40.6	32.8	29.7	30.3	28.7	20.7	461
	KNMI [%]	2010–2040	43	69	28	−13	−17	−16	−10	−7	36	31	5	24	474
		2041–2070	165	241	76	−28	−54	−50	−56	−38	−20	8	2	96	435
		2071–2100	155	195	84	−2	−36	−47	−48	−50	−7	17	22	101	479
	MPI [%]	2010–2040	−7	11	2	−8	8	15	21	−3	26	15	1	−4	489
		2041–2070	49	113	31	3	3	2	−6	−22	-4	15	4	30	502
		2071–2100	97	147	56	4	−10	−22	−30	−36	−15	34	30	69	504

to the KNMI scenario, the monthly flow will gradually decrease by 2% up to 40% in the months of May to August. A similar situation may be expected under the MPI climate scenario; the only difference can be seen in the horizon of 2025, where there would be an increase in the runoff compared to the reference period. In the autumn term an increase in runoff in both scenarios may be expected when compared with the values of the runoff in the reference period with the current climate conditions.

The eastern part of Slovakia is represented by the Laborec—Humenné and Topľa —Hanušovce river basins. A similar feature for both basins is a decrease in runoff from March to August. The maximum increases in monthly runoff are in the winter months of December and January in the Laborec River basin; i.e., according to the KNMI scenario, up to 63%, and according to the MPI, up to 45%. For the vegetation period a decrease in discharges can be expected for both basins, i.e., in the Laborec River basin to −45%. In the Topla River basin similar changes in future runoff can be observed, i.e., in the winter period up to a 100% increase according to the KNMI scenario, and in the summer months, e.g., August, up to a 38% decrease according to the MPI scenario in comparison to the reference period.

We can see the decreasing runoff in the Turiec River basin starting from the spring (April) to the late summer (August) from i.e., −45 to −60% for the KNMI. The MPI scenario also presents a decrease but a little bit lower, i.e. (−18 to −46%), which is the highest decrease for the 2071–2100 scenario. Similar to the other basins, an increase in runoff from December to March can be seen; the highest is in January from 40 to 105% in comparison to the reference period.

The northern part of central Slovakia is represented by the Váh River basin (Table 3) with its outlet at the Liptovský Mikuláš stream gauging station. For this river basin, the maximum increases in the long-term mean monthly runoff may mainly occur in February (according to the KNMI scenario for the 2071–2100 horizon; the increase will be up to 200%). A decline in the long-term average monthly runoff may be expected in the months of April to September.

The scenarios considered suggest that practically all the simulated basins could be at risk from summer or autumn droughts. Based on the simulated catchments in this study, it is likely that this effect will also apply to the whole territory of Slovakia. On the other hand, it is possible that the runoff will increase in the winter. A lack of water stored as snowpack in the winter could affect the availability of water for the rest of the year. In the summer months rising demands for water for irrigation, household and industrial use can be observed.

Changing climatic conditions may also present themselves as a persistent reduction in the potential of surface and water resources, which should also be taken into account in the planning and management of water resources in the future.

From the results presented, we can conclude for the whole territory of Slovakia that both the KNMI and MPI scenarios gave similar seasonality change prognoses. They predict a general increase in precipitation amounts, with the highest precipitation amounts from July to September and less precipitation from May to July. The air temperature should increase, mainly during the winter period, and this could result in less snow accumulation and increased winter snow-melt runoff. While the onset or dry periods should be more frequent, with low precipitation, low runoff and less water storage, the most pronounced seasonality change is expected to be evapotranspiration.

Climate models indicate a change in the distribution of atmospheric precipitation on earth and a change in the frequency and intensity of extreme weather events. According to the climate change models described in the Seventh National Report on Climate Change, the total rainfall in Slovakia will be about 10% lower than now; the utilizable water resources will decrease by 30–50% over the horizon of 2075–2100 in Slovakia. It is assumed that there will be a much more uneven distribution of precipitation totals over the year and in the individual regions of Slovakia. This will also be in line with the evolution of the runoff regime in Slovakia.

Dry periods could be interrupted by heavy rainfall or strong storms with intense precipitation, while the number of days with storms compared to the current amount (15–30 in the summer) should not change, but very strong storms are likely to be up to 50% more.

There is a visible moderate linear increase in long-term annual precipitation in Slovakia. The runoff coefficient is calculated as the ratio between runoff and precipitation depths, and this highlights a decreasing trend. While the long-term runoff coefficient value approximates the 32.3% value established for 1961–2000, this decreased to 29.8% for 1981–2015 and 27.9% between 2001 and 2015. The decreasing runoff depth coefficient value is an explicit consequence of greater losses in the hydrological balance caused by increased evapotranspiration from rising air temperatures (Fendeková et al. 2018).

6 Adaptation Measures

Adaptation measures in the water sector in Slovakia could be divided into two parts (7th NC SK 2017). The first is the elimination consequences of droughts, e.g., a decrease in the flow rates and water yields, and the second is to minimize the impact of floods, especially flash floods in mountainous areas. It is necessary to prepare and implement proper adaptation measures to eliminate the adverse impacts of climate change. A lot of attention is paid to water resources and their protection and efficient use in all sectors. Water is becoming a critical strategic resource in our country. This resource has to be protected and its effective and efficient use managed to ensure its sustainable use and sustainable development in general. Adaptation to climate change in the area of water management should therefore be focused on the implementation of measures for better management of runoff in individual catchments.

To complete the system of water reservoirs for the purpose of water supply and public drinking, flood protection and water for agriculture and industry, should be carried out: the following main strategies (7th NC SK 2017)

- Continuing with the flood protection system of selected river basins in high flood risk areas, such as levees, polders, etc.

- Revitalization of structures and the gradual implementation of hydromelioration measures in forestry and agriculture to increase flood protection, especially in headwaters.

The following additional measures are suggested on the national level for adaptations to climate change in accordance with the Water Plan of the Slovak Republic:

- Re-evaluate the safety of water structures according to the actual estimations of design maximum discharges
- Review future water needs in all sectors.
- Assess water abstractions for the water supply, electrical generation, and the augmentation of minimum flows.
- Develop a methodology for drought assessments.
- Re-evaluate droughts and their impact on the ecological status of water bodies.
- Support and increase research on the impacts of climate change.

7 Conclusion

The aim of this study was to detect the impact of climate change on flood regimes in selected catchments of Slovakia. An evaluation of the scenarios of the long-term mean discharges and comparing them with the reference period of 1981–2010 shows that changes in the long-term mean monthly flows can be expected in the future. These changes may be reflected differently, depending on the land use and climate scenarios.

The KNMI and MPI climate change scenarios represent less extreme changes (the A1B emission scenario). The scenarios considered suggest that practically all the basins analysed could be at risk from summer or early autumn droughts. Prolonged droughts can cause significant water shortages. These dry periods may be interrupted by short episodes of extreme rainfall or severe storm activity with rainfall inducing the formation of flash floods. According to current developments, it is likely that climate change can have a significant negative impact on local water resources with low water yields, especially in the sub-mountainous regions of the Slovak Republic. On the other hand, it is possible that the long-term mean monthly runoff will increase in the winter. This could be due to higher temperatures and earlier snowmelt in these regions. The lack of water stored as snowpack in the winter could affect the availability of water for the rest of the year. It could also cause earlier snowmelt floods. Based on the results for the five basins from the north, central and eastern parts of Slovakia, it is likely that this effect will apply to the whole territory of Slovakia.

The results of the simulation are highly dependent on the availability of the input data, the parameterization of the land uses, the different types of vegetation in the model, and the schematization of the simulated processes; therefore, they need to be interpreted with a sufficient degree of caution and confronted with other results from the literature and experimental measurements. The outputs of the study could be used in an adaptation strategy for integrated river basin management and especially in the organization of the river basin management process and the assessment of the impacts of changes the use of river basin on runoff and the size of erosion-accumulation processes.

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References

Arnold JG, Srinivasan R, Muttiah RS, Williams JR (1998) Large area hydrologic modeling and assessment part I: model development. J Am Water Resour Assoc 34(1):73–89
Blauhut V, Stahl K, Stagge JH, Tallaksen LM, De Stefano L, Vogt J (2016) Estimating drought risk across Europe from reported drought impacts, drought indices, and vulnerability factors. Hydrol Earth Syst Sci 20:2770–2800
Fendeková M, Poórová J, Slivová V (eds) (2018) Drought and prognosis of its development in Slovakia. Monograph, Bratislava, pp 300. ISBN 978-80-223-4510-1
Freire-González J, Decker C, Hall JW (2017) The economic impacts of droughts: a framework for analysis. Ecol Econ Manag 132:196–204
Hlavčová K, Szolgay J, Kohnová S, Bálint G (2008) Hydrological scenarios of future seasonal runoff distribution in Central Slovakia. Earth Environ Sci 4(012022):9
Hlavčová K, Lapin M, Valent P, Szolgay J, Kohnová S, Rončák P (2015) Estimation of the impact of climate change-induced extreme precipitation events on floods. Contrib Geophys Geodesy 45(3):173–192. ISSN 1335-2806. https://doi.org/10.1515/congeo-2015-0019
Kulhavý Z, Kovář P (2002) Use of hydrological models for water balance in small watersheds (Využití modelů hydrologické bilance pro malá povodí). VÚMOP, Prague, pp 123
Lapin M, Bašták I, Gera M, Hrvoľ J, Kremler M, Melo M (2012) New climate change scenarios for Slovakia based on global and regional general circulation models. Acta Meteorol Univ Comenianae 37:25–73
McFarlane DJ, George RJ, Farrington P (1993) Changes in the hydrologic cycle. Reintegrating fragmented landscapes. Springer, New York, NY, pp 146–186
Milly PCD, Betancourt J, Falkenmark M, Hirsch RM, Kundzewicz ZW, Lettenmaier DP, Stouffer RJ (2008) Stationarity is dead: whither water management? Science 319(5863):573–574
Misra AK (2014) Climate change and challenges of water and food security. Int J Sustain Built Environ 3(1):153–165
Rončák P, Hlavčová K, Látková T (2016) Estimation of the effect of changes in forest associations on runoff processes in basins: case study in the Hron and Topla river basins. Slovak J Civil Eng 24(3):1–7. ISSN 1210-3896. https://doi.org/10.1515/sjce-2016-0011
Rončák P, Lisovszki E, Szolgay J, Hlavčová K, Kohnová S, Csoma R, Poórová J (2017a) The potential for land use change to reduce flood risk in mid-sized catchments in the Myjava region of Slovakia. Contrib Geophys Geodesy 47(2):95–112
Rončák P, Hlavčová K, Kohnová S, Szolgay J (2017b) Changes in design discharges in selected catchments in Slovakia in future decades (zmena návrhových prietokov vo vybraných povodiach na Slovensku v budúcich desaťročiach). Acta Hydrol Slovaca 18(2):174–182
Štefunková Z, Hlavčová K, Lapin M (2013) Runoff change scenarios based on regional climate change projections in mountainous basins in Slovakia. Contrib Geophys Geodesy 43(4):327–350. ISSN 1335-2806
Tegelhoffová M (2010) Analysis of the development of a hydrological balance for future decades in the Senianska depression in the Eastern Slovak lowland. Slovak J Civil Eng 18(4):30–40

The Seventh National Communication of the Slovak Republic on Climate Change (2017) Ministry of Environment of SK. http://ghg-inventory.shmu.sk/documents.php
Valent P, Rončák P, Maliariková M, Behan Š (2016) Utilization of historical maps in the land use change impacts studies: a case study from Myjava River basin. Slovak J Civil Eng 24(4):15–26
Wang Z, Batelaan O, De Smedt F (1996) A distributed model for water and energy transfer between soil, plants and atmosphere (WetSpa). Phys Chem Earth 21(3):189–193

Adaptation Strategies to Reduce the Impact of Climate Change on Yield Loss in Northern Carpathians, Slovakia

Matej Žilinský, Jozef Takáč and Bernard Šiška

Abstract In the Northern Carpathians region (Slovakia), a significant increase of mean annual temperatures was registered in the last 40 years, reflecting the significant impacts of climate change. In this paper, levels of CO_2 in the atmosphere and soil water scarcity have been studied in order to forecast how their changes could affect agricultural production in the future. For this purpose, meteorological data were generated according to the general circulation model ARPEGE, while water balance measures in the Northern Carpathians (Slovakia) were evaluated by using agroecological model DAISY. Two emission scenarios were evaluated: RCP 8.5 (equiv. SRES A2) and RCP 6.0 (equiv. SRES B2). According to both, consequent increase of potential evapotranspiration and crop water requirements will gradually increase by 2071–2100. In addition, the availability of soil water will decline and the number of days with available water capacity below 50% AWC will increase during the growing season of field crops and evoke an increase of irrigation requirements. The results of this study predicted that the irrigation season will start earlier and will persist for a longer period in the future. Therefore, irrigation can be, in case of insufficient water sources, limiting factor for sustainable field crop production.

Keywords Climate change · Water use efficiency · Field crops · Adaptations
Northern carpathians

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1 Introduction

Changes in climate are one of the main threats to global and domestic agriculture, biodiversity and forestry. In the Northern Carpathians region (Slovakia), a significant increase of mean annual temperatures (by 2 °C) was registered during the period of 1881–2016. Overall precipitation has increased by 0.8% on the national level, but, on the other side, a significant decrease of 10% has been registered in the south of Slovakia where the best quality fertile soils are located. Thus, the increase in air temperature and decrease in precipitation have caused a significant reduction in relative air humidity and elevation of potential evapotranspiration by 5% (ME SR 2017). Climate change affects agricultural production in various ways. Firstly, it has been predicted that the environmental conditions in the near future will be completely different than nowadays. In the southwest of Slovakia, according to the IPCC's A2 greenhouse gases SRES scenario, the mean air temperatures is projected to be 3.8 °C higher in the period between 2071–2100 when compared with average air temperatures in the period between 1961–1990. According to the IPCC's B2 scenario, the mean air temperatures is projected to be by 3.1 °C higher for the same reference period in the Carpathian region (Melo 2004). This increase in average temperature is the highest during the summer period (4.8 °C) and lowest in spring (3.1–2.5 °C) in the same period. According to the scenarios, the changes in precipitations are not significant during seasons in the region. However, the trend is decreasing in summer, and increasing in winter (Melo et al. 2009). In Slovakia, annual precipitation is expected to decrease by 4.0–8.2% in summer and to increase by +4.5–9.0% in winter (Bartholy et al. 2009).

The increase of air temperature and the shortage of precipitations create preconditions for drought to occur, especially in the Lowlands of Slovakia (Šiška and Takáč 2008). These air temperature conditions will cause growing season to start earlier and finish later, and this change might cause the crop to be damaged by frost at the beginning of vegetation period. On the other hand, increasing concentrations of greenhouse gases might have various effects on crops and their yields and biomass production. If the concentrations of CO_2 increase twofold to 660 ppm, the biomass production of C3 plants (for example: wheat, barley) will be 41% higher, in case of C4 plants, such as corn, the production will be higher by 22%. Nevertheless, this is limited by air temperature and sufficient levels of soil water, therefore plants might not be capable of benefiting from a higher concentration of CO_2 in natural conditions (Poorter 1993). Combining predictions for CO_2 concentration in the atmosphere and environmental conditions, cereal yields are expected to slightly increase, while maize is expected to decrease. By 2100, winter wheat yields will increase by 45% according to SRES A2 scenario and by 11% according to SRES B2 scenario. In addition, spring barley grain yields will increase by 31% (A2) and decrease by 4% (B2). Maize response on CO_2 concentration is not significant when compared to cereals, however negative climatic conditions during its growing season will reduce the yield in future by 36% (A2) and by 21% (B2) by 2100 (Šiška and Takáč 2008). If irrigation and fertilizing are applied, spring barley yields could increase by 53% (A2) and 42% (B2). In the same way, yields of winter wheat in Slovakia could increase by 88% (A2) and 35% (B2) by 2080 (Takáč and Šiška 2009).

During summer season, the mean soil water content will decrease below 50% of available water capacity (AWC) up to the time horizon of the year 2075 in the southern part of Danubian Lowland and Zahorie Lowland, and below 60% in the East Slovakian and Northern parts of Danubian Lowlands (Takáč 2001). Need for irrigation water will significantly increase in response to climate change. Thus, detailed agricultural planning should be part of adaptation strategies in the sense of water efficiency (Riediger et al. 2016).

The goal of the paper is to present results of crop modelling with the aim to set optimum efficiency of water use and irrigation needs which could reduce yield loss in Danubian Lowland as part of Northern Carpathians (Slovakia) by 2100 under RCP scenario 6.0 and 8.5.

2 Methodology

Climate change impacts on the soil water regime for different field crops in the Danubian Lowland of Slovakia were evaluated by using the agroecological model DAISY. Daisy model was used to predict the impact of various climate projections on the water requirements of crops. Meteorological data generated according to the general circulation Action de Recherche Petite Echelle Grande Echelle (ARPEGE)—a research project on small and large scales, were applied according to the emission scenarios RCP 8.5 and 6.0. Irrigation requirements and the consequent increase of CO_2 concentration in the atmosphere were considered for evaluations.

DAISY is an agroecological, one-dimensional model that simulates water balance/losses, crop growth, nitrogen and soil organic matter balance. Crop development and yield is possible to simulate dependently on crop rotation and various management strategy. DAISY simulates plant growth and development, including the accumulation of dry matter and nitrogen content in different plant parts. The main plant-growth processes considered in DAISY are photosynthesis, respiration, partitioning of assimilates, stress factors and leaf and root development. In addition, DAISY facilitates creation of complex management scenarios (Hansen et al. 1990; Hansen 2000), and it showed the best performance in soil water estimations, when compared with other models such as APES-ACE, CROPSYST, DSSAT-CERES, FASSET, HERMES, MONICA, STICS and WOFOST (Rötter et al. 2012).

Global radiation, mean air temperatures and precipitation were estimated by general circulation model ARPEGE. Meteorological data for the reference period for Northern Carpathians—Danubian Lowland, was obtained by the climatic station Hurbanovo (47°52′ N, 18°12′ E). Crop yields were simulated for the reference period form 1966–1990 in variants for emission scenarios RCP 8.5 and RCP 6.0. The SRES scenarios are comparable with new RCP scenarios in the following way: A2 scenario represents RCP 8.5, B2 scenario equivalent to 6.0 RCP (van Vuuren and Carter 2013).

Crop parameters were set up according to the experimental field data obtained from the Research Institute of Irrigation located in Most (near Bratislava) during the period 1981–1987. Calibration and validation of the model was based on the results from (a) experimental plots in Lehnice farm; (b) data obtained from the Stationary Field Experiment of the Research Institute of Irrigation for the period from 1990–1994 (Takáč and Koščo 1995) and (c) the experimental data from field experiments realized by co-operating departments at the Slovak University of Agriculture in Nitra—Dolna Malanta (Takáč and Šiška 2011). Rainfed and irrigated variants were evaluated.

The DAISY model calculates photosynthesis rate using a light saturation response curve. In addition, the effect of CO_2 concentration was included in the DAISY parameterization according to the light-saturated photosynthesis rate Fm [g CO_2 m^{-2} h^{-1}] and initial light use efficiency ϵ [(g CO_2 m^{-2} h^{-1})/(W m^{-2})]. The efficiency of photosynthetically active radiation for winter wheat, spring barley, maize and sugar beet was recalculated in dependence upon CO_2 concentration in the atmosphere (Cure and Ackock 1986) for emission scenarios RCP 8.5 (equiv. SRES A2) and RCP 6.0 (equiv. SRES B2) (IPCC 2013). The gradual increase of CO_2 concentration was considered. Evapotranspiration (ET_0) is calculated by the DAISY model according to Penman-Monteith equation which is based on the ARPEGE outputs and real measurements (1966–1990). Crop-specific evapotranspiration (ETc) is calculated by the model with used to K_c coefficient multiplying by ET_0 (Hansen et al. 1990). Crop coefficient (K_c) represents the effects of characteristics that distinguish field crops from grass (Allen et al. 1998).

Based on the statistical analyses of soil hydrophysical properties (Nováková 1996) medium textured chernozem soil profile with 3.5% humus content in topsoil was considered as representative for the Danubian Lowland. The horizons of soil profile were defined according to their texture, bulk density, parameters of retention curves, hydraulic conductivity, humus content and C/N ratio. Rooting depth was not limited by the soil.

Crop rotations of six crops (spring barley, winter wheat, maize, sugar beet, alfalfa, potato) were set up. The water regime was simulated in 2 variants: rainfed and water limited irrigation. Irrigation was applied automatically after decreasing of soil water content below 50% of AWC for each evaluated crop. Irrigation interval up to 10 days and the amount of 30 mm was set up in simulation. This assumption should cover sufficient irrigation need both from the point of view AWC limit over 50% and limited irrigation water available expected in the condition of climate change (Takáč and Šiška 2009).

3 Results and Discussion

Water balance of soil profile is significantly influenced by evapotranspiration. The reference crop evapotranspiration (ET_0) in the reference period of 1966–1990 was 819 mm. The shortage of available water, especially during growing season, caused

Table 1 Mean annual totals of reference crop evapotranspiration (ET_0) and actual evapotranspiration ET in the period 1966–1990, and in future periods according to the different climate change scenarios

Scenario	Period	ET_0	ET
	1966–1990	819	481
RCP 8.5	2011–2040	852	542
	2041–2070	881	514
	2071–2100	918	502
RCP 6.0	2011–2040	851	521
	2041–2070	860	530
	2071–2100	879	546

that actual evapotranspiration (ET) was only 481 mm. According to RCP 6.0, ET_0 would increase by about 7% (879 mm) and by 12% (918 mm) according to RCP 8.5. Annual ET will increase consequently towards more distanced time horizons according to RCP 6.0 only (Table 1). According to RCP 8.5, the increase of ET is expected only in the near future because the shortage of water in the soil profile in the far future will reduce evapotranspiration (Table 1).

Considering only the period from sowing to harvest, a more significant increase of ETc can be expected for the summer crops. Relatively higher increase in ETc values is supposed for summer time crops (e.g. maize) as compared to the wintering crops or crops of the spring growing season. According to RCP 6.0 crop specific evapotranspiration will increase by 5.2% for maize, by 3.7% for winter wheat and by 2.8% for spring barley in 2071–2100 in comparison with reference period 1966–1990. According to RCP 8.5 ETc will increase by 11% for maize, by 7.5% for winter wheat and by 7.2% for spring barley in the same two periods (Table 2).

In general, agroecological crop models are characterized by a high level of uncertainty which can lead to different results in comparison to other models. For instance, the model DAISY in ETc spring barley value had the deviation (D_i) in scale by 2–29% (Pohanková et al. 2018) which means that the model slightly underestimates the ETc

Table 2 Crop-specific potential evapotranspiration (ETc) from sowing to harvest in the period 1966–1990 and in future periods according to the different climate change scenarios

Scenario	Period	Winter wheat	Spring barley	Maize
		ETc	ETc	ETc
	1966–1990	548	427	649
RCP 8.5	2011–2040	561	439	666
	2041–2070	568	436	687
	2071–2100	589	458	721
RCP 6.0	2011–2040	558	435	668
	2041–2070	561	434	672
	2071–2100	569	439	683

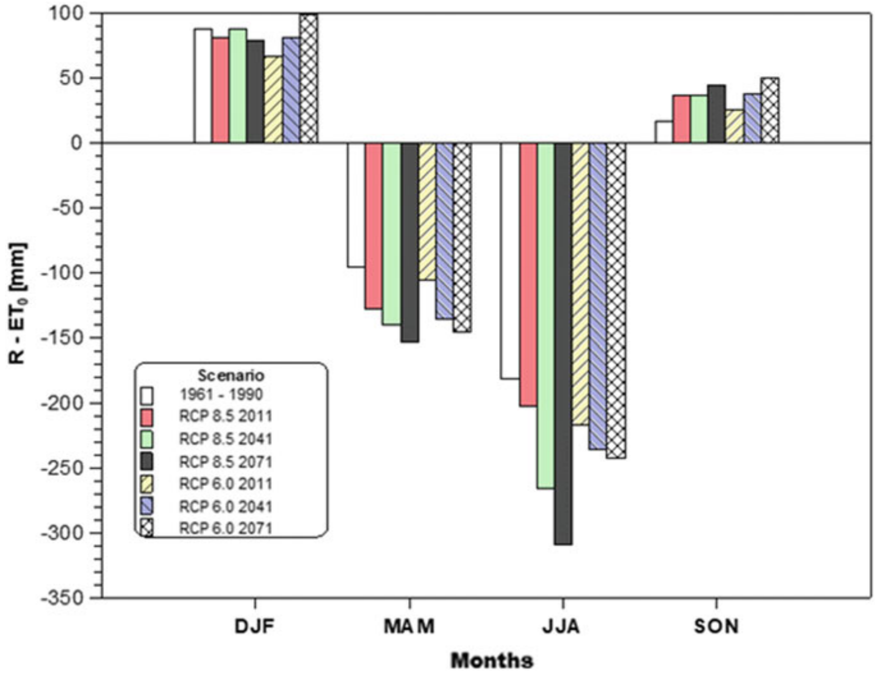

Fig. 1 Seasonal climate water balance in the period 1961–1990 and future periods according to the different climate change scenarios

results in contrary to its real measurements. Increase in evaporation will lead to higher water scarcity in spring and summer, despite the fact that total precipitation in the area will increase (Fig. 1). Nevertheless, all RCP scenarios showed that precipitation would increase in winter months and decrease in summer months, which will affect agricultural production and demand for irrigation (Fig. 1).

Soil moisture is one of the most variable soil properties. Soil moisture regime is seasonally influenced in the Lowlands of Slovakia (Takáč 2013). The maximum soil water content is recorded with winter rains or snow melting at the end of the winter period or at the beginning of spring, and the minimum soil water content is recorded during summer months. According to the model simulation the AWC below 50% was found in period from June until the end of September in every other year during 1960–1990 period (Fig. 2). Simulations using climate change scenarios data increase the variability of water content regime during the growing season. Generally, the decline of soil water content during occurs in growing seasons especially from May until September (Fig. 2). Simulations according to RCP 8.5 show that the water content in soil layer (from 0–100 cm) will be below 50% of AWC in the period from mid-June until mid-September in prediction from 2071–2100. On the other hand, in some years the AWC below 50% are not observed.

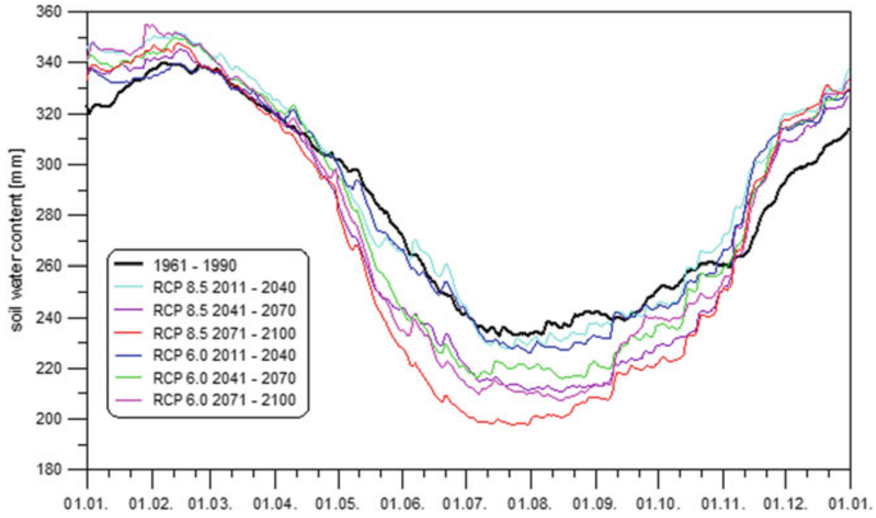

Fig. 2 Annual course of mean soil water content in the Danubian Lowland in the period 1961–1990 and future periods according to the different climate change scenarios

Affected by climate change, the number of days with SWC below 50% of AWC will rise (Fig. 3), as well as the continual period of days when SWC is below 50% of AWC. The extreme period of drought, considering this parameter, was simulated by using the RCP 8.5 scenario in the period from late May until mid-December. The most frequent decrease of SWC below 50% of AWC (20 days on average) is predicted for July and August. According to RCP 8.5, this decrease could be recorded during whole of July and August at later time horizons. This trend of increased drought periods has been recorded even during recent years. Comparing the results of simulations for both periods (1966–1985 and 1986–2005), SWC below 50% of AWC was in average four days longer in the second period, in the Danubian Lowland. The same trend was found for the duration of the continual drought with an estimated increase of up to 12 days.

On the other hand, rising concentration of CO_2 in the atmosphere can positively influence Water Use Efficiency (WUE), especially for C3 crops, while C4 crops are not influenced significantly (Figs. 4 and 5).

Nowadays, total rainfalls and their distributions in growing season do not fulfil raising water demand of plant production. Therefore, irrigation has an important role in achieving sustainable field crops production. Simulated irrigation requirements for different crops in the reference period (1966–2000) and future climate change scenarios are represented in Fig. 6.

According to RCP 6.0 irrigation requirements of different field crops can increase by 21–103.85% up to evaluated horizons of climate change and by 20–55% according to RCP 8.5 as compared to the reference period of years. The highest increase in

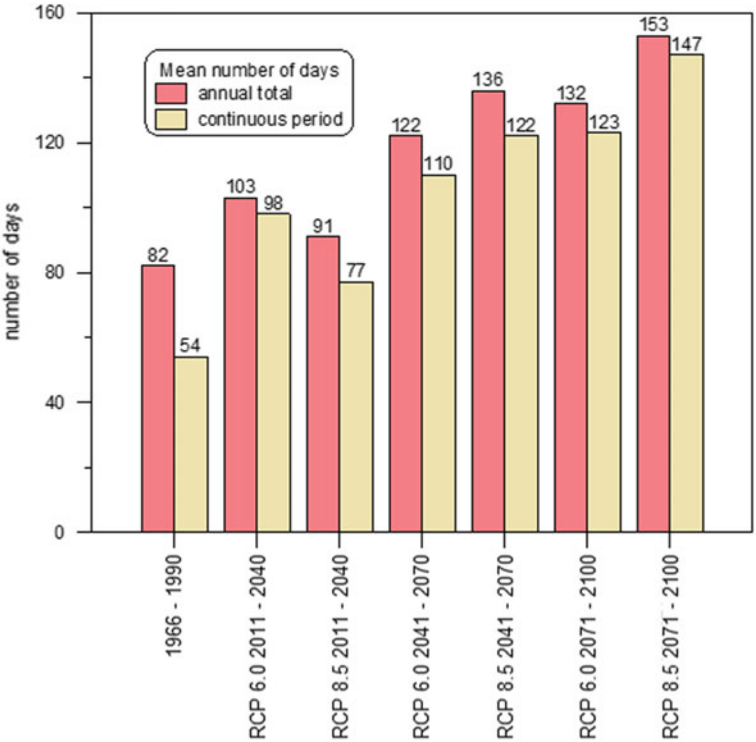

Fig. 3 Mean annual number of days with soil water content below 50% of available water capacity in the period 1961–1990 and future periods according to the different climate change scenario

irrigation requirements was found for sugar beet crops: 56–103.85% according to RCP 6.0 and 50–155% according to RCP 8.5.

Another aspect of irrigation requirement under the effect of climate change is an increase of its variability. The crops with growing season during summer have a bigger variability of irrigation need. RCP 6.0 scenarios are less risky than RCP 8.5 considering irrigation need. The maximum (650 mm) of irrigation need was simulated in RCP 8.5 scenario for sugar beet in 2071–2100, the highest spread (from 250 to 650 mm) was in this period for sugar beet and for maize (from 40 to 440 mm) in RCP 6.0 scenario during 2041–2070. This is caused by different climate conditions during the years (for instance rotation of extreme years in precipitation and periods of drought). In general, irrigation need and variability of irrigation need is increasing. The increase of variability in irrigation requirements in a different year is shown in Fig. 7.

The impact of climate change on irrigation requirements is significant. Runoff-Prophet model shows around 27% less runoff in surface rivers, which could be potentially used as a source of irrigation water, in Central Europe by 2099 in the condition of scenario SRES A1B (equiv. RCP 4.5) (Knoppova and Marton 2018).

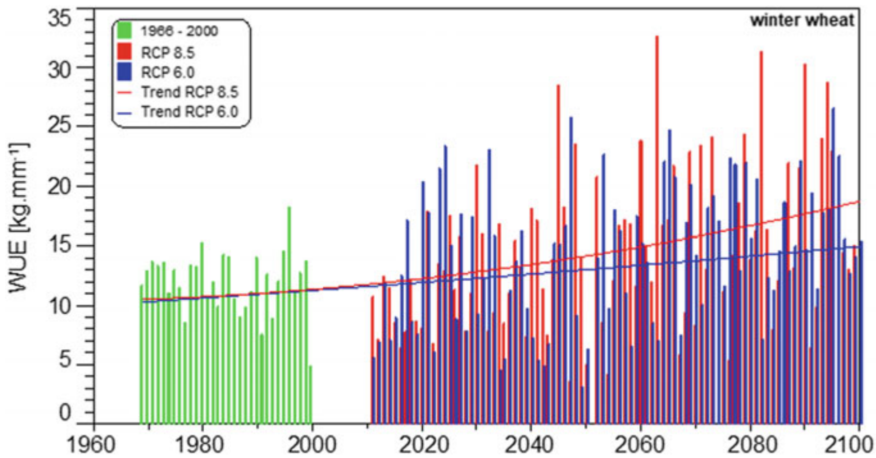

Fig. 4 Winter wheat (C3 plant) Water Use Efficiency (WUE) [kg mm^{-1}] in 1966–2000 and future periods according to the different climate change scenario

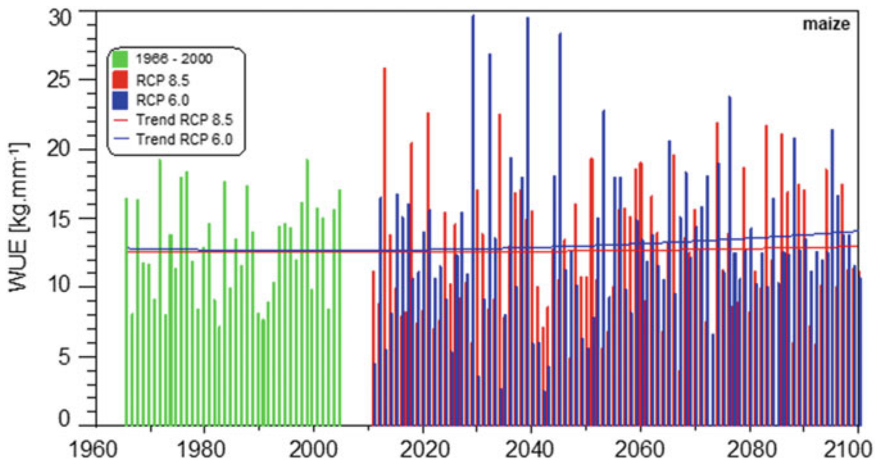

Fig. 5 Maize (C4 crop) water use efficiency WUE [kg mm^{-1}] in 1966–2000 and future periods according to the different climate change scenario

Irrigation water demand will be limited by rainfall that means that adaptations and mitigations are needed. Adaptations are necessary mainly at the regional level in terms of supply side: increasing the storage capacity of reservoirs; and demand side: efficiency in the distribution of water, recycling of water and wastewater usage (Ronco et al. 2017).

Warmer climate, uneven distribution of precipitation and higher irrigation need during future periods described by RCP scenarios will cause that the time schedule of irrigation will also change during the growing season of field crops. Depending on

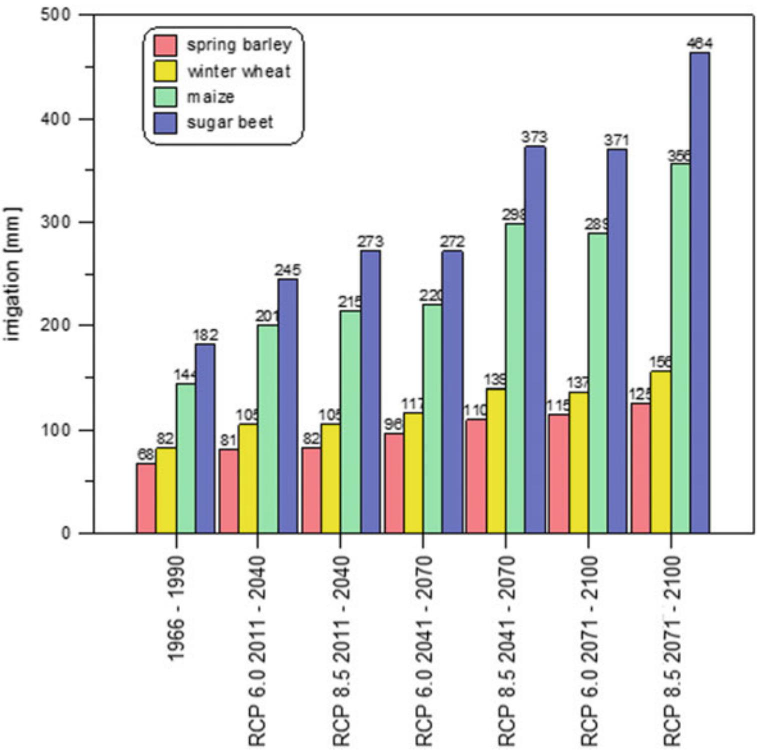

Fig. 6 Average irrigation requirement [mm] of different field crops (maize, spring barely, winter wheat, sugar beet) in the period 1966–1990 and future periods according to the different climate change scenario

crop, scenarios and time horizon of climate change, it has been predicted that the first irrigation should be applied in average 7–27 days earlier than under the reference period (1966–1990) and 11–38 days in extreme years (2071–2100) in the Danubian Lowland (Table 3). Duration of irrigation season will be longer by 13–56% under the conditions predicted by RCP 6.0 and 33.5–68.75% in the most extreme scenario RCP 8.5 (Table 4). Considering the obtained results, the water will become the most important limit of sustainable plant production in the future years.

According to global circulation model outputs (temperature), growing season will be prolonged by 2100 (Šiška and Špánik 2008). Combination of higher temperatures, a higher amount of evapotranspiration and poor rainfall distribution will cease to longer irrigation season in Northern Carpathian region. The results clearly show that irrigation will be one of the most important adaptations to climate change. On the other hand, the total amount of ground water that is currently allowed for irrigation might not be sufficient (mainly under the condition of scenario with the highest

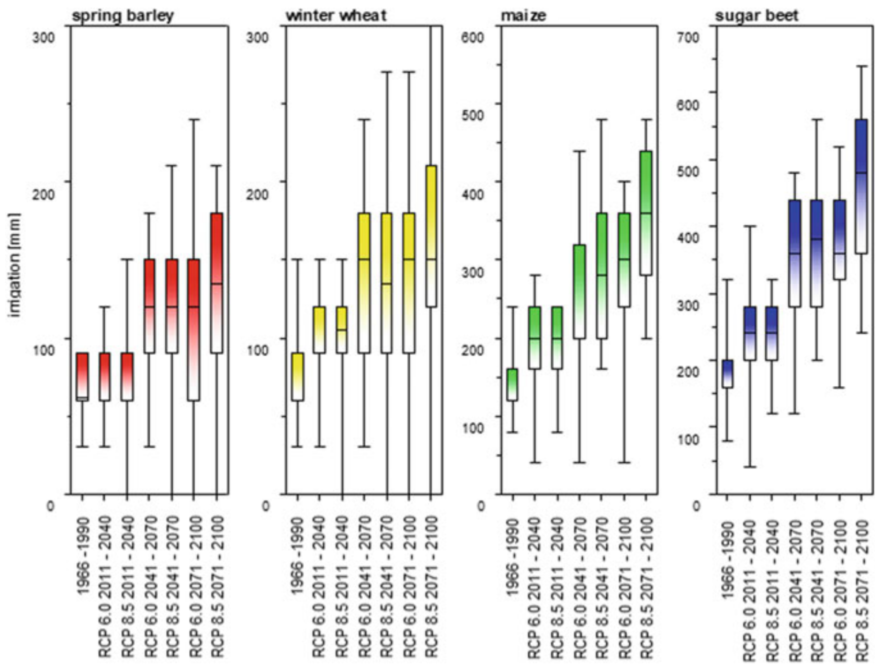

Fig. 7 Statistical characteristics of irrigation requirement [mm] of field crops in the period 1966–1990 and future periods according to the different climate change scenario

Table 3 Earliest (e) and mean (m) date of first irrigation of selected crops in the period 1966–1990 and according to the climate change scenarios

Scenario	Period	Spring barley		Winter wheat		Maize		Sugar beet	
		e	m	e	m	e	m	e	m
	1966–1990	9.5	20.5	13.5	23.5	23.6	6.7	6.6	15.6
RCP 8.5	2011–2040	27.4	10.5	17.4	6.5	7.6	25.6	19.5	9.6
	2041–2070	21.4	6.5	11.4	2.5	28.5	14.6	7.5	28.5
	2071–2100	20.4	5.5	8.4	2.5	30.5	9.6	30.4	21.5
RCP 6.0	2011–2040	28.4	11.5	19.4	5.5	16.5	22.6	16.5	8.6
	2041–2070	26.4	13.5	21.4	10.5	30.5	16.6	6.5	28.5
	2071–2100	23.4	7.5	18.4	6.5	31.5	13.6	8.5	27.5

temperature rise—RCP 8.5) in the future to secure common agricultural pattern and yields (Riediger et al. 2014). This means that the irrigation season will be interrupted by lack of water sources.

Table 4 Mean duration of the irrigation season (days) of selected crops on Danubian Lowland in the period 1966–1990 and according to the climate change scenarios

Scenario	Period	Spring barley	Winter wheat	Maize	Sugar beet
	1966–1990	24	30	41	64
RCP 8.5	2011–2040	26	41	46	67
	2041–2070	30	40	60	89
	2071–2100	33	40	67	108
RCP 6.0	2011–2040	26	41	50	67
	2041–2070	31	41	59	88
	2071–2100	31	34	64	96

4 Conclusions

According to both emission scenarios (RCP 8.5 and RCP 6.0), consequent increase of potential evapotranspiration and crop water requirements will gradually increase up to the time horizon 2071–2100. Rising CO_2 concentration will positively influence the productivity of C3 crops due to the increase of water use efficiency, while C4 crops will not be significantly affected.

As shown in simulations of climate change impacts, the availability of soil water will decline. The number of days with available water capacity below 50% will increase during the growing season of field crops and evoke an increase of irrigation requirements. The results of this study predicted that the irrigation season will start earlier and will persist for a longer period in the future.

Therefore, irrigation can be, in case of insufficient water sources, limiting factor for sustainable field crop production.

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References

Allen RG, Pereira LS, Raes D, Smith M (1998) Crop evapotranspiration—guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Food and Agriculture Organization, Rome

Bartholy J, Pongrácz R, Gelybó G, Kern A (2009) What climate can we expect in Central/Eastern Europe by 2071–2100? In: Bioclimatology and natural hazards. pp 3–14

Cure JD, Acock B (1986) Crop responses to carbon dioxide doubling: a literature survey. Agric For Meteorol 38:127–145. https://doi.org/10.1016/0168-1923(86)90054-7

Hansen S (2000) DAISY a flexible soil—plant—atmosphere system model. Equation section 1. The Royal Veterinary and Agricultural University, Copenhagen, pp 1–47

Hansen S, Jensen HE, Nielsen NE, Svendsen H (1990) DAISY—a soil plant system model. Danish simulation model for transformation and transport of energy and matter in the soilplant-atmosphere system. The National Agency for Environmental Protection, Copenhagen, pp 1–272

IPCC (2013) Climate change 2013: the physical science basis. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp

Knoppová K, Marton D (2018) Rainfall-runoff model for long-term prognosis under climate change. In: Rožnovský J, Litschmann T (eds) Hospodaření s vodou v krajině. Česká bioklimatologická společnost; Třeboň 2018, pp 1–13. ISBN 978-80-87361-83-2

ME SR (2017) The seventh national communication of the Slovak Republic on climate change. Ministry of the Environment of the Slovak Republic, Bratislava, pp 1–228 http://www.minzp.sk/files/oblasti/politika-zmeny-klimy/7nc_svk.pdf. Accessed 28 June 2018

Melo M (2004) Air temperature, atmospheric precipitation and specific humidity in Hurbanovo under the original emissions scenarios "IS92a" and new emission scenarios A2 SRES and B2 SRES. In: ŠIŠKA B et al (eds) Climate change—weather extremes—organism and ecosystems: international bioclimatological workshop 2004. Slovenská bioklimatologická spoločnosť; Viničky, 2004, pp 45–54

Melo M, Lapin M, Damborska I (2009) Methods for the design of climate change scenario in Slovakia for the 21st century. Bull Geogr Phys Geogr Ser 1:77–90. https://doi.org/10.2478/bgeo-2009-0005

Nováková K (1996) Hydrophysical properties of Žitný ostrov soils. Scientific papers of the Research Institute of Irrigation, Bratislava, vol 22, pp 127–140

Pohanková E, Hlavinka P, Orság M, Takáč J, Kersebaum K, Gobin A, Trnka M (2018) Estimating the water use efficiency of spring barley using crop models. J Agric Sci, 1–17. https://doi.org/10.1017/s0021859618000060

Poorter H (1993) Interspecific variation in the growth response of plants to an elevated ambient CO_2 concentration. Vegetatio 104(105):77–97

Riediger J, Breckling B, Nuske RS, Schroder W (2014) Will climate change increase irrigation requirements in agriculture of Central Europe? A simulation study for Northern Germany. Environ Sci Eur. Bridging Science and Regulation at the Regional and European Level 26:18. https://doi.org/10.1186/s12302-014-0018-1

Riediger J, Breckling B, Svoboda N, Schröder W (2016) Modelling regional variability of irrigation requirements due to climate change in Northern Germany. Sci Total Environ 54:329–340. https://doi.org/10.1016/j.scitotenv.2015.09.043

Ronco P, Zennaro F, Torresan S, Critto A, Santini M, Trabucco A, Zollo AL, Galluccio G, Marcomini A (2017) A risk assessment framework for irrigated agriculture under climate change. Adv Water Resour 110:562–578. https://doi.org/10.1016/j.advwatres.2017.08.003

Rötter PR, Palosuo T, Kersebaum KC, Angulo C, Bindi M, Ewert F, Ferrise R, Hlavinka P, Moriondo M, Nendel C, Olesen EJ, Patil HR, Ruget F, Takáč J, Trnka M (2012) Simulation of spring barley yield in different climatic zones of Northern and Central Europe: a comparison of nine crop models. Field Crops Res 133:23–36. https://doi.org/10.1016/j.fcr.2012.03.016

Šiška B, Špánik F (2008) Agroclimatic regionalization of Slovak territory in condition of changing climate. Meteorologický časopis 11:61–64

Šiška B, Takáč J (2008) Dôsledky klimatickej zmeny na úrody poľných plodín na Podunajskej nížine. In: Lapin, M., Nejedlík, P. (eds) Národný klimatický program SR, VII, 2008, zv. 12, MŽP SR, SHMÚ, Bratislava, pp 113–122. ISBN 978-80-88907-63-3

Takáč J (2001) Climate Change Impacts on Water Balance in Agricultural Landscape. NKP 10/2001. MoE SR, SHMI Bratislava, pp 16–26

Takáč J (2013) Assessment of drought in agricultural regions of Slovakia using soil water dynamics simulation, Agriculture (Pol'nohospodárstvo) 59(2):74–87. https://doi.org/10.2478/agri-2013-0007

Takáč J, Koščo V (1995) Unsaturated zone and agriculture. Final Report. PHARE Project No. PHARE/EC/WAT/1 Danubian Lowland Ground Water Model. Bratislava: MoE SR, Bratislava, 64 p

Takáč J, Šiška B. (2009) Climate change impact on spring barley and winter wheat yields on Danubian Lowland. In: Střelcová K et al (eds) Bioclimatology and natural hazards. Springer, pp 283–288

Takáč J, Šiška B (2011) Kalibrácia a validácia modelu DAISY pre podmienky Slovenska. VUPOP, Bratislava, pp 161–172. ISBN 978-80-89128-91-4

van Vuuren DP, Carter TR (2013) Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with old. Clim Change 122:415–429. https://doi.org/10.1007/s10584-013-0974-2

Adaptation of Eastern Europe Regional Agriculture to Climate Change: Risks and Management

Dara V. Gaeva, Galina M. Barinova and Evgeny V. Krasnov

Abstract This paper presents a comparative analysis of the regional specificity of climate change adaptation strategies in some countries and regions of Eastern Europe. The authors explore the role of extreme temperatures and changes in precipitation in agricultural production. Possible ways to achieve an ecologically sustainable increase in agricultural productivity for dry and wet areas in Eastern Europe are discussed. Attention is drawn to the role of environmental education and public participation in addressing climate change issues for sustainable development of agrarian ecosystems. A special attention is paid to increasing social responsibility for minimizing negative consequences of climate change.

Keywords Climate change · Agroecosystems · Regional specificity
Risks and adaptation types · Eastern Europe

1 Introduction

Many parts of Eastern Europe have been facing consequences of climate change, negatively affecting agroecosystems, increasing their vulnerability to extreme changes in temperature and precipitation, and hampering their sustainable development. To manage the risks in agricultural production, it is necessary to better understand the regional specificity of interaction between ecosystems and anthropogenic factors. It is impossible to elaborate a strategy for the development of competitive agriculture without a comparative study of the regional specificity of

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climate change and its impact on agricultural landscapes in the spatial-temporal frameworks. It also requires an analysis of changes, which determine natural soil fertility, and consequently, crop yields.

In this respect, the study of Russian regions and countries of the Baltic Sea Basin is of particular importance. Climate change is more clearly noticeable in coastal zones and catchment areas with periodically alternating dry and wet periods, storms, floods and other adverse weather conditions. Advanced monitoring, forecasting and risk assessment for agriculture can help to minimize negative environmental effects of climate change in many regions of Eastern Europe. Another important measure is an increased social responsibility for the present and future generations of agricultural producers, for environmental sustainability of agricultural production, which can be achieved on the basis of new knowledge about minimizing and preventing soil pollution and new advanced technologies in agriculture.

Regional environmental policy is to play an exceptionally important role in the perfection of legislation and development of eco-partnership, which will gradually strengthen the importance of these measures in the regions of Eastern Europe. Special measures aimed to restore the mineral and acid balance of soils and to modernise land drainage systems both in the zone of excessive moisture and in arid zones are of particular importance for the optimization of agrarian nature management.

Identifying solution to environmental problems in agriculture requires better involvement of public institutions, civil society and mass media. Independent sociological surveys and expert assessments can help to adjust goals and objectives related to identifying risks and improving management of the adaptation of regional agroecosystems to the constantly changing weather and climate conditions of agricultural production.

2 Extreme Fluctuations in Temperature and Precipitation and Their Impact on Agricultural Production

According to FAO, Eastern Europe produces more than half of European wheat (Fig. 1) and about 19% of the world's wheat yield, thus playing an important role in global food security. However, crop yields strongly depend on weather conditions during growth, maturation and harvesting. In Eastern Europe and former Soviet republics climate variability accounts for 23–66% of the variability in wheat yields (Ray et al. 2015).

Most climate models show that climate change in Europe results in higher temperatures and an increase in precipitation (IPCC 2014). Numerous weather monitoring data show that there is a substantial increase in the risk of floods in most countries of Central and Western Europe. In Eastern Europe, the risk of floods is smaller (Alfieri et al. 2018). However, despite having similar patterns of atmospheric circulation, there are multidirectional climate changes in different regions of Eastern Europe. Undoubtedly, this factor brings about both positive impacts and serious challenges,

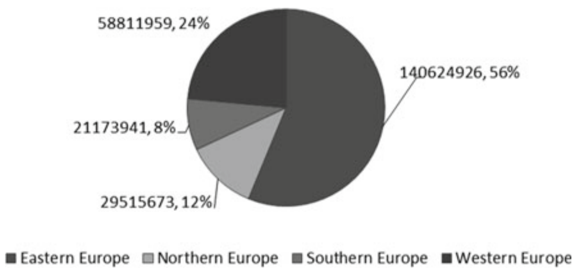

Fig. 1 Wheat production in Europe, 2016 (tonnes). *Source* Authors (according to data: FAOSTAT (2018), http://www.fao.org/faostat/en/#data/RFN)

requiring an active adaptation of agriculture to the changing climatic conditions. For agricultural production, major risks are primarily associated with a decrease in precipitation and an increase in the frequency of extreme weather events. The analysis (Pinke and Lövei 2017) of the correlation between temperature, precipitation, drought intensity and crop yields in Hungary (1921–2010) shows a gradually increasing negative effect of rising temperatures on crop yields. In 1981–2010, the temperature increase of 1 °C reduced the yield of four main crops by 9.6–14.8%.

Extremely high air temperatures during the growing season have a negative impact on the yield of most important food, fodder, energy and fibre crops. With air temperature close to 30 °C and above, the process of photosynthesis of plants that require 20–25 °C for growth is disrupted.

In temperate latitudes, plants develop faster, accumulating fewer carbo-hydrates, fats, and proteins (Fedoroff et al. 2010). In some regions of Eastern Europe (Poland, the Kaliningrad region), there has been an increase in the number of days with air temperatures equal or exceeding 30 °C. The intensity and duration of heat waves and their spatial distribution (Barinova et al. 2015; Wypych et al. 2017; Wibig 2017) pose a risk for the growth and development of plants.

In the winter of 2007, most countries of Eastern Europe faced precipitation deficit. At the end of spring and early summer 2007, south-eastern Europe, Romania, Ukraine, Bulgaria and Turkey suffered from drought (EDR 2018). The drought in Moldova was the most severe during the whole observation period. It was an extreme manifestation of drier weather conditions that became particularly noticeable in the early 1990s. The drought led to a decrease in winter crops yields (mainly wheat and barley by 40 and 55% respectively) and spring crops (sunflower, corn, grapes, etc.). The production from home gardens, contributing significantly to family daily food needs of 70% of the population sharply decreased (FAO 2007). In 2007, the average yield of cereal and leguminous crops in Moldova was about 9 quintals/hectare. During the period 1990–2017, the minimum grain yield was registered in Ukraine in 2003 (18 quintals/hectare). However, the yield of crops has been increasing during the last two decades and has reached 40 quintals/hectare. The same trend has been observed in Poland. Yet, in Poland, unlike in Ukraine and Moldova, there are lower interannual fluctuations in yields (Fig. 2).

At the end of the 20th century, the Czech Republic suffered severe droughts during the April–June period resulting in considerable yield variability (Potopová

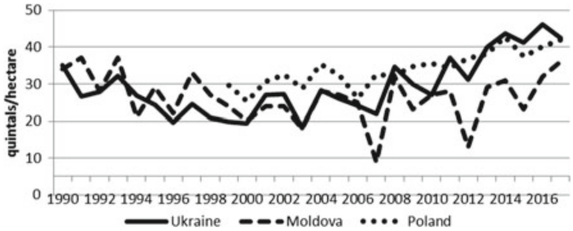

Fig. 2 Average yield of cereals and leguminous crops—total, quintals/hectare in Ukraine, Moldova and Poland. *Source* Authors (according to data: Biroul national de statistica, http://statbank.statistica.md; State Statistics Service of Ukraine, https://ukrstat.org; Statistics Polan, http://stat.gov.pl)

et al. 2015). The extremely dry growing seasons of 2003 and 2012 negatively affected crop yields and decreased domestic agricultural production in the Czech Republic.

In 2011–2015, in the steppe regions of Moldova, there was an even greater acceleration of precipitation deficit. Much drier conditions resulted in a decrease in legumes production by 30–70% (Voziyan et al. 2017). Climate models show a possible decrease in wheat yield in the agriculturally important steppe zone of Ukraine. In general, according to forecasts until 2070, wheat production in Ukraine may decrease 6.5–11.4% (Müller et al. 2016).

Calculations show that in Central Poland extreme meteorological droughts can potentially halve the yield of late potatoes. The lowest yield reduction is projected for winter wheat and winter rape (Łabędzki and Bąk 2017).

Arid periods during spring months can occur in coastal regions. In the Kaliningrad region (Russia) in the first decade of the XXI century, the number of years characterized by high aridity in May sharply increased. In 2002, due to the drought in May, the yield of cereals and leguminous crops was one of the lowest after the reforms of the agricultural sector in the region (Barinova et al. 2015). Nevertheless, despite long-term forecasts (Balkovič et al. 2014) until 2050 and 2090, which indicate a decrease in wheat yield in Eastern Europe by almost 20% compared to 2000, dry land farming in this region has a sufficient land potential, which compensates for the negative effects of climate change.

3 Regional Specificity and Climate Change Adaptation Strategies

Climate observations confirm that in the XX and XXI century, climate change affects Russia, countries of Eastern Europe and many other countries in different part of the world. However, the degree and trends of climatic transformations have a different impact on the structure and management of agriculture in different regions of Europe. The growth of temperatures and the lengthening of the growing season in European countries entailed a general redistribution of areas under agricultural crops. In Eastern Europe, the volume of corn gross output increased from 21.8 million tons (1996) to 72.8 million tons (2016); soybeans—from 0.4 million tons (1996) to 8.2 million tons (2016). In 2005, in Poland, one of the leading European producers of rye, sugar beet and potatoes, the area occupied by maize for grain increased from 339 to 594 thousand hectares. At the same time, the area under potato decreased from 588 to 301 thousand hectares (Statistics Poland 2018).

In Belarus, specializing in the production of crops of the temperate zone, in 2004–2015, 20% more land was allocated for sugar beet, 18.5% more for fodder crops, 30% more for vegetables, and 44% more for flax. However, the area under potato reduced by 39%. The area of maize for grain increased from 10.9 (2004) to 124.29 (2016) thousand hectares. Belarus is located in the zone of risky farming, and climate changes led to a 15-20% change in the gross agricultural product. Depending on meteorological conditions, the gross grain harvest can vary from 5.5 to 9.5 million tons and in certain years may go down to 60% of the minimum level of food security of the country (Clima East 2017).

According to (Bacon et al. 2014), climate change is likely to increase the risk of invasive species of arthropods in Europe. In Belarus, the increase in climatic suitability for quarantine arthropod species in agriculture will be about 33.5% (the results of comparing the KG climate classification in 1951–2000 with the predicted climate classification in 2076–2100).

The regional specificity of climate change adaptation strategies in the European part of the Russian Federation manifests itself in a number of negative tendencies in land use, for instance, increasing monoculture cropping, a reduction of arable land in areas with marginal soils, etc. This negative tendencies have been observed since the 1990s (Klyev 2017). There are certain regularities in the territorial differentiation of the reduction of arable lands. These regularities are mainly associated with soils, different agroclimatic conditions of Russian regions, as well as with their historical and ethnic traditions. Research has shown that biggest relative decrease in areas under crops occurred in the regions having the lowest soil and agro-climatic potential and relatively low transport accessibility. In the non-chernozem zone (Kirov region), during the period 1990–2010, the yield of all crops decreased by 61.3%, grain crops—by 70.6% (Mukhin 2013). Given climate change and its consequences for agriculture, the reduction of the area under crops is accompanied by a change in the structure of crops. For example, in 1990–2010, the Kirov region practically speaking lost its flax cultivation sector. In parallel with the decrease in the area of cultivated land, there was a decrease in the agrotechnical level of the agricultural sector. The use of organic and mineral fertilizers and the liming of soil went down. The European part of Russia has always played an important role in the production of wheat. However, interannual fluctuations in precipitation and an insufficient use of nitrogen fertilizers prevent the agrarian sector from boasting a bigger wheat yield. According to Schierhorn et al. (2014), the expansion of irrigated areas in combination with the optimal application of nitrogen (N) fertilizers is the key to increasing the production of wheat in this region by 9–32 million tons. In Europe, there is a difference between east and west with respect to agriculture. Regions in the west are characterised by

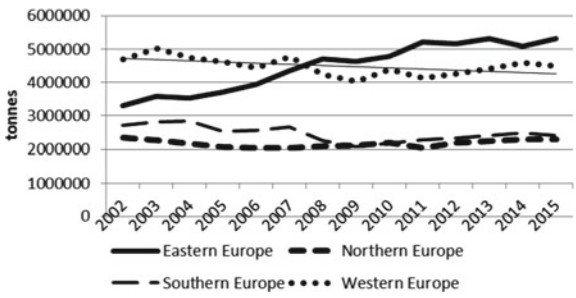

Fig. 3 The use of nitrogen fertilizers in different regions of Europe during 2002–2015. *Source* Authors (according to data: FAOSTAT (2018), http://www.fao.org/faostat/en/#data/RFN)

a more intensive land use compared to those in the east. Marginal areas display a reduction in arable land (Kuemmerle et al. 2016).

There are many wetlands in Eastern Europe. In the past, many East European wetlands were turned into agricultural lands, and the remaining wetlands will be drained. Drained wetlands are usually used for cultivating various food and non-food crops as well as for the extraction of peat. A different hydrological regime caused by climate change can speed up the invasion of farmlands into wetlands (Hartig et al. 1997). On the other hand, there is strong agreement that the risks of floods and erosion rise due to global warming particularly in territories located in coastal zones. Despite decreasing warm-season precipitation, the intensity of rainfall has been increasing. This rise in the frequency of floods and the leaching of nutrients from agricultural lands are caused by heavy rains. Consequently, there is a need for adaptation to these phenomena. Such conditions require a more extensive use of fertilizers. The biggest increase in the use of nitrogen fertilizers is observed in the eastern part of Europe—from 3.2 million tons in 2002 to 5.3 million tons in 2015 (Fig. 3). A study in Poland shows a rising acidity of soils and, consequently, an increasing risk of leaching of phosphorus (P) and nitrogen (N). Liming is recommended for the majority (72%) of Pomeranian farms (Ulén et al. 2016). However, the intensification of agricultural production, including a more extensive use of nitrogen fertilizers and lime in the cultivation of non-leguminous crops (corn, wheat), leads to a rise in greenhouse gas emissions (Powlson et al. 2014).

Europe will certainly be able to adapt to climate change. Its well-developed transport, industrial production, energy infrastructure, financial resources, a mature system of decision-making are likely to make the adaptation process more effective than, for example, in Asia or Africa. In many cases, adaptation to the effects of climate change promises very significant benefits for the economic development of individual countries and their regions. On the one hand, agriculture bears losses from the effects of global warming. On the other hand, agriculture is one of the main causes of climate change. Studies have shown that the production of food accounts for the largest share of greenhouse gas emissions (carbon footprint) with almost 20% of the global carbon footprint, followed by the communal sector, transport, services, industrial production and construction (IPCC 2014).

Further intensification of food production in agroecosystems using traditional approaches (for example, extensive use of fertilizers and pesticides, precision agriculture technologies, wider use of transgenic crops, which will further reduce the genetic diversity) will not be sustainable, as a result of losses due to the adaptation of the populations of vertebrates and pathogens. A truly sustainable intensification of food production requires a reorganization of the existing agroecosystems and the introduction of dynamic diversity in order to suppress the rapid emergence of new and severely damaging plant pathogens (Mcdonald and Stukenbrock 2016). With increasing frequency of extreme weather events, it is necessary to create new high-yielding genotypes that are better adapted to the temporary changes in precipitation and water availability and having increased tolerance to heat stress (Semenov et al. 2014).

Given the growing demand for higher agricultural productivity, researchers are looking for more effective methods to identify target regions for the intensification of local crop production. The use of space probing data already now allows researchers to single out several clusters of agricultural territories. The MODIS Normalized Difference Vegetation Index (NDVI), Estel et al. (2016) helps to identify six clusters according to the intensity of land use. The intensity of crop production was the highest in Germany, Poland, and East European black earth regions, having a high yield factor. As numerous field surveys and statistical data show, Eastern Europe is characterized by low agriculture intensity outside the Chernozem region.

4 Agri-Environmental Effects of Climate Change: The Kaliningrad Region (Russia) and Poland

Climate change impacts in Eastern Europe are both positive (increase in the growing season duration and in the sum of effective temperatures) and negative (increase of the number of extreme weather events and interannual variability of weather conditions etc.). Temporal changes in the average monthly air temperature follow different seasonal trends. The analysis of the average values of air temperature at the Kaliningrad meteorological station in 1981–2010 and 1961–1990 shows the most significant increase (>1 °C) in air temperature in January, February, April and July. There is no change in autumn temperature (Fig. 4).

In the Kaliningrad region, the sum of effective temperatures for agricultural crops ($T \geq 10^{\circ}$) during the active growing period (Barinova et al. 2015) in 1949–2011 increased with the rate of up to 2.4 days each 10 years. The duration of the period with a temperature above 5 °C grew at a rate of 1.6 days each 10 years. In Poland (Wypych et al. 2017), a statistically significant change in the duration of growing ($T \geq 5$ °C) and frost-free periods ($T > 0$ °C) was identified. The increasing duration on the growing season—4 days each 10 years—has a positive impact on the development of agriculture, reaching a maximum of along the Baltic Sea coastal zone. The change in the duration of the frost-free season is spatially much more differentiated. In

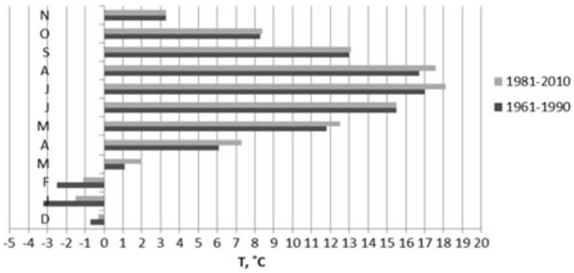

Fig. 4 The average monthly air temperature in Kaliningrad in 1961–1990 and 1981–2010. *Source* Authors (according to data: Vserossiyskiy nauchno-issledovatel'skiy institut gidrometeorologicheskoy informatsii, http://meteo.ru/)

southern and central Poland the frost-free period became longer (more than 5 days each 10 years).

In the analysed period spring temperatures rose, especially in March, and there was a decrease in the number of days with T < 0 °C for most of the territory. However, there is a danger of extreme weather events and low air temperatures. During the last 10 year, thermophilous plants have been introduced to the crop rotation in the Kaliningrad region. One of them is buckwheat (*Fagopyrum esculentum* L.), a plant, which is especially sensitive to even a short-term decrease in the surface air temperature below +1 °C. Its sown area increased in the region from 1.1 thousand hectares in 2003 to 7.5 thousand hectares in 2016. This is due to the transition of the last frost date to earlier periods. This is a positive trend since buckwheat is a honey, forage and green manure plant, tolerant to acidic soil.

Despite the general increase in the average air temperature, its internal fluctuations pose a risk for the cultivation of winter crops. It is necessary to consider the frequency of occurrence of extremely severe winter conditions, similar to those recorded in the frosty and snowy January of 2006 in Poland, when the mean monthly temperature was 4–6.5 °C lower than the norm. The warm winter of 2007 is an opposite example: the winter was the warmest in the history of meteorological measurements throughout Europe. Poor winter survival of crops in Poland is caused by an insufficient thickness of snow cover on frosty days rather than by a decrease in air temperature below critical values for a given species. Even in typically most snowy and frosty winter months, i.e. in January and February, in western Poland, the thickness of snow cover on the day of the lowest air temperature is minimal (Czarnecka et al. 2008). In 2010, in the Kaliningrad Region, the absence of snow cover combined with extremely low temperatures in January (the average air temperature was −8.1 °C, the lowest in the last 20 years) caused damage to 80% of rapeseed/canola sown area (*Brassica napus* L.) and (Barinova et al. 2015).

With increasing air temperature in spring and summer, the phenological asynchrony in the system plant-pollination also increases. The analysis of the Kaliningrad region has revealed positive shifts in the time of blooming of horticultural crops (Barinova and Kokhanovskaya 2015). However, phenological asynchrony may lead to a decrease in the quality of pollination. In temperate zones, where the blooming of the first honey plants does not coincide with the beginning of the active period for bees, an increase in asynchrony can result in starvation and, consequently, a decrease in the population of wild and honey bees. From year to year, asynchrony varies considerably. In the Kaliningrad region, the differences between the dates of the beginning of the blooming of dandelions (*Taraxatum officinale*), an important fodder plant for bees, in the spring and the beginning of the active period for bees were 32 days in 2002, and in 2014—75 days (Gaeva 2015). However, some authors note an increase in honey production of bee colonies, associated with a rise in temperature in late spring and summer (Langowska et al. 2017).

5 Public Participation in Mitigating Negative Climate Change Consequences

Risk mitigation can be achieved by better management, the use of advanced technologies and exchange of best practices. The perception of climate change by the population plays an important role in the implementation of adaptation and prevention measures. Understanding the anthropogenic causes of climate change is the most effective measure of preventing climate change. It is especially important in the countries of Latin America and Europe. There is a need to improve basic education, climate literacy and the general understanding of local aspects of climate change. These are vital measures to enhance public support for climate action (Lee et al. 2015).

Research results (Raška 2015) for European countries show the efficiency of government measures aimed at flood risk reduction in Central and Eastern EU member states. The general public often perceives severe floods as a rare event, and flood risk reduction is perceived as a temporary issue discussed primarily during the floods.

In 2016, researchers conducted a survey in the Kaliningrad region and Saxony-Anhalt (n = 274). The survey showed that there is a need to organize public awareness campaigns on the local level. The survey participants were asked to describe their attitude to the problem of global climate change and answer the question "What do you think about public discussions of climate change?". The following answer options were proposed: (1) I do not care because there is no climate change; (2) I do not care because climate change is a natural process; (3) this is an important issue for me because climate change can affect the quality of my life; (4) other opinions. The majority of the respondents—65.4% in the Kaliningrad region and 76.5% in Germany—chose the third answer (Fig. 5).

16.9% of respondents in Saxony-Anhalt expressed their opinion about climate discussions in the following way: "it is very important but there is a lot of empty talk", "climate change is not discussed seriously", "politicians are discussing this issue not knowing what they are speaking about", "climate change adaptation strategies are very relevant", "I know that this is important, but I do not follow the debate. Anyway,

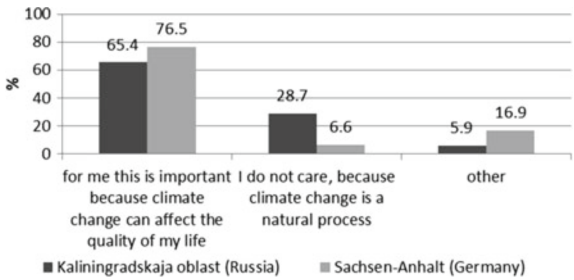

Fig. 5 Responses of respondents in the Kaliningrad Region (Russia) and Saxony-Anhalt (Germany) to the question "What do you think about actual discussions about climate change?" *Source* Authors

nothing will change", "I do not care, the quality of my life is not affected", "politicians abuse the topic". 6% of Russians expressed their opinion in the following way: "I do not care until it affects my health", "climatologists exaggerate the risks", "climate change discussions are important but words do not solve problems, because in this world only money matters".

The results of the survey showed that 44.5% of respondents in Germany and 51.5% in Russia feel they are poorly informed about the consequences of climate change. Understanding climate change is important for both urban and rural residents since the volume of greenhouse gas emissions, including those from agriculture, largely depends on the behaviour patterns of consumers. Calculations show that the production and consumption of animal products contribute more to greenhouse gas emissions than the production of vegetables (Scarborough et al. 2014). In the long term, a reduction in the consumption of meat and dairy produce will be indispensable for achieving a 2 °C target particularly if there are no unprecedented technological breakthroughs (Hedenus et al. 2014).

There is a need to create information centres, a database of best practices, introduce special climate literacy courses for farmers, promote and disseminate examples of successful adaptation to climate change and efficient disaster risk management (FAO 2010). A survey in Hungary showed that farmers use more adaptive agriculture technologies in areas where they are more involved in social life and education activity etc. They sell more, receive higher profit and manage larger farms with better soil quality (Li et al. 2017).

An increase of social responsibility for climate change and its consequences can also be achieved by ecological literacy courses and increasing the interest in agriculture among schoolchildren. A combination of education and extracurricular activities with a special focus on agriculture can provide a deeper and more comprehensive understanding of the importance of agriculture for a sustainable future (Bickel et al. 2014). Nikezić and Marković (2015) analyse the results of a student project on situating a housing complex in the context of the agrarian landscape. The project confirms the role of a territory, including agrarian areas as a resource for a new sustainable urban lifestyle. The study proves that "place-based education" can increase public awareness and social responsibility to the environment. This approach to education proves to be useful and can potentially result in better and more environmentally friendly architectural designs benefiting local communities.

6 Conclusions

The global impact of climate change on agricultural production is quite clear: half or more of the agricultural output may by directly affected by weather and climate conditions, the remaining part of the output depends on agroecological properties of soils, farmers' qualification, professionalism, educational level, agricultural equipment, financing, socio-economic and geopolitical factors, etc.

Regions of Eastern Europe have to take into account their zonal and climatic conditions of agricultural production and pay much more attention to environmental and economic education of agrarian specialists, interregional and international cooperation between science, education and business communities. These are necessary measures to achieve the goal of a more sustainable development of the agrarian sector, forestry (to increase forest cover by 20–25%), the fuel and energy sector, improve the quality of life and health of the population (including minimizing the negatives effects of climate change), to develop tourism and recreation activities related to the environmentally friendly production of agricultural produce and to achieve synergy of all the above-mentioned areas for regional development.

Despite regional differences in climatic conditions in Eastern Europe, interannual fluctuations of rainfall, availability of water resources for agriculture and their management are limiting factors for crop production. However, there is a positive factor facilitating the development of agricultural production in Eastern Europe. Rising air temperatures make it possible to gradually increase the area and yields of soybeans and maize, which play an important role in ensuring food security. At the same time, agricultural areas under monocultures are enlarging. It results in decreasing biodiversity of agroecosystems. The introduction of multifunctional crops (fodder, honey, green manure, energetic and fibre plants), the expansion of areas under perennial fodder crops that efficiently use soil moisture (clover, alfalfa) and increasing semi-natural areas within agroecosystems may play an important role in reaching environmental sustainability.

Government policies of adaptation to climate change should be aimed primarily at mitigation and prevention of the regional and local impacts of climate change on agriculture. Policies having greater emphasis on mitigating negative consequences of adverse weather phenomena (e.g., extreme weather events, precipitation deficit, etc.), may be more effective for promoting climate adaptation and literacy among farmers compared to the ones, which are too general and linked only to long-term climate change consequences (e.g., global warming) (Li et al. 2017). The transition towards a more environmentally sustainable agriculture in Eastern Europe can be facilitated by the creation of a legal framework for adaptive agricultural land use (including in non-EU countries), better involvement of agricultural managers in this work, and their responsibility for the environment and the implementation of government policies for sustainable development.

References

Alfieri L, Dottori F, Betts R, Salamon P, Feyen L (2018) Multi-Model projections of river flood risk in Europe under global warming. Climate 6(1):6. https://doi.org/10.3390/cli6010006

Bacon SJ, Aebi A, Calanca P, Bacher S (2014) Quarantine arthropod invasions in Europe: the role of climate, hosts and propagule pressure. Divers Distrib 20(1):84–94. https://doi.org/10.1111/ddi.12149

Balkovič J, Velde MVD, Skalský R, Xiong W, Folberth C, Khabarov N, Smirnov A, Mueller ND, Obersteiner M (2014) Global wheat production potentials and management flexibility under the representative concentration pathways. Glob Planet Change 122:107–121. https://doi.org/10.1016/j.gloplacha.2014.08.010

Barinova G, Kokhanovskaya M (2015) Climate change monitoring on the basis of phytophenological observations in Kaliningrad region. Pollut Atmosph 226:2268–3798. https://doi.org/10.4267/pollution-atmospherique.5009

Barinova GM, Krasnov E, Gaeva DV (2015) Changes of South Baltic Region climate: agroecological challenges and responses. In: Handbook of climate change adaptation. Springer, Berlin, pp 1635–1655. https://doi.org/10.1007/978-3-642-40455-9_17-1

Bickel M, Strack M, Bögeholz S (2014) Measuring the interest of German students in agriculture: the role of knowledge, nature experience, disgust, and gender. Res Sci Educ 45(3):325–344. https://doi.org/10.1007/s11165-014-9425-y

Biroul national de statistica (2018) http://statbank.statistica.md/pxweb/pxweb/en/40%20Statistica%20economica/40%20Statistca%20economica__16%20AGR__AGR020/AGR020100.px/table/tableViewLayout1/?rxid=b2ff27d7-0b96-43c9-934b-42e1a2a9a774

Clima East (2017) Strategii adaptatsii sel'skogo khozyaystva Respubliki Belarus' k izmeneniyu klimata. http://climate.ecopartnerstvo.by/sites/default/files/2017-09/Adaptation%20strategy%20for%20belarus%20agriculture%20RUS.pdf

Czarnecka M, Koźmiński C, Michalska B (2008) Climatic risks for plant cultivation in Poland. Acta Agrophisica 169(1):78–97

EDR (2018) http://www.geo.uio.no/edc/droughtdb/edr/DroughtEvents/2007_Event.php

FAO (2007) https://reliefweb.int/report/moldova/special-report-faowfp-crop-and-food-supply-assessment-mission-moldova-25-sep-2007

FAO (2010) http://www.fao.org/docrep/013/i1881e/i1881e00.pdf

FAOSTAT (2018) http://www.fao.org/faostat/en/#data/RFN

Fedoroff NV, Battisti DS, Beachy RN, Cooper PJ, Fischhoff DA, Hodges CN, Knauf VC, Lobell D, Mazur BJ, Molden D, Reynolds MP (2010) Radically rethinking agriculture for the 21st century. Science 327(5967):833–834. https://doi.org/10.1126/science.1186834

Gaeva DV (2015) Opyleniye kak ekosistemnaya usluga v agrarnom prirodopol'zovanii. Vestnik Baltiyskogo federal'nogo universiteta im. I. Kanta. Baltiyskiy federal'nyy universitet im. Immanuila Kanta, Seriya: Yestestvennyye i meditsinskiye nauki 1:19–34

Hartig EK, Grozev O, Rosenzweig C (1997) Climate change, agriculture and wetlands in Eastern Europe: vulnerability, adaptation, and policy. Clim Change 36(1–2):107–121. https://doi.org/10.1023/A:1005304816660

Hedenus F, Wirsenius S, Johansson DJA (2014) The importance of reduced meat and dairy consumption for meeting stringent climate change targets. Clim Change 124(1–2):79–91. https://doi.org/10.1007/s10584-014-1104-5

IPCC (2014) Intergovernmental Panel on Climate Change. Climate Change 2014: fifth assessment report (AR5). http://ipcc.ch/report/ar5/

Klyev NN (2017) Agrarnoye prirodopol'zovaniye v rossiyskikh regionakh: ekologo-resursnyy dissonans. Izvestiya Russkogo geograficheskogo obshchestva 149:4–15

Kuemmerle T, Levers C, Erb K, Estel S, Jepsen MR, Müller D, Plutzar C, Stürck J, Verkerk PJ, Verburg PH, Reenberg A (2016) Hotspots of land use change in Europe. Environ Res Lett 11(6):064020. https://doi.org/10.1088/1748-9326/11/6/064020

Łabędzki LŁ, Bąk B (2017) Impact of meteorological drought on crop water deficit and crop yield reduction in Polish agriculture. J Water Land Dev 34(1):181–190. https://doi.org/10.1515/jwld-2017-0052

Langowska A, Zawilak M, Sparks TH, Glazaczow A, Tomkins PW, Tryjanowski P (2017) Long-term effect of temperature on honey yield and honeybee phenology. Int J Biometeorol 61(6):1125–1132. https://doi.org/10.1007/s00484-016-1293-x

Lee TM, Markowitz EM, Howe PD, Ko C-Y, Leiserowitz AA (2015) Predictors of public climate change awareness and risk perception around the world. Nat Clim Change 5(11):1014–1020. https://doi.org/10.1038/nclimate2728

Li S, Juhász-Horváth L, Harrison PA, Pintér L, Rounsevell MD (2017) Relating farmers perceptions of climate change risk to adaptation behaviour in Hungary. J Environ Manage 185:21–30. https://doi.org/10.1016/j.jenvman.2016.10.051

Mcdonald BA, Stukenbrock EH (2016) Rapid emergence of pathogens in agro-ecosystems: global threats to agricultural sustainability and food security. Philos Trans R Soc B: Biol Sci 371(1709):20160026. https://doi.org/10.1098/rstb.2016.0026

Mukhin GD (2013) Strukturno-funktsional'naya transformatsiya agrolandshaftov Nechernozem'ya v usloviyakh rynochnogo zemlepol'zovaniya (na primere Kirovskoy oblasti)/sb. Strukturno-dinamicheskiye osobennosti, sovremennoye sostoyaniye i problemy optimizatsii landshaftov. Voronezh 260:264

Müller D, Jungandreas A, Koch F, Schierhorn F (2016) Impact of climate change on wheat production in Ukraine: © 2016 German-Ukrainian Agricultural Policy Dialogue. Institute for Economic Research and Policy Consulting, Kyiv

Nikezić A, Marković D (2015) Place-based education in the architectural design studio: agrarian landscape as a resource for sustainable urban lifestyle. Sustainability 7(7):9711–9733. https://doi.org/10.3390/su7079711

Pinke Z, Lövei GL (2017) Increasing temperature cuts back crop yields in Hungary over the last 90 years. Glob Change Biol 23(12):5426–5435. https://doi.org/10.1111/gcb.13808

Potopová V, Štěpánek P, Možný M, Türkott L, Soukup J (2015) Performance of the standardised precipitation evapotranspiration index at various lags for agricultural drought risk assessment in the Czech Republic. Agric For Meteorol 202:26–38. https://doi.org/10.1016/j.agrformet.2014.11.022

Powlson DS, Stirling CM, Jat ML, Gerard BG, Palm CA, Sanchez PA, Cassman KG (2014) Limited potential of no-till agriculture for climate change mitigation. Nat Clim Change 4(8):678–683. https://doi.org/10.1038/nclimate2292

Raška P (2015) Flood risk perception in Central-Eastern European members states of the EU: a review. Nat Hazards 79(3):2163–2179. https://doi.org/10.1007/s11069-015-1929-x

Ray DK, Gerber JS, Macdonald GK, West PC (2015) Climate variation explains a third of global crop yield variability. Nat Commun 6:5989. https://doi.org/10.1038/ncomms6989

Scarborough P, Appleby PN, Mizdrak A, Briggs ADM, Travis RC, Bradbury KE, Key TJ (2014) Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. Clim Change 125(2):179–192. https://doi.org/10.1007/s10584-014-1169-1

Schierhorn F, Müller D, Prishchepov AV, Faramarzi M, Balmann A (2014) The potential of Russia to increase its wheat production through cropland expansion and intensification. Glob Food Secur 3(3–4):133–141. https://doi.org/10.1016/j.gfs.2014.10.007

Semenov MA, Stratonovitch P, Alghabari F, Gooding MJ (2014) Adapting wheat in Europe for climate change. J Cereal Sci 59(3):245–256. https://doi.org/10.1016/j.jcs.2014.01.006

State Statistics Service of Ukraine (2018) https://ukrstat.org/en/operativ/operativ2006/sg/sg_rik/sg_e/rosl_e.html

Statistics Poland (2018) http://stat.gov.pl/en/topics/statistical-yearbooks/statistical-yearbooks/statistical-yearbook-of-agriculture-2017,6,12.html

Ulén B, Pietrzak S, Ramnerö B, Strand L (2016) Agricultural soil acidity and phosphorus leaching risk at farm level in two focus areas. Acta Agriculturae Scand Sect B—Soil Plant Sci 66(4):359–368. https://doi.org/10.1080/09064710.2015.1126631

Voziyan V, Yakobutsa M, Avedeniy L, Unguryanu V (2017) Reaktsiya novykh sortov zernobobovykh kul'tur na vozdeystviye zasushlivykh usloviy Beletskoy stepi Rspubliki Moldovy Nauchno – proizvodstvennyy zhurnal «Zernobobovyye i krupyanyye kul'tury» 1:4-8

Vserossiyskiy nauchno-issledovatel'skiy institut gidrometeorologicheskoy informatsii (2018) http://meteo.ru/

Wibig J (2017) Heat waves in Poland in the period 1951–2015: trends, patterns and driving factors. Meteorol Hydrol Water Manage 6(1):37–45. https://doi.org/10.26491/mhwm/78420

Wypych A, Sulikowska A, Ustrnul Z, Czekierda D (2017) Temporal variability of summer temperature extremes in Poland. Atmosphere 8(3):51. https://doi.org/10.3390/atmos8030051

Cross-Boundary Cooperation Between Bosnia and Herzegovina and Their Neighboring Countries Focusing on an Efficient Hail Protection as an Active Response to Global Climate Changes

Milenko Živković, Tihomir Dejanović and Mira Mandić

Abstract Consequences of climate change affect development processes, geo-system sustainability, the long-term development goals, and provoke raising demand for adequate models and approaches to development strategies. The paper discusses matters related to natural disasters and risk reduction, with a focus on hail occurrence, examining its consequences within Bosnia and Herzegovina (B&H). The final aim of this research is to provide a contribution towards seeking an active response to problems related. Considering a whole range of pertinent geographical facts, historical experiences and presumptions, it has been suggested that the cross-boundary cooperation concept is the optimum solution for the defined problems and achievement of appropriate sustainable development strategy. Therefore, the topic has been addressed through the role and relevance of cross-boundary cooperation between Bosnia and Herzegovina (focusing only on the B&H entity—Republic of Srpska as a hail-exposed area possessing anti-hail protection) and its neighbouring countries (Croatia and Serbia). Within this context, real and potential hail risks and consequences, as well as measures and long-term activities defined for the purpose of addressing and minimizing these problems, have been discussed. Comparative analyses of relevant indicators and methodological procedures were capitalized in order to meet the primary goal. Among other things, the paper defines measures and long-term activities of mitigation and efficient management of hail risk, in order to improve geo-system sustainability by initiating cross-boundary cooperation between Bosnia and Herzegovina and neighbouring countries. The paper is both fundamental and

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applicative and its recommendations can be applied to development strategies and might provide a crucial contribution to the integral sustainable development of the areas along the borderline of the defined geographical region and its geo-systems (ecosystem, settlement system, commercial system, etc.).

Keywords Bosnia and Herzegovina · Climate changes · Hail
Cross-boundary cooperation · Risks · Geo-systems · Sustainable development

1 Introduction

Bosnia and Herzegovina is part of the Southeast Europe association (West Balkans). It consists of the two political-geographical subjects (entities)—Federation of Bosnia and Herzegovina (FB&H) and the Republic of Srpska (RS) and one self-governing administrative unit—Brčko District. Bosnia and Herzegovina covers 50,129 km^2 and has a population of around 3,800,000 people (2013). The country's geographical space is determined by different morphological units: Pannonia in the north, mountain-lowland area in the central and eastern part of the country and Adriatic in the south. The borderline is mostly determined by river streams as follows: the Una and Sava rivers (northwest and north) on the Croatian border and the Drina River (east) on the Serbian border.

Global climate changes are, by multiple criteria (scientific, economic, ecological, political), one of the urgent problems of the modern world (IPCC 2014). Along with its neighboring countries, Bosnia and Herzegovina (being a poorly developed geo-space) is sensitive to consequences of global climate change. This has been supported and elaborated by earlier studies and the current state of affairs. Frequent hail occurrence is one of the global climate change consequences and Bosnia and Herzegovina is located at longitudes typical for thunderstorms and hail during spring and summer periods. It is hail that causes damages to agriculture as well as to other material goods, both movable and immobile, and threatens sustainability of specific geo-systems and overall development processes (Anti-hail protection 2005–2014).

Over the last few decades, hail studies have been paid large attention since this phenomenon is one of elementary weather conditions. In addition, global climate changes have largely affected the air temperature increase and fluvial regime, which has led to atmospheric instability. North Bosnia and Herzegovina (the Republic of Srpska) and most of its regional surrounding areas (continental Croatia and Serbia) have been targeted by anthropogenic activities focusing on anti-hail protection over the last five decades. Modern anti-hail protection in these countries was initiated in SFR Yugoslavia in the 1960s. However, due to the geopolitical disintegration of Yugoslavia, poor inter-state relations and connections are present, affecting anti-hail activities as they became uncoordinated and the anti-hail rocket usage was limited within the areas along the borderline (up to 10 km). This limitation directly impaired the methodology of actions against hail clouds, which demand strokes against the front side of the cloud where the strongest upward flows are located. Taking into account that all these countries use an identical anti-hail system, there is a 20 km wide belt of inadequate anti-hail protection coverage along both sides of the borderline.

The climate change trend is yet another aggravating circumstance. According to climate models presented by Intergovernmental Panel on Climate Change (IPCC), the negative global climate change trend shall continue in this century (IPCC 2014). The connection between climate changes and hail occurrence originates in the increased temperatures on Earth, which directly lead to atmospheric instability and frequent and intensive hail. The disturbance of the pluviometric regime, in which precipitation occurs with greater intensity during shorter periods, causes the same problems. Hence, in the actual scenario of climate change, the active anti-hail protection is a direct response with a single objective: to prevent and decrease negative consequences of climate changes. The problem of the current global climate change and its impact demands novel environmental models, as well as individual and integral development strategies (Trbić et al. 2010; Trbić et al. 2018) at multiple levels (local, regional, state, cross-boundary, etc.), based on principles of sustainability.

There are many international agreements on global climate change (United Nations Framework Convention on Climate Changes, Kyoto protocol, etc.) which make it mandatory for the signatory countries, including B&H, to mutually cooperate and exchange experience, knowledge and technologies, and develop strategies focusing on the reduction of consequences of climate change. The 6th "Environment for Europe" Ministerial Conference (Belgrade 2007) resulted in the adoption of the so-called *Belgrade Initiative on Climate Changes,* which started the cooperation within the countries of the Southeast Europe. Eventually, the 2008 Regional Framework Action Plan for Climate Changes and International Cooperation (CCA Forum 2012) was finalized. Therefore, as a new type of spatial-functional organization of bordering areas, the cross-boundary cooperation is regarded to be the most adequate approach to this and similar problems of bordering area development.

Practice in some countries has confirmed that the concept of cross-boundary cooperation integrates a range of development problems crucial for the sustainable development of bordering areas (Živkovic and Mandić 2012). Therefore, this paper has been focused on demands for cross-boundary connections between Bosnia and Herzegovina (the Republic of Srpska) and its neighboring countries (Croatia and Serbia) by starting a whole range of activities targeting a more efficient anti-hail protection and sustainability of borderline geo-systems.

2 Methodological Approach

The methodological approach is based on both empirical knowledge and methods of comparative analysis of multiple indicators. The evaluation of hail frequency is provided through the comparative analysis of timeline (1995–2004 and 2005–2014) within the observed areas in Bosnia and Herzegovina (the Republic of Srpska), Croatia and Serbia. Earlier data was used to monitor hail occurrence only in Croatia and Serbia and therefore it has not been included in the analysis. The comparative analysis of data obtained from relevant institutions (weather institutes, ministries, institutes) and other pertinent sources which deal with the defined issues, was performed and the analytic-synthetic method was used to determine real and potential hail risks and consequences, as well as essential problems of the active anti-hail protection. Based on the obtained results, we have defined measures and long-term activities which should help solve current issues. Hence, the analytic-synthetic approach and the application of different techniques and methods (comparative interpolation, approximation, regressive analysis, etc.) were capitalized in order to address the aim of the paper.

The applied methodology resulted in a concise definition of hail dynamics, i.e. definition of real and potential hail risks and consequences, as well as potential protection improvements in some geo-systems (agrarian, settlement, ecosystem, etc.) by using the cross-boundary cooperation approach, which was the primary objective of the paper.

3 Results

3.1 Geospatial Determinants of Bosnia and Herzegovina Within the Context of Cross-Boundary Cooperation and Development

The bordering areas along the Sava and Drina rivers (Croatian and Serbian borders respectively) are the only hail-protected areas in B&H and they are completely located within the Republic of Srpska entity (Fig. 1). These areas are the most densely populated areas in RS and are characterized by mostly cultivated agrarian soil, developed urban and rural systems, and valuable ecosystems.

The basic anti-hail problem within the defined geographical space (10,000 km^2) is the inability to fully activate the anti-hail protection as it is a bordering area, and it is forbidden to launch rockets 10 km along the borderline. Croatia and Serbia are facing identical problems in their areas bordering the Republic of Srpska. These problems reduce the efficiency of the anti-hail service in these countries.

The inadequately protected area in RS covers more than 500 km along the borderline, a surface of around 5000 km^2 (50% of the protected territory) with approximately 300 settlements and 300,000 people (1/4 of RS population). Apart from the anti-hail protection, the bordering area suffers from a whole range of development issues such as the bordering river flow valorization (sail, tourism, hydro-potential, etc.), flood protection, water ecosystem protection, and improvement of economic, social and infrastructural problems. Hence, there emerges a question of the optimum valorization and a more rational spatial-functional organization, i.e. the total sustainable development of the bordering areas.

The European Union (EU) addresses the matter of a rational spatial-functional organization of bordering areas through the concept of cross-boundary cooperation.

Fig. 1 Areas covered with anti-hail protection in Bosnia and Herzegovina (red), Serbia (blue) and Croatia (yellow)

When it comes to the development policies of EU, cross-boundary cooperation has the primary role in the spatial-functional organization of bordering areas, with an aim to improve the coherency and development sustainability by including them in the development processes of the regional environment (Živković et al. 2016a). In B&H and its neighboring countries, cross-boundary cooperation is insufficiently recognized as a factor of development of bordering areas. Even some Interreg IPA programs of cross-boundary cooperation between B&H and the neighboring countries exist, including the risk prevention program. However, they are nothing but informative. The problem is the lack of information about the role and relevance of the current paradigms on regional EU policies in solving a whole range of development issues, including the development problems defined in this paper (Živković et al. 2016b). Therefore, the application of the cross-boundary cooperation concept may help treat the matter of anti-hail defense in both B&H and its direct regional environment.

3.2 The Real and Potential Problems of Hail Risk and Consequences

The worldwide monitoring of global climate changes and their consequences indicates a growing climate change within the geographical space of B&H and the neighboring countries. The Second B&H National Report, in line with the UN Framework

Convention dating from June 2013, outlined the trend of the local climate change. Based on comparative analysis for the 1961–1990 and 1981–2010 periods, the estimated annual temperature increase was 0.4–0.8 °C and, during the vegetation period, the increase reached 1 °C. The precipitation comparison for the provided periods registered a decrease of days with precipitation of less than 1 mm and an increase of days with intensive precipitation. In other words, the pluviometric regime was disturbed (Second National B&H Report 2013). Hence, these are all negative trends in the behavior of climate elements which directly affect the hail occurrence.

Over the past decades, Bosnia and Herzegovina, Serbia and Croatia have performed individual analyses for the purpose of their own anti-hail services. These analyses treated different time periods and hail occurrence within the defended areas of the three countries. The 2004–2014 analysis of hail occurrence in Bosnia and Herzegovina reveals that in the north part of the country, during the warm period of the year (April–October), we can expect 27.6 hail days, when compared to the 1995–2005 period which had an average of 10.5 hail days (Dejanović 2015). The frequency of hail days almost tripled, as well as the coverage of the defended area (Table 1).

The hail frequency becomes even more evident if we compare it with the monitored periods in Croatia, where the defended area is identical, and in Serbia, where it is smaller. In addition, the number of hail days in both countries has increased (Table 1). According to Croatian research studies, the average hail days for the 2002–2017 period was 59. If we compare it with the 1981–2001 period, when there were 75 thunder days, 35 hail days and 19 days with hail damage, we may infer that there has been a large increase in the number of days with hail damage (Počkal 2012). The comparative analysis of the 1995–2004 and 2005–2014 periods indicates a mean hail frequency increase per 4.3 days, i.e. the number of days increased from 58.5 to 62.6 a year.

A similar tendency in climate element change was observed in Serbia. The comparative analysis of hail occurrence in Serbia for the 1995–2005 and 2005–2014 periods indicates a mean hail frequency increase from 49.2 to 55.8 days a year (Table 1). The same study found an annual average of 57.5 hail days in Serbia for the 2001–2012 period. The fluctuation of climate element values and frequent hail occurrence are evident as we compare the minimum and maximum values. The minimum number of hail days in Serbia was registered in 1985 (30 days) and the maximum number of days was registered in 2002 (83 days) (Nađ and Vujović 2017).

The monitoring corroborates the growing frequency of cumulonimbus hail clouds (Cb), the hail occurrences and, finally, the damages it causes to specific geosystems. As we compare the hail-exposed territory and the hail frequency, it becomes evident that the B&H (RS) area is susceptible to hail risks as a consequence of hail cloud movement. The territory profile, the altitude, the long state borderline, and the methodology of actions against the hail clouds only complicate the problem of an efficient protection. This is the main reason why the cross-boundary cooperation is crucial. It is the inclusion of Croatia and Serbia into the system of anti-hail protection within the observed area of B&H (RS) that would help improve the efficiency of protection in the entire region.

Table 1 Number of hail and sleet days and surface (km^2) of the defended area in Bosnia and Herzegovina, Republic of Croatia and Republic of Serbia for the 1995–2004 and 2004–2014 periods

Periods	Bosnia and Herzegovina (The Republic of Srpska)			The Republic of Croatia			The Republic of Serbia		
	Hail and sleet (days)	Annual average (days)	Surface (annual average km^2)	Hail and sleet (days)	Annual average (days)	Surface (annual average km^2)	Hail and sleet (days)	Annual average (days)	Surface (annual average km^2)
1995–2004	105	10.5	3110	585	58.5	25,000	492	49.2	81,900
2005–2014	276	27.6	8290	626	62.6	25,000	558	55.8	77,500

Source Anti-hail Prevention Service of the Republic of Srpska; Croatian State Weather Institute; Serbian State Weather Institute

3.3 The State and Problems of the Active Anti-hail Protection in B&H and Neighboring Countries

The organized hail defense was initiated in Serbia and Croatia in 1967 and in Bosnia and Herzegovina in 1971 (Dejanović and Kovačević 2014). In the former SFR Yugoslavia, the hail protection was well-planned in Slovenia and Macedonia, but it was never initiated in Montenegro. Once Slovenia gained independence, the state's hail protection service ceased to operate and the same happened in Kosovo as the crisis began in this Serbian province. The hail protection services are still active in Bosnia and Herzegovina, Croatia, Macedonia and Serbia. Generally, they use anti-hail rockets as the basic tool for the injection of silver iodide reagent (AgI) into the cumulonimbus hail clouds (Cb). In addition, Croatia uses ground generators which burn the silver iodide from acetone. The efficiency of anti-hail services in Bosnia and Herzegovina and neighboring countries ranges within 50–70%. Some of the effects are as follows: rarer hail occurrence, decrease of hail grain size and its kinetic energy, the hail becomes more liquid and softer which minimizes the damages, and the threatened area is smaller.

The B&H anti-hail protection service is a public company named „Anti-hail prevention of the Republic of Srpska" and operates under the jurisdiction of the RS Ministry of Agriculture, Forestry and Waters. It covers 24 local governments, which is more than 10,000 km^2 of protected area (Fig. 1). The Service has been active since 1971 and it is generally engaged in the protection of agricultural production in the north of B&H (RS) where the majority of the state's agricultural production is located. The PRV-11 radar with a 200 km reach was introduced in 1995, after which modern computer and telecommunication tools have been engaged in order to provide satellite and radar footage from the neighboring countries. Nowadays, „Anti-hail prevention of the Republic of Srpska" owns the modern DWSR-3501C weather radar (the installation of the second radar of this type is pending). The long-reach anti-hail rockets are set off from 215 anti-hail stations. During the legally regulated season (April 15–October 15), there are approximately 50 days characterized by unstable atmosphere, and the meteorological criteria for action is 27 days. In average, around 750 anti-hail rockets are set off yearly. The key effect of the Service's actions is the decrease in hail damages of up to 70%, mostly in agricultural production (Dejanović and Kovačević 2014).

In Serbia, the anti-hail protection is under the jurisdiction of the Republic Weather Institute of Serbia. The Service has at its disposal 13 radar centers and 1650 active anti-hail stations, from which anti-hail rockets of 6 and 8 km reach are set off. The whole Serbian territory, except Kosovo and Metohia, is protected, which is a surface of more than 77,500 km^2 (Fig. 1). In average, Serbia has 110 days of potential hail clouds and they use rockets during approximately 60 days. The war year of 1999 was atypical because back then the anti-hail protection in Serbia did not work. The state registered an increase in hail-affected areas in 1999, which was a direct consequence of no action taken against hail clouds. According to the internationally verified and published results, the efficiency of anti-hail protection in Serbia is of

63–74%. The mean hail frequency has been 25% smaller ever since the hail protection was introduced when compared to the earlier period (Kardum 2007).

Activities of anti-hail protection in Croatia are conducted under jurisdiction of the State Weather Institute. The protected geo-space covers the space between the Sava and Drava rivers, Medjimurje, and a part of the area between the Sava and Kupa rivers (Fig. 1). The defended surface is around 25,000 km^2 with 590 generator stations out of which 365 are equipped with rockets. The state service has at their disposal 8 radar centers. In 2001, a law regulating the hail protection system was adopted and its primary objective was to point out the protection pertinence and regulate funding within this field in the Republic of Croatia. Based on information obtained through years of monitoring by the Croatian State Weather Institute, the Hail Department, pertinent data has been obtained on the efficiency of hail protection, indicating a decrease in the mean number of hail days within the defended area (April–October season) by 22% (Croatian State Weather Institute).

The Zagreb and Belgrade Weather Institutes were responsible for the anti-hail protection in the former SFR Yugoslavia. The modern interstate cooperation (B&H, Croatia, and Serbia) dates back from that period, when they jointly designed methodology for hail prevention, and the cooperation continued after the 1990s. The initiator of the cooperation was the RS Anti-hail protection service (B&H). The new level of cooperation among the anti-hail services of B&H, Serbia and Croatia was prompted by the necessity to improve the methodology of action against cumulonimbus hail clouds (Cb), radar equipment, and the agreement on free anti-hail rocket launching along the borderline. The Republic of Srpska Anti-hail Service (B&H) benefited from the cooperation with Serbia and Croatia and the methodology of action against hail clouds was "scientifically refreshed". In addition, radar footage was easily transferred from meteorological radars via links.

As the direction and speed of hail clouds movement, their life cycle and the area where they emerge are observed, the geographical defended area in these three countries is rather small. However, if we consider the problem of hail within a wider context, we might refer to it as the regional anti-hail protection in Pannonia and the south Peri-Pannonian rim where anti-hail services from Bosnia and Herzegovina (RS), Serbia, Croatia, Hungary and Romania are active. Because the hail clouds intrude B&H and neighboring countries from the west, southwest and northwest, it is in Serbia's and Croatia's interest to help technical-methodological improvement of RS anti-hail protection, its territorial reach, and, finally, specific types of cooperation (transfer of anti-hail methodology, staff training and exchange, transfer of radar footage and measurements). Having compared anti-hail methodologies from the Serbian and Croatian Weather Institutes, a most efficient methodology of anti-hail action in Bosnia and Herzegovina was obtained. Hence, the hail-risky clouds were weakened and suppressed before they crossed the Sava and Drina rivers. The Agreement on special and parallel connections between Serbia and The Republic of Srpska helped and supported a more intensive cooperation.

Despite certain types of cooperation between the anti-hail services of Serbia, Croatia and B&H (The Republic of Srpska), their relations are still not official and the benefits from the information and technological progress within the field of anti-hail protection are not fully capitalized on. In addition, initiatives for free launching of anti-hail rockets along the borderline have never been properly discussed among the authorities in Croatia, Serbia and Bosnia and Herzegovina. Meanwhile, the B&H anti-hail service has, technologically speaking, either overtaken or outperformed services in Serbia and Croatia, which have been meeting more and more difficulties with radar resources and staff age.

3.4 Potential Improvement of Anti-hail Protection Through Cross-Boundary Cooperation

The cross-boundary cooperation among the B&H (RS), Serbian and Croatian anti-hail services is realized through the exchange of radar footage, design of joint composite radar image, exchange of technologies and improvement of methodology of hail suppression. Speaking of the interstate cooperation of the three countries, it is crucial to solve the issue of activities of anti-hail rocket system along the borderline area.

A good example of a technical solution is the transfer of radar footage via a link and independent measurements (initiated by the Republic of Srpska prevention team). The practice has confirmed the advantages of this innovation and others have shown interest into its application. Apart from saving electricity, there is also a rational amortization of the radar resources. The greatest achievement is the ability to take over the radar footage from neighboring radar centers and the continuous measurement and monitoring of hail clouds. The technical properties of radars owned by Bosnia and Herzegovina, Serbia and Croatia enable coverage of most of the geographical area encompassed by the unique composite radar footage (Fig. 2). It is this procedure that would provide a more precise image of meteorological processes and cloudiness, as it would be taken from different angles. A sound ground for the realization of this technical solution is the successful design of an internal composite image in Serbia and Croatia by their national weather bureaus. If realized, the solution would help the initiative for the creation of composite footage, not only in these three countries but also in Southeast European countries and Europe in general.

The technology transfer among the three countries is most probable to be a success if the technical solutions [i.e. the ground silver-iodine generators (AgI)] from Croatia are applied in B&H and Serbia as well. This French-originated technology came to Croatia through Hungarian experiences. It is less efficient than the rocket technology of reagent injection into the clouds. Still, its advantage is that it is a free application in line with air traffic and bordering areas regulations.

It is crucial to improve the hail-protection methodology and exchange it among the three services. In this regard, it should be pointed out that results have been achieved in the Republic of Srpska (B&H) where several double-polarized meteorological radars were introduced into parameters of cumulonimbus hail clouds (Cb). Still, the

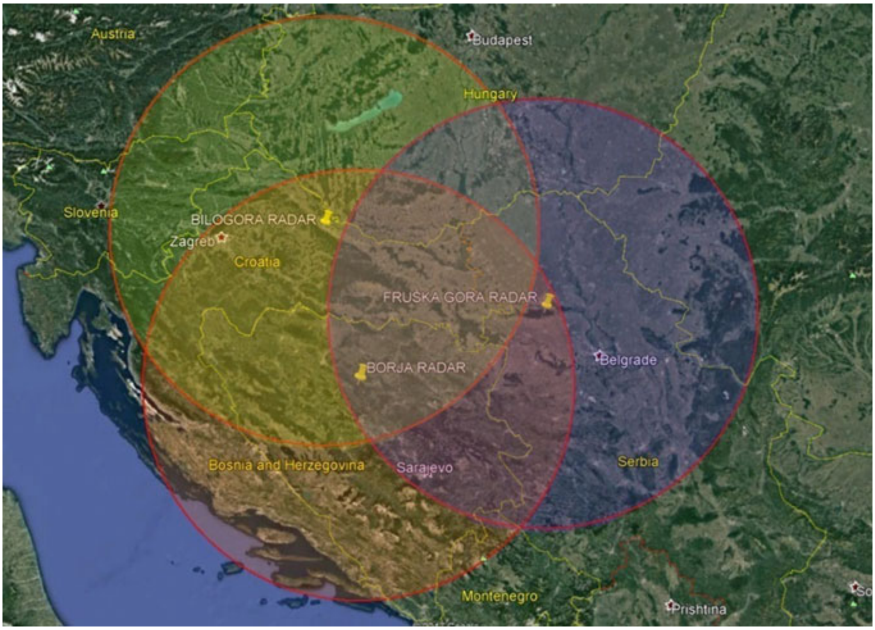

Fig. 2 Radar coverage by meteorological radars in Borja (B&H)—yellow, Bilogora (Croatia)—green and Fruška Gora (Serbia)—blue, within 200 km observation reach

novel methodology should be virtually verified and participation of more interested parties would help a more adequate implementation in social practice.

4 Conclusions and Recommendations

Results of hydro-meteorological measurements and monitoring of values of specific climate elements (specifically hail) within Bosnia and Herzegovina and its wider environment corroborate the theory of global climate change. Climate changes do produce different crises, negatively affecting the overall national and regional development. Generally, risk management should be treated as a part of integral development and resource management in order to sustain and improve ecosystem development, including economic, social, settlement and infrastructural systems. These facts indicate that it is crucial to integrate the anti-hail systems of Bosnia and Herzegovina, i.e. the Republic of Srpska, within the systems in the neighboring countries (Serbia, Croatia) due to the increasing frequency of hail occurrence.

A necessarily joint and coordinated anti-hail system would only confirm the relevance of cross-boundary cooperation at different levels. Cross-boundary cooperation on an example of anti-hail protection of Bosnia and Herzegovina (RS), Serbia and

Croatia displays positive results. These results refer to the regional cooperation of anti-hail services, monitoring, information exchange and harmonization of monitoring methodology.

The cooperation still needs to be expanded, based on international agreements, and institutional capacities must be improved in order to efficiently support the sustainability of the existing geo-systems and the total development. The lack of political wills (poor international cooperation) represents the limitation to an efficient system. The factors which still obstruct the total development are poor awareness and lack of education on climate change risks, geo-system threats, and the necessity to set cross-boundary cooperation. Finally, there are several recommendations to be pointed out within the target subject:

- Improvement of knowledge and awareness of the global climate change issues, more specified hail occurrence and consequential negative effects on development strategies and total sustainable development.
- Estimation of hail dynamics, problems and potentials of the active anti-hail protection within the defined geographical area.
- Need for designing framework for measures and long-term activities in hail prevention and addressing hail-caused consequences in different ecosystems (improvement of anti-hail systems and establishment of regional cooperation).
- Designing framework for initiation of programs and projects within the climate change field, which means institutional participation, cross-boundary cooperation, development and transfer of technology and knowledge for the purpose of sustainable development.

References

Anti-hail Protection Report (2005–2014) Documentation, Croatian State Weather Institute, Department of anti-hail protection, Zagreb

CCA Forum (2012) South East European forum on climate change adaptation, estimation of vulnerability to climate changes. Belgrade

Councils of Ministers (2013) The second Bosnia and Herzegovina National Report in line with UN framework convention on climate change. B&H, Sarajevo-Banja Luka

Dejanović T (2015) Hail as a weather condition in the north Republic of Srpska (Master thesis). The Faculty of Mathematics and Natural Sciences, University of Banja Luka

Dejanović T, Kovačević J (2014) Anti-hail Protection in European Countries. Grafomark, Laktaši

IPCC (2014) Climate change 2014: synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change [Core Writing Team, RK Pachauri and LA Meyer (eds)]. IPCC, Geneva, Switzerland, p 151

Kardum Đ (2007) Anti-hail protection in Serbia, 1967–2007. State Weather Institute, Belgrade

Nađ J, Vujović D (2017) Trend of hail occurrence in Serbia in the period 1981–2012. Paper presented at The Second European Hail Workshop. University of Bern, Switzerland

Počkal D (2012) Energy of hail grains in continental Croatia (Doctoral thesis). Department of Geophysics, Faculty of Mathematics and Natural Sciences, University of Zagreb

Report on the Annual Work (2005–2014) Documentation, Anti-hail Prevention of the Republic of Srpska, A.D. Gradiška

Report on the Annual Work (2005–2014) Documentation, Serbian State Weather Institute, Belgrade
Trbić G, Ducic V, Rudan N, Majstorovic Z, Lukovic J (2010) Regional changes of precipitation amount in Bosnia and Herzegovina. In: 6th international scientific conference dedicated to the international earth day, 16–17 Apr 2010, Sofia, Bulgaria, pp 62–64
Trbić G, Bajic D, Djurdjevic V, Ducic V, Cupac R, Markez Đ, Vukmir G, Dekić R, Popov T (2018) Limits to adaptation on climate change in Bosnia and Herzegovina: insights and experiences, limits to climate adaptation. Cham, Switzerland, pp 245–259
Živković M, Mandić M (2012) Cultural landscape in theory and practice of spatial planning. Herald 16:61–73. Geographic Society of Republic of Srpska, Banja Luka
Živković M, Mandić M, Papić D, Stanojević M (2016a) Cross-boundary cooperation as a factor of development of Bosnia and Herzegovina within the EU integration pocesses. Int J Econ Manag Syst 1:208–213
Živković M, Mandić M, Papić D, Stanojević M (2016b) Cross-boundary cooperation in service of development of Bosnia and Herzegovina—the sample of priority backward areas along the borderline. Weas Trans Envir Dev 12:326–331

Analysis of Existing Disaster Risk Reduction Programs and Enhancement of Capacity Development for Health Risks from Floods in Western Balkan

Gethmini Pabasara Appuhamilage, Jelena Barbir and Xavier Rodriguez Lloveras

Abstract Natural hazards are a result of changing climate and environmental conditions and, as such, they are inevitable. However, the scale of the negative outcomes of these natural hazards can be significantly reduced through management and adequate preparation. Therefore, integration of Disaster Risk Reduction (DRR) policies and programs with risk management is necessary in order to reduce the impact of disastrous situations, and Capacity Development is the catalyst for the successful implementation of such programs. This paper presents an analysis of international frameworks for risk reduction such as the Hyogo Framework for Action (HFA), the Sendai Framework, the South Eastern Europe Disaster Risk Mitigation and Adaptation Programme (SEEDRMAP), as well as few individual national programs within the Western Balkan countries. After analyzing the aforementioned programs and policies, special emphasis has been given to the need for capacity development for human health factors in regards to flooding (the most frequent natural hazard in the region). The revision showed poorly addressed human health effects (physical and mental) caused directly or indirectly by floods in the region. Therefore, the paper presents several recommendations which could foster implementation of prerequisites for those absent policies and programs for human health, with final aim to contribute to healthier solutions during the aftermath of flooding for people in the Western Balkan area.

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1 Introduction

In the fifth assessment report submitted in the year 2014, the Intergovernmental Panel on Climate Change (IPCC) stated that many climate-related hazards are projected to increase in frequency and intensity, with significant variations within different regions of Europe. Furthermore, specific climate changes in Eastern Europe were predicted as follows:

- Extreme meteorological and climatic events such as heat waves, droughts and intense precipitations are expected to increase (Beniston et al. 2007; Lenderink and Meijgaard 2008).
- Hydrology of river basins is expected to suffer significant changes (IPCC 2012). As an example, Danube tributary basins are expected to provide increased discharges to the river as a consequence of the precipitation intensity increase (Dankers and Feyen 2008).
- In addition to meteorological and climatic factors, urban development is projected to boost all over Europe (Reginster and Rounsevell 2006, especially in Eastern Europe, with the magnitude of increases depending on population growth, economic growth and land use planning policy. Although changes in urban land use will be relatively small in terms of expansion, mainly affecting local environmental quality, they will result in increased exposure of persons and properties to floods (Barredo 2009).
- According to an indicator-based report on climate change impacts and vulnerability in Europe in 2016, flood risks are highest in large parts of Eastern Europe, in terms of regional gross domestic product (GDP).
- Another consequence of floods is the stress that flood victims are exposed to which, besides affecting their mental health during that period, can persist a long time after the event has passed. Health system infrastructures (e.g. hospitals) are vulnerable to extreme weather consequences, in particular to floods, which cause disruption of health services, access to safe water, sanitation and transportation (Radovic et al. 2012; Stanke et al. 2012; Brown and Murray 2013; WHO and PHE 2013).

In this study, international, regional and national policies of Disaster Risk Reduction (DRR) in Eastern Europe over the last 10 years have been reviewed. In addition, consideration of impact of floods on human health in Eastern Europe in the DRR's agenda was evaluated.

Table 1 Total number of victims from natural disasters in Croatia

Period	No. of natural disasters	Total no. of victims (people killed or affected) by natural disaster
1994–98	2	2000
1999–03	6	1200
2004–06	4	257

Source UNISDR (2008)

1.1 Overview of Disaster Risk Reduction and Capacity Development

Disaster Risk Reduction (DRR) is the concept and practice of reducing disaster risks through the systematic analysis and management of the causal factors of disasters, including hazards exposure reduction, people and property vulnerability decrease, implementation of sustainable measures of land and environment management and improvement of preparedness for adverse events (UNISDR 2017).

Individuals are familiar with the term 'natural disasters', which are Earth processes over which humans have no direct control. However, human actions, focused on awareness and resilience increase, can reduce the level of vulnerability of communities exposed to natural hazards.

Advances in technology, early experiences assisting the formation of new policies and DRR programs can prominently decrease the severity of a natural disaster's outcome. The table below depicts how in Croatia the number of victims was decreased due to measures mentioned above (Table 1).

DRR focuses on improving prevention and mitigation of natural disaster effects, rather than simply reacting to them. Natural, environmental phenomena become 'disasters' due to a lack of resilience defined as the capacity to respond or cope with its effects. Hence, capacity development is a central strategy for reducing disaster risk (ISDR 2007).

The UNDP defines Capacity Development as "the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time (UNDP 2016)."

$$Risk = \frac{Hazard \times Vulnerablity \times Exposure}{Capacity} \quad (1)$$

According to the above Eq. (1), risk is one part of a composite form which is generated by hazards, vulnerabilities and exposure. Of these three factors, the human activities can produce changes in vulnerability and exposure, as hazard is generally referred to the natural phenomena which can hardly be prevented. Regarding vulnerability it can be listed in general terms as socially accepted impediments such as poverty and gender inequality. As for exposure, this is usually increased by urbanization pressure which forces the construction on areas susceptible to suffer the effects of natural disasters (such as flood plains). Furthermore, capacity is the only factor that can reduce the disaster risk. In common terms, this factor can be described as the resources available for use in planning, achieving and recovering.

1.2 Overview of Existing Disaster Risk Reduction Programs

1.2.1 The Hyogo Framework for Action (HFA)

The World Conference on Disaster Reduction was held from 18 to 22 January 2005 in Kobe, Hyogo, Japan, and adopted the Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters. The Conference provided a unique opportunity to promote a strategic and systematic approach to reduce vulnerabilities and risks. It underlined the need to identify and develop measures of resilience building for nations and communities, in front of natural disasters (UN 2005).

The HFA was conceived to give further force to the global work under the International Framework of Action for the International Decade for Natural Disaster Reduction of 1989, and the Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action, adopted in 1994 and the International Strategy for Disaster Reduction of 1999.

HFA is the key instrument for implementing Disaster Risk Reduction, adopted by the Member States of the United Nations. Its overarching goal is to build the resilience of nations and communities to disasters, by achieving substantive reduction of disaster losses by 2015—in lives and in the social, economic, and environmental assets of communities and countries. The HFA offers five areas of priorities for action, including guiding principles and practical means for achieving disaster resilience for vulnerable communities in the context of sustainable development.

The Five Areas of Priorities for Action are:

1. Make Disaster Risk Reduction a Priority—ensure that Disaster Risk Reduction is a national and local priority with a strong institutional basis for implementation.
2. Know the Risks and Take Action—identify, assess, and monitor disaster risks and enhance early warning.
3. Build Understanding and Awareness—use knowledge, innovation, and education to build a culture of safety and resilience at all levels.
4. Reduce Risk—reduce the underlying risk factors.
5. Be Prepared and Ready to Act—strengthen disaster preparedness for effective response at all levels.

Since the adoption of the HFA, numerous global, regional, national and local bodies have addressed Disaster Risk Reduction more systematically, although much more remains to be done. The United Nations General Assembly has called for the implementation of HFA and has reconfirmed the multi-stakeholder ISDR System and the Global Platform for Disaster Risk Reduction to support and promote it. The General Assembly has encouraged Member States to establish multi-sectorial national platforms to coordinate DRR in countries. Many regional bodies have formulated strategies on a regional scale for DRR in line with the HFA, in the Andean region, Central America, the Caribbean, Asia, Pacific, Africa and Europe. More than 100 governments have designated official focal points for the follow-up and the implementation of the HFA (March 2007). Some have taken actions to mobilize political commitment and establish centres to promote regional cooperation in disaster risk reduction (ISDR 2007).

1.2.2 The Sendai Framework for DRR

The Sendai Framework for Disaster Risk Reduction 2015–2030 is the successor instrument to the Hyogo Framework for Action (HFA) 2005–2015: Building the Resilience of Nations and Communities to Disasters. This framework was adopted at the Third United Nations World Conference on Disaster Risk Reduction.

The framework places a strong emphasis on disaster risk management with a view towards achieving substantial reductions in disaster losses over the next fifteen years. The Sendai Framework emphasizes the inclusion of gender, age, disability and cultural perspectives in all policies and practices (UNISDR 2017).

The Four Priorities for Action are:

1. Understanding disaster risk—disaster risk management should be based on an understanding of disaster risk in all its dimensions, such as vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be used further on for risk assessment, prevention, mitigation, preparedness and response.
2. Strengthening disaster risk governance to manage disaster risk—disaster risk governance at national, regional and global levels are very important for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.
3. Investing in disaster risk reduction for resilience—public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment.
4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction—the growth of disaster risk means that there is a need to strengthen disaster preparedness for response, to take action in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase is a critical opportunity to 'build back better', including through integrating disaster risk reduction into development measures.

The Seven Global Targets

1. Substantially reduce global disaster mortality by 2030, aiming to lower the average global mortality rate of 100,000 in the decade 2020–2030 compared to the period 2005–2015.
2. Substantially reduce the number of affected people globally by 2030, aiming to lower average global figure of 100,000 in the decade 2020–2030 compared to the period 2005–2015.
3. Reduce direct economic loss in relation to global gross domestic product (GDP) by 2030.
4. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, such as health and educational facilities by 2030.
5. Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.
6. Substantially enhance international cooperation with developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030.
7. Substantially increase the availability of, and access to multi-hazard early warning systems and disaster risk information and assessments for people by 2030 (UNISDR 2017)

In the Hyogo Framework for Action 2005–2015, scarce information was given about the important role of disaster risk reduction strategies in improving health outcomes for people at risk or affected by emergencies and disasters. Sendai Framework changed this, and health resilience is strongly promoted throughout the Framework (Maini et al. 2017).

1.2.3 The South Eastern Europe Disaster Risk Mitigation and Adaptation Programme (SEEDRMAP)

This program is a collaboration developed by the World Bank (WB) and the United Nations International Strategy for Disaster Reduction (UNISDR) Europe office with help from International Strategy for Disaster Reduction (ISDR) system partners, including the European Commission (EC), the European and Mediterranean Major Hazards Agreement, the Disaster Preparedness and Prevention Initiative for South Eastern Europe (DPPI SEE), the Regional Cooperation Council for South Eastern Europe (RCC SEE), the World Meteorological Organization (WMO), the United Nations Development Programme (UNDP) and other partners.

The objective of SEEDRMAP along with HFA is to reduce human, economic and financial losses due to disasters caused by the impact of natural and technological hazards, while enhancing countries' and communities' resilience to those hazards through a regional approach (UNISDR 2008).

The aim of SEEDRMAP is to develop and strengthen national capacities in this region by enforcing three components: (i) Disaster risk management institutional capacities and governance; (ii) Hydro-meteorological services and their cooperation with sectors; and (iii) Financial risk transfer mechanisms, to assist the beneficiaries in reducing risks associated with natural hazards.

The SEEDRMAP result assessment concluded that:

- It should explore the possibility of making funds available for translation of relevant documents into the languages of South Eastern European countries, and plan national events to increase the visibility of its products. Surveys and other tools could be used for information dissemination, informing different sectors, academies, media etc., along with enhanced information sharing among HFA focal points and national platforms in South Eastern Europe.
- Investments in prevention and preparedness should continue to be carefully examined to avoid duplications and should be based on a coordinated approach to implement regional strategies that would further ensure sustainability at national level.
- Objectives of the program and envisaged activities under this component should also be screened and specified to avoid duplications and redundancies, and clarify their suitability for the regional approach. Expected outputs should be specified and indicators used to monitor progress identified. It should be more specific about building relationships, i.e. in line with the implementation of the SEEDRMAP objective of anticipating possible partnerships, their expected outputs and the benefits of those partnerships.

2 Current Situation Regarding Disaster Risk Reduction in Western Balkan Region

2.1 Regional Background

The topography of the Western Balkan region is fundamentally determined by the Basin of the Danube River and its tributaries. Whereas the area of the Western Balkan mainly belongs to the catchment of the Danube, the southern and the south-western rivers discharge to the Adriatic Sea.

The large flatlands and the important variations of the terrain and the river network mean that large areas in the region are prone to be flooded, to a various degree. The occurrence of floods over the past five years has shown the importance of regional flood control and sustainable water management. The frequency and extent of severe floods along the Danube and the Sava River basin and their main tributaries (for example the Drina in Bosnia and Herzegovina (BiH) and the Kolubara in Serbia), justify the growing concern for human life, homes, heritage and the environment potentially affected.

The geo-morphological characteristics, the hydrological features of the watercourses, the geo-technical information and soil use and state (saturated soil conditions during heavy rains, steepness and vegetal cover of hill sides, ravine location, presence of gullies), have strong influence on flood types. In some areas of the Western Balkan, such as in Albania, Macedonia and Montenegro, terrain characteristics can favour devastating flash floods as a consequence of torrential precipitation. In Kosovo, topography and terrain characteristics can induce flash floods in hilly areas, while major flooding can occur in low lands and even "dam-failure" situations are plausible (breakage or leakage due to the operational structure and locks failing to support increased water pressure, earthquakes, landslides or rock falls). All this could result in major flood damage. In fact, there is potentially significant flood risk throughout the entire region, especially in highly populated areas. However, Albania, Bosnia and Herzegovina and Serbia appear to be the most vulnerable countries in the WB Region, as they have been the most affected areas over the past five years. Although floods can occur at any time of the year, most of them occur during spring, due to the seasonal rainfall increase and snow melting (Fig. 1).

The Western Balkan countries are every day more exposed to the impact of climate change. They are experiencing increased periods of extreme heat in the summer months and increased rainfall during the cooler seasons. According to long-term projections, the average annual temperature will increase by 2–3 °C by 2050 and precipitation will decrease in the summer, resulting in longer dry periods followed by more sudden, heavy rainfalls. This combination increases the likelihood of sudden floods as well as their destructive nature whilst decreasing the region's reaction time to these floods. In short, the risks of floods, which already constitute the most frequent natural disaster in the region, are increasing (EC 2014).

2.2 Analyzing Regional and National DRR Frameworks and Programs in Western Balkan

All the aforementioned countries have their own national policies/frameworks/programs regarding disaster risk reduction based mainly on the HFA and Sendai Framework.

Education and innovation are important elements that have a high potential to effectively contribute to DRR. Little progress has been made in documenting systematically how and what organizations and nations have learned from past disasters, what improvements have resulted from them, and how the lessons learned can be better monitored and evaluated. Examples of innovations in DRR exist, but its documentation and dissemination remains poor. We advocate that more attention should be paid to the lessons emerging from the AG literature, and that more research should be conducted on how communities learn and innovate from different types of disasters and within all stages of DRR (Djalante 2012). Nevertheless, recently new national initiatives have appeared in countries with increased risks to natural disasters.

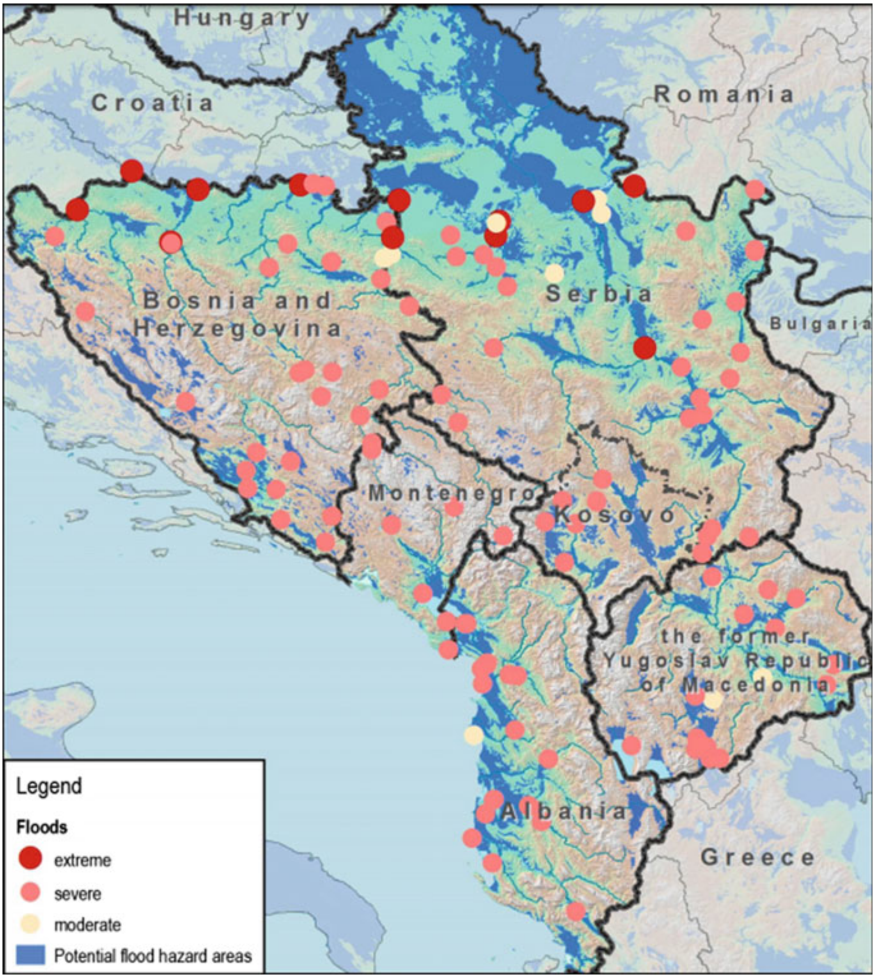

Fig. 1 The Flood History of 2010–2015 in Western Balkan. *Source* WBIF (2015)

2.2.1 Republic of Albania

Albania is vulnerable to floods, earthquakes, landslides, drought, extreme temperatures, windstorms and heavy snowfalls (which can generate avalanches) (Fig. 2). Therefore, the objective of new project "Albania Disaster Risk Mitigation and Adaptation Project (AL-DRMAP)" is to strengthen institutional capacities to: (a) reduce Albania's vulnerability to natural and man-induced hazards; and (b) limit human, economic and financial losses related with disasters (World Bank 2014).

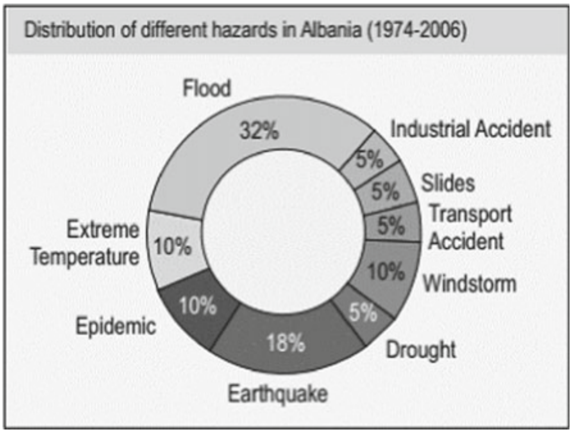

Fig. 2 Distribution of different hazards in Albania. *Source* UNISDR (2008)

2.2.2 Bosnia and Herzegovina (BH)

Flooding is the most frequent natural hazard in Bosnia and Herzegovina, occurring with yearly frequency and causing considerable damage to properties (UNDP 2015).

A framework for 'Law on Protection and Rescue' of people and material goods in case of natural or other disasters in BH came into force on July 2008. Operational-communicational center was formed and put into function in 2010 under the aforementioned law. Protection and rescue plan was implemented with following objectives,

- determining of organization, engagement and activities of the protection and rescue system, tasks and competences of manpower and necessary resources; measures and procedures for conduct of protection and rescue activities in case of natural or other disasters, i.e. for improvement of planning quality and enhancement of preparedness for natural and other disasters.
- determining of guidelines for development of protection and rescue plans in entities and Brčko District of BH.

However, this plan is still under development.

2.3 Republic of Croatia

Floods are the most prominent and frequent natural disaster, together with droughts, recorded in the country during the period 1989–2006. This disaster produces an average of nine victims per year and affects almost 109,000 people yearly (UNISDR 2008).

The project 'Disaster Risk Mitigation and Adaptation Project for Croatia (HR-DRMAP)' has being introduced in 2009, which intend to have two main components: (a) disaster preparedness and response; and (b) improvement of weather forecasting. Additionally this program has a secondary objective aimed to support project management.

The objectives of the project are: to enhance country's preparedness, to improve response to disasters, and to effectively monitor weather-related hazards. These objectives were developed in order to reduce disaster risk, and are expected to be achieved through strengthening the capacity to: (i) manage and effectively respond to natural and man-made disasters; (ii) monitor weather-related hazards through provision of accurate hydro-meteorological forecasts and services; and (iii) coordinate wildfire hazard risk reduction and response (DRMAP 2009).

The country's existing legislation indicates that its disaster-related laws are oriented to crisis management rather than to disaster preparedness or mitigation. The incorporation of risk reduction measures into development plans of various sectors seems weak in the country. Hence it is clear that Croatia does not have a proper hazard vulnerability or capacity mapping/assessment at the moment.

2.3.1 Former Yugoslav Republic of Macedonia

Macedonia is vulnerable to floods in terms of severity, impact and intensity. Flooding has contributed towards 44% of the natural disasters during the period of 1989–2006 (UNISDR 2008).

Legislations considered in different development plans, but it is not apparent that these plans include risk preparedness and mitigation. However, the "Law for Protection and Improvement of Living Environment" and the "Law for Spatial and Urban Planning" are providing a general umbrella under which Macedonia's disaster risk reduction efforts can be integrated. The legislation is focused towards rescue and security aspects. There is an existing framework for an emergency management system, with regional and local headquarters and regional and local task forces. There are also efforts towards legislative harmonization with European Union.

The country's initiatives to incorporate risk management into sectorial development plans that address both urban and rural areas are weak. The national report that was prepared for the 2005 World Conference on Disaster Reduction in Kobe, Japan, recommends research interaction with regional initiatives focused on implementing environmental management technologies. The report also recommends improvement of existing monitoring technology, and the development and deployment of a countrywide GIS-based disaster and environment management system. However, even though there is a common consensus in the country supporting development of this system, it is advancing due to lack of funds (UNISDR 2008).

2.3.2 Montenegro

Montenegro is vulnerable to earthquakes, floods and fires (forest and industrial). There are also man induced threats due mining and other industrial activities in the country. The Montenegro more fertile croplands are regularly flooded (UNISDR 2008).

The country has developed a broad framework under the Ministry of Interior for handling emergency situations and civil security. The National Spatial Plan of Montenegro is a comprehensive document highlighting some of the major hazards in the country which recommends a mitigation measures design plan. The report integrates mitigation measures into the spatial development plan. Nevertheless, vulnerability towards different hazards is still too high. In accordance with this report, developing a country-level GIS database can not only leverage the spatial planning activities, but also can help in a disaster management plan preparation for the country.

Montenegro requires legislation on land-use planning and building codes. It also requires an improvement on the fire fighting system, particularly in the most populated areas of the country. UNDP is present in Montenegro, assisting on the strengthening of the national capacities to manage the external assistance efficiently. Considering the size of the country and its geographical and geological characteristics, trans-boundary initiatives play a crucial role in disaster mitigation and preparedness (UNISDR 2008).

2.3.3 Republic of Serbia

According to a national report on disaster reduction progress, the biggest disasters that have affected Serbian citizens are floods, fires, earthquakes and technological hazards. The large watercourses that cross Serbian plains, agglutinates the largest settlements and the most fertile lands, which include critical infrastructure and most of the industry. These broad plains close to large watercourses are prone to floods.

In order to cope with these hazards, the National Disaster Risk Management program (NDRMP) supported by the Government of Serbia since 2015, creates a comprehensive program for disaster resilience. This program will be used as an umbrella framework to coordinate and channel funds to implement activities focused to reduce and manage risks in Serbia.

Analysis of the above programs and frameworks shows how poorly Eastern Europe addresses the Disaster Risk Reduction, and highlights the need to improve its development.

2.4 Health Risks Caused by Floods in Western Balkan

As mentioned above, it is evident that floods are the most common and disastrous natural hazards in Western Balkan. The health status is a key factor behind the vulnerability and resilience of communities to disasters, and is a major determinant of development outcomes associated with DRR (UN 2014).

The damaging effects of floods are complex. Floods frequently cause major infrastructural damage, including disruption of roads and rail lines, airport activity, electricity supply systems, water supplies and sewage disposal systems. The economic effects of floods are often much greater than indicated by the physical effects of water coming into contact with buildings and their contents. Indirect economic losses typically spread well beyond the flooded area and may last much longer than the flood itself. The local and regional economy may be badly affected by a major flood disaster and this may seriously affect the national economy (WHO 2002).

However, after assessing all the above frameworks and programs it is observed an absence of physical and mental health consideration as a consequence of disasters and its effects. The health sector is usually well-integrated into national disaster risk management systems in those countries with well-developed capacities. On the contrary, in other countries, there is a greater need to strengthen the limited capacity to cope with disasters of the health sector (UN 2014).

Bridging the transition from emergency health response to local health systems has not been adequately addressed in most post-conflict or post-disaster settings and especially in poor regions afflicted by recurrent conflicts or natural disasters. Abrupt departures of emergency teams may also leave patients without locally viable follow-up nursing care. Resolving such transitional issues, by reducing vulnerabilities and strengthening the resilience of local systems, will inform the strategies needed to address the root causes of these crises (Leaning and Guha-Sapir 2013).

The physical health effects that occur during or after flooding include: death, injuries, and infectious and respiratory diseases. The literature review showed that data on the health effects of floods is scarce. A critical priority in the studied countries must be the development or improvement of the data collection systems to provide the information necessary to determine the health systems vulnerabilities in front of floods. Additionally, it is necessary to develop instruments to improve the health risks assessment, as the lack of health data diminish the vulnerability mapping and the development of resilience building strategies.

The intersection of health and disaster risk reduction is a field of critical inquiry (Aitsi-Selmi and Murray 2015), essential to ensure the comprehensive implementation of the Sendai Framework—four of which are directly health-related. Health sector authorities and workers must be key contributing stakeholders to manage disaster risks by building community resilience (Lo et al. 2017).

There are many effects of floods on common mental disorders (including anxiety and depression), post-traumatic stress disorder (PTSD) and suicide. Most studies exploring the effects of flooding on common mental disorders came from high or middle-income countries, and results revealed significant increases in depression, anxiety and psychological distress among flooded adults; relatively few studies examined the effects of flooding on children, but those that did revealed increases in aggression, bedwetting and moderate to severe stress symptoms (Ahern et al 2005). In addition, certain subgroups of the population (children, low income families, etc.) are likely to be more vulnerable to mental disorders. The psychological effects may continue for months or even years after the flood events. This may imply that anxiety remains high in populations in flood prone areas due to the threat of future flooding. This also may reflect the stress of working with insurance companies, builders, etc., to repair flood damage. In general, most of the available funds are directed towards implementation of new programs/structural measures such as early warning systems, but less in victim's psychological and physical security.

3 Conclusions and Recommendations

Implementation of frameworks and programs is not necessarily enough when it comes to natural hazards. Different and varying forms of hazards which constantly change need specific research in national and regional DRR programmes. At the moment, regarding DRR, international journals address only some of the Eastern European countries when analyzing data. Therefore, it is necessary to complement this information regionally and nationally, by developing comprehensive strategies in which all the sectors may benefit. Regional mitigations and cross country policies can be crucial in Eastern Europe to overcome political barriers and development differences between countries, strengthening the capacity to address socio-economic issues and to mitigate natural disaster effects in the region.

Since, floods are the most common natural disaster in Eastern Europe, the health risks associated with this phenomenon are insufficiently considered, especially victims' physical and psychological damages and sequels. The paper addresses the need of inclusion of health in the capacity development for DRR. In addition, it recommends that focus must expand beyond the number of deaths and include injured, affected by disaster-related diseases, and loss of quality of life as long-term indicators of health and social outcomes. Health Personnel and Government sectors should be included in new plans in order to effectively handle health risks. Finally, this research stresses the fact that structural measures are highly important, but also emphasises the necessity to complement these measures with human physical and mental health safety, as it has long-term implications on an individuals' quality of life.

References

Ahern M, Kovats RS, Wilkinson P, Few R, Matthies F (2005) Global health impacts of floods. Epidemiologic Evidence 27(1):36–46

Aitsi-Selmi A, Murray V (2015) The Sendai framework: disaster risk reduction through a health lens. Bull World Health Organ 93(6):362

Barredo JI (2009) Normalised flood looses in Europe: 1970–2006. Nat Hazards Earth Syst Sci 9:97–104

Beniston M, Stephenson DB, Christensen OB, Ferro CAT, Frei C, Goyette S, Halsnaes K, Holt T, Jylhä K, Koffi B, Palutikof J, Schöll R, Semmler T, Woth K (2007) Future extreme events

in European climate: an exploration of regional climate model projections. Climatic Change 81:71–95
Brown L, Murray V (2013) Examining the relationship between infectious diseases and flooding in Europe. Disaster Health 1(2):117–127
Dankers R, Feyen L (2008) Climate change impact on flood hazard in Europe: an assessment based on high resolution climate simulations. J Geophys Res 113:D19105
Djalante R (2012) Adaptive governance and resilience: the role of multi-stakeholder platforms in disaster risk reduction. Natl Hazards Earth Syst Sci 12:2923–2942
DRMAP (2009) Disaster risk mitigation and adaptation project—project report. Retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/A823AFB0A958A4D14925754D0018E8CE-Full_Report.pdf. Accessed Mar 2018
EC (2014) Flood prevention and management—instrument for pre-accession assistance (2014–2020) (n.p) Retrieved from https://ec.europa.eu/neighbourhood-enlargement/sites/near/files/pdf/key_documents/2014/20140919-multi-country-strategy-paper.pdf. Accessed Jany 2018
IPCC (2012) Summary for policymakers. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KJ, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) Managing the risks of extreme events and disasters to advance climate change adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp 1–19
ISDR (2007) Disaster risk reduction: 2007. Global Review. The hyogo framework for action (HFA)Retrieved from https://www.preventionweb.net/globalplatform/2007/first-session/docs/session_docs/ISDR_GP_2007_3.pdf. Accessed April 2018
Leaning J, Guha-Sapir D (2013) Natural disasters, armed conflicts and public health. N Engl J Med 369:1836–1842
Lenderink G, Meijgaard EV (2008) Increase in hourly precipitation extremes beyond expectations from temperature changes. Nat Geosci 1:511–514
Lo STT, Chan EYY, Chan GKW, Murray V, Abrahams J, Ardalan A, Kayano R, Yau JCW (2017) Health emergency and disaster risk management (Health-EDRM): developing the research field within the sendai framework paradigm. Int J Disaster Risk Sci 8(2):145–149
Maini R, Clarke L, Blanchard K, Murray V (2017) The sendai framework for disaster risk reduction and its indicators—where does health fit in? Int J Disaster Risk Sci 8(2):150–155
Radovic V, Vitale K, Tchounwou PB (2012) Health facilities safety in natural disasters: experiences and challenges from South East Europe. Int J Environ Res Public Health 9(5):1677–1686
Reginster I, Rounsevell M (2006) Scenarios of future urban land use in Europe. Environ Plan 33(4):619–636
Stanke C, Murray V, Amlôt R, Nurse J, Williams R (2012) The effects of flooding on mental health: outcomes and recommendations from a review of the literature. PLOS Curr Disasters 30:4
UN (2005) Final report of the World Conference on Disaster Reduction. Retrieved from https://www.unisdr.org/2005/wcdr/intergover/official-doc/L-docs/Final-report-conference.pdf. Accessed March 2018
UN (2014) First Version prepared for the Prepcom of the WCDRR, Health and Disaster Risk. Retrieved from http://www.wcdrr.org/uploads/HEALTH.pdf. Accessed May 2018
UNDP (2015) Project Document. Disaster Risk Reduction Initiative in Bosnia and Herzegovina. Retrieved from https://info.undp.org/docs/pdc/Documents/BIH/Project_Document_signed.pdf
UNDP (2016) Human Development Report, Risk-Proofing the Western Balkans; Empowering people to prevent diseases. New York, USA. Retrieved from http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf. Accessed May 2018
UNISDR (2008) South Eastern Europe disaster risk mitigation and adaptation programme. Retrieved from https://www.unisdr.org/files/18136_seedrmapevaluation.pdf. Accessed April 2018
UNISDR (2017) EFDRR Survey on Sendai Framework Implementation in Europe. Retrieved from https://www.preventionweb.net/files/51991_efdrrsurveyreport.pdf. Accessed Feb 2018

WBIF (2015) Flood prevention & management, Flood history of the region. Retrieved from https://europa.ba/wp-content/uploads/2015/09/FLOOD-PREVENTION-AND-MANAGEMENT-GAP-ANALYSIS-EXECUTIVE-SUMMARY1.pdf. Accessed June 2018

WHO (2002) Floods: climate change and adaptation strategies for human health. UK, Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0007/74734/E77096.pdf. Accessed May 2018

WHO and PHE (2013) Floods in the WHO European Region. Health effects and their prevention. Retrieved from: http://www.euro.who.int/__data/assets/pdf_file/0020/189020/e96853.pdf?ua=1. Accessed June 2018

World Bank (2014) Albania-Disaster Risk Mitigation and Adaptation Project. Washington, DC, USA. Retrieved from http://documents.worldbank.org/curated/en/313781468193510916/Albania-DisasterRisk-Mitigation-and-Adaptation-Project. Accessed May 2018

Impacts of Climate Change on Water Resources of the Republic of Srpska (Entity of Bosnia and Herzegovina)—Geopolitical Aspect

Igor Zekanović

Abstract The Republic of Srpska has many significant natural resources, which represent an important segment in the evaluation of its economic and geopolitical position in Europe. The most important resource is fresh water, including mountain and plain rivers, karst areas, natural and artificial lakes, and thermal and mineral springs. Considering the emerging crisis in drinking and industrial water supply, caused, among other things, by the negative effects of climate change at global and local level, the water resources of the Republic of Srpska can rightfully be considered as a key development resource, which has its own geopolitical dimension. This study is based on the analysis of the impact of climate change on water resources of the Republic of Srpska, including adaptation to climate change and optimal exploitation and preservation of freshwater resources. While respecting the criteria of sustainable development, the present situation has been examined through the prism of geopolitical aspect specific for the Southeastern Europe. Also, the research addresses national priorities, as well as the mutual connection between natural and geographical factors on one side and "the geopolitics of resources" on another. The results of this research offer both theoretical and applied value to the current situation in the country, and the Republic of Srpska could become a successful example of adaptation to climate change under specific geopolitical circumstances.

Keywords Water resources · Climate change · The Republic of Srpska Bosnia and Herzegovina · Geopolitical characteristic · Geopolitics of resources

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1 Introduction

Natural resources can be defined as the sum of elements of the environment related to the integral natural complex. Besides being naturally present in the specific area, natural resources have a temporal function which determines their political and geographical character for a specific country or political and territorial community. They can be conditionally divided into those which have always been essential, such as water, air and land, and those whose character is changing depending on the level of historical, geographical or economic development of a country (coal, oil, nuclear energy).

The study of mutual conditionality between "geographical" and "political" aspects, as well as the impact of geographic features on national politics, represents the basic guidelines of political geography. It can be defined as "the study of effects of political actions in the social geography, which contains a spatial analysis of political phenomena" (Grčić 1989). Therefore, "geopolitics of resources" is an indispensable element in contemporary international relations, because of the access and safe disposal of natural resources and raw material bases which determine the international status and relations between political and territorial communities at the local, regional and global level.

Global climate change and its impact on the environment and humans, as well as natural resources is the subject of interest of various international institutions, experts, public media, etc. Nowadays, one of the most important segments of the impact of climate change is the impact on the water resources. More frequent floods and droughts, and other disorders of the natural water regime, caused by the global climate change, as well as the crisis in the supply of drinking water and water quality have been registered globally. Therefore, various water management strategies have been developed in order to mitigate and adapt to these changes. This approach requires the development of strategies and plans of a unique and integrated management.

In preparing these plans and their implementation, with the aim of rational use and protection of water resources, all relevant factors must participate on local, regional and global level.

This work references to the valid literature on climate change in Southeastern Europe, of which we highlight the most relevant:

1. First National Report of Bosnia and Herzegovina in accordance with United Nations Framework Convention on Climate Change, from October 2009 (UNFCCC 2009);
2. Second National Report of Bosnia and Herzegovina in accordance with United Nations Framework Convention on Climate Change, from October (UNFCCC 2013);
3. Strategy of Adaptation to Climate Change and Low Emission Development for Bosnia and Herzegovina, from October 2013 (Council of Ministers of Bosnia and Herzegovina 2013);

4. Third National Report and Second Biennial Report on Greenhouse Gasses of Bosnia and Herzegovina in accordance with United Nations Framework Convention on Climate Change, of July 2016 (UNFCCC 2016);
5. Strategy of Integral Water Management of the Republic of Srpska, until 2024 (2012);
6. Action Plan for Protection from Floods and River Management of Bosnia and Herzegovina, 2014–2017 (Council of Ministers of Bosnia and Herzegovina 2014);
7. Flood Prevention and Management. Gap analysis and needs assessment in the context of implementing the EU Floods Directive, from September 2015 (European Commission 2015).

1.1 Natural and Geographical Characteristics of the Republic of Srpska

The Republic of Srpska is an entity within Bosnia and Herzegovina, which spreads over the area of 24,641 km^2. It spreads over about 48% of overall territory of B&H. Mathematically and geographically, it occupies the northern and eastern part of the geographical space of B&H, between 42°33′18″ and 45°16′36″ of north latitude and 16°12′18″ and 19°37′44″ of east longitude (Table 1). According to the results from the Census from 2013, it had 1,170,342 residents (Republic of Srpska Institute of Statistics 2017a).

Natural characteristics of the Republic of Srpska are conditioned by belonging to different natural and geographic regions. They are therefore characterized by heterogeneous geomorphological, climatological, vegetation, hydrological and pedological structure (Zekanović 2011).

Different climatic impacts on the geospace of the Republic of Srpska are the result of natural elements and the legality of general circulation of air masses over a wide area. The climate is affected by several factors: geographic latitude, relief—which predominantly has mountain character, proximity of the Adriatic Sea and continental masses—primarily Euroasian mainland. Therefore, in this region, different cli-

Table 1 Geographical coordinates of the endpoints of the Republic of Srpska

	North latitude	East latitude	Municipality	Populated places
North	45°16′36″	16°56′08″	Kozarska Dubica	Donja Gradina
South	42°33′18″	18°26′45″	Trebinje	Podštirovnik
East	44°02′59″	19°37′44″	Bratunac	Žlijeb
West	44°56′52″	16°12′18″	Krupa na Uni	Srednji Bušević

Source Republic of Srpska Institute of Statistics (2017b) mate types are represented: moderate-continental, continental (steppic), mountain, mountain-depression and modified-Adriatic.

In the northern and western part of the Republic of Srpska, in the areas up to 500 masl, the annual average temperature has a value from 10 to 11 °C in the central mountain area. The areas over 500 m above the sea level, is characterized by the annual average temperature in the interval from 4 to 10 °C, except for the highest mountain peaks, at which the temperature is under 4 °C. The warmest part of the Republic of Srpska is the area of low Herzegovina and southern part of Herzegovinian grasslands, where the annual average temperature has the value from 11 to 14 °C, and the area of Trebinje and Popovo experience around 14 °C (Trbić and Bajić 2011).

Thus, northern, peri-Pannonian part of the Republic of Srpska, is characterized by moderate continental climate with warm summers, moderately cold winters and average annual temperature over 10 °C (Fig. 1). Precipitations are generally equally distributed, and the greatest precipitation is in the period of May–June. The amount of precipitation decreases from the west (1500 mm) to the east (700 mm), because of the crucial impact of western air currents. The wind from the North and Northwestern direction is dominating. The duration of snow cover is 30–45 days.

The areas with higher altitude have mountain and mountain-depression variant of climate, characterized by fresh and short summers, and long, cold and snowy winters. Snowfalls are often plentiful and remain for a long time, and annual average of precipitation is over 1200 mm.

Mountain-depression variant of climate impact prevails in the hills and depression-valley areas. Average winters last longer than the winters of moderate-continental type. Snowfalls last in average 30–60 days. Precipitations are equally distributed, annual average amounts 750–1000 mm. Summers are moderately warm (from 18 to 20 °C). Average annual temperature is lower than 10 °C.

Southern part of the Republic of Srpska is characterized by altered variant of Adriatic climate. It is characterized by very warm summers and mild winters. Annual amount of precipitation is over 2000 mm.

2 Hydrographic Characteristics of the Republic of Srpska

From the hydrological point of view, geospace of the Republic of Srpska is characterized as rich surface and underground hydrological network. Fresh water network is represented by the main rivers: Una, Sana, Vrbas, Bosna, Sava, Drina and Trebišnjica (Table 2).

However, in addition to the main rivers listed above, various small lowland rivers, mountain rivers and rivers of karst areas contribute efficiently to the richness of the network. Additional natural and artificial lakes and thermal and mineral springs form part of overall fresh water resources of the Republic of Srpska converting it to one of the richest fresh networks of Eastern Europe (Fig. 2).

Shaft of the Black Sea is the Sava River, which runs by the northern border of the Republic of Srpska, about 200 km long, from the mouth of the Una River in the west

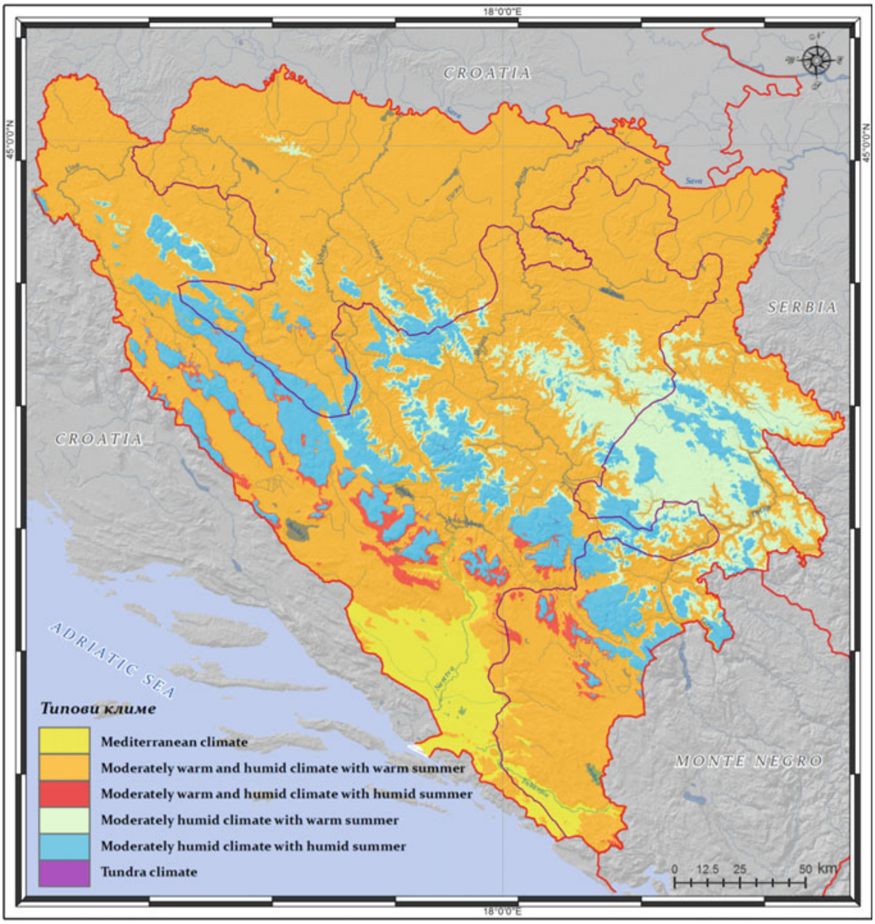

Fig. 1 Types of climate of the Republic of Srpska. *Source* Author

to the Drina River in the east. The Sava River is the richest river with water power on the Balkan Peninsula.

The flow of the Sava River is low-sited and all major rivers of the Republic of Srpska flow to it (Una with Sana, Vrbas, Ukrina, Bosna and Drina). They have a composite character of river valleys with large declines, and they also have a significant waterpower potential. Rivers Una, Vrbas and Bosna contain 14.3 billion m^3 per year. However, waterpower potential of these rivers cannot be compared with waterpower potential of the Drina River.

The Drina River is the largest tributary to the Sava River. The length of the flow is 341 km, and the basin area is about 19,570 km^2. In the basin area of the Drina River, 9 hydro power plants were built so far, with installed capacity of 1932 MW and average annual production of 6350 GWh (Jokanović 2016).

Table 2 Main rivers of the Republic of Srpska

Rivers[a]	Length, km	
	Total	In Republic of Srpska
Sava	945	204.85
Drina	341	308.52
Vrbas	249.9	131.91
Vrbanja	95.4	95.4
Sana	157.7	85
Una	212.5	91.8
Ukrina	80.9	80.9
Bosna	279.4	98.03
Gomjenica	68.5	68.5
Drinjača	91.37	61
Trebišnjica	96.5	56
Lim	234	44
Prača	62.6	42
Mušnica	41.8	41.8
Neretva	225	39
Ćeotina	92.6	36.07
Spreča	147.32	72.42
Sutjeska	35.54	35.14
Rzav	54.3	28.63
Pliva	31.45	20
Usora	25.99	6.54

[a]Rivers with river basins larger than 500 km
Source Republic of Srpska Institute of Statistics (2017c)

Southeast area of the Republic of Srpska hydrographically gravitates to the Adriatic Sea (Eastern Herzegovina). In Adriatic basin, the Trebišnjica River is the main watercourse link, and historically its riverbed was regulated by anthropogenic impact and it was the largest underground river in the world.

The effect of the rivers of the Republic of Srpska has insulating and integrative role. The most significant rivers are at the same time border rivers where Una and Sava form a border with the Republic of Croatia and Drina with the Republic of Serbia. In political and geographical terms, "transit waters" are dominating at the territory of the Republic of Srpska, since it has about 10% of domicile waters. From major watercourse links, the Ukrina River, throughout its flow length of 80.9 km and Vrbanja River (99.68% at the territory of the Republic of Srpska)" belong to the Republic of Srpska (Rajčević and Crnogorac 2011).

Hydrographic potentials are based on large possibilities of exploitation and hydropower generation, because waterpower potential of the rivers with coal reserves forms the basis of electricity production. The estimated waterpower potential of

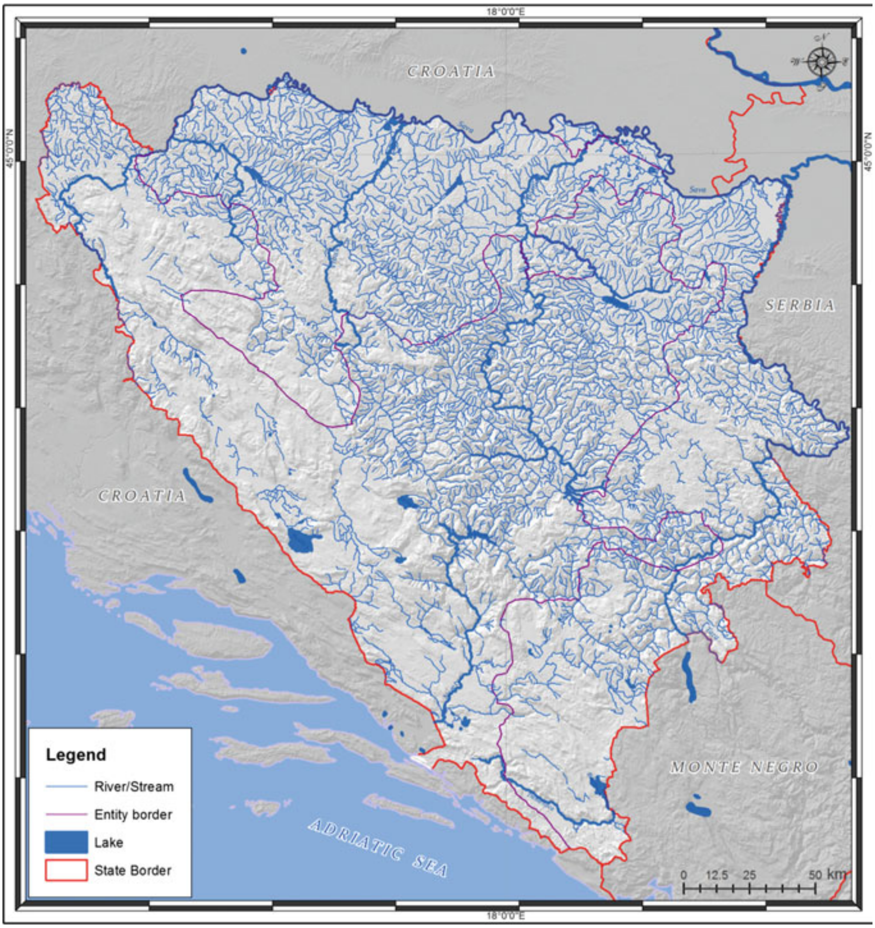

Fig. 2 Hydrographic network of the Republic of Srpska. *Source* Second National Report of Bosnia and Herzegovina in accordance with United Nations Framework Convention on Climate Change (UNFCCC) (2013)

watercourse links in the Republic of Srpska is about 10,000 GWh per year, of which about 35% of the total waterpower potential is used through four hydropower plants: Hydropower Plant Višegrad, Hydropower Plant Trebinje 1, Hydropower Plant Trebinje 2 and Hydropower Plant Bočac, and a few smaller hydropower plants: Bogatići, Mesići, Tišća and Vlasenica. Hydropower Plant Dubrovnik is at the territory of the Republic of Croatia and uses water from the basin of Trebišnjica River. Production of this power plant is divided in the ratio of 50:50 between the Electric Company of RS and the Electric Company of Croatia. The Republic of Srpska, by production, fully meets the demands for the electricity, and owns waterpower potentials with which it can become a significant exporter of electricity (Zekanović and Živković 2015).

Table 3 The largest lakes and ponds

	Surface area, km^2	Elevation, m	Largest depth, m	Water quantity, m^3
Artificial lakes				
Bilećko (at Trebišnjica R.)	27.064	400	104.0	1280.0
Perućačko (at Drina R.)	12.401	290	70.0	355.0
Zvorničko (at Drina R.)	8.876	140	28.0	89.0
Višegradsko (at Drina R.)	8.900	336	78.0	161.0
Bočac (at Vrbas R.)	2.330	282	62.0	52.7
Natural lakes				
Štitarsko (at Zelengora)	0.129	1672	4.5	0.255
Kotlinačko (at Zelengora)	0.044	1528	10.0	0.250
Uloško (at Crvnje)	0.043	1058	14.0	0.255
Donje Bare (at Zelengora)	0.021	1475	4.5	0.057
Orlovačko (at Zelengora)	0.021	1438	5.0	0.054
Ponds				
Saničani (at Gomjenica R.)	11.179	143	4.0	…
Bardača (at Matura R.)	7.472	90	2.2	…
Prnjavor (at Vijak R.)	6.664	134	3.5	…
Sjekovac (at Ukrina R.)	3.980	85	3.0	…

Source Republic of Srpska Institute of Statistics (2017b)

Despite being rich in running waters, the Republic of Srpska is relatively poor in standing waters, since there are no major natural lakes, but artificial hydro-reservoirs with the purpose of waterpower exploitation (the most important ones are located at the rivers: Vrbas, Drina and Trebišnjica) (Table 3).

Different geological construction and composition of geotectonic units and heterogeneous hydro-geological function of rock masses impacted the formation of a variety of ground waters. The southern part of the Pannonian Basin is quantitatively richest in ground waters.

On the territory of the Republic of Srpska, four main hydrogeological areas can be distinguished and divided into lesser or greater hydrological units:

1. North Bosnian hydrogeological area;
2. Banjaluka—Kladanj—Višegrad hydrogeological area;
3. Middle Bosnian hydrogeological area;
4. Herzegovina and Southeastern Bosnian area (Ministry of Agriculture, Forestry and Water Management of RS 2012).

These locations represent the most important sites of groundwater for water supply of settlements in the Republic of Srpska. The quality of groundwater can be divided in four groups: (1) the first group includes the sources of groundwater from which the water can be used without previous treatment (Semberija, Posavina); (2) the second quality group includes the sources of groundwater from which water can be used after disinfection, and that is the water accumulated in the alluvium and the rocks of fracture-karst porosity; (3) the third group includes the sources from which the water has to be subjected to different treatments (filtration, softening, remove of Fe, Mn and other components); and (4) the fourth group that includes the sources whose quality of water cannot be used for water supply even after treatment (Gligorić 2008).

Thermal and thermo-mineral waters are widespread in a broad belt from the western part of the Republic of Srpska, starting from the municipalities of Krupa na Uni and Novi Grad to the eastern part and City of Bijeljina. There are more explored and potential sources in the eastern part, and the most significant are located in the area of Srebrenica and Višegrad. These waters are used mainly in balneological and recreational purposes. Based on these potentials, it has already been built and affirmed several spa and recreational centers: Mlječanica, Laktaši, Slatina, Banja Vrućica, Dvorovi, Guber and Vilina Vlas.

Therefore, distribution of different water resources in the Republic of Srpska is the following: 71.30% of available fresh water consists of ground waters and springs, 25.50% are running waters and only 2.70% are accumulations and lakes (Fig. 3).

In addition to the great possibilities of exploiting the hydropower potential, hydrographic network of the Republic of Srpska provides great opportunities in irrigation

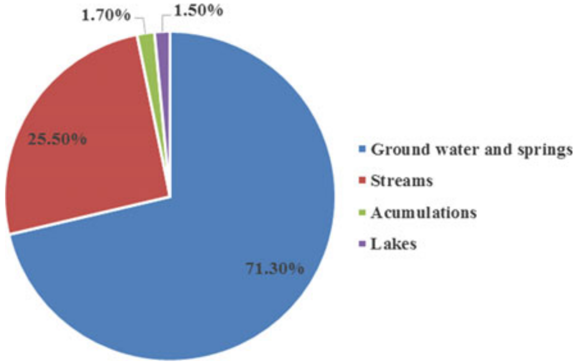

Fig. 3 Water sources of public supply system of the Republic of Srpska. *Source* Republic of Srpska Institute of Statistics (2017b)

of farmlands, development of fisheries, possibilities for river traffic and affirmation of fishing and spa tourism. Rivers of the Republic of Srpska, with its excellent water quality and rich fish stock (especially salmonidae fish species), provide a very good basis and important component in the development of tourism.

Therefore, the Republic of Srpska has sufficient water quantities to satisfy national needs. In addition, the water resources are not a limiting factor of economic and social development, and its elevated quantity and quality can be preserved by the corresponding protection measures. However, due to the extreme spatial and temporal unevenness of waters, as a consequence of exposure to the impact of climate change, and unregulated water regimes, a successful realization of all development goals in the area of water resources usability and environment development can be achieved only by realization of large integral systems on the level of great basins, which means mutual and coordinated action of all political-geographical entities in regions of Western Balkans and Southeastern Europe.

3 The Impact of Climate Change on the Geospace of the Republic of Srpska and Possibilities for Adaptation

Global climate change represents one of the most current ecological, economic and political problems of the modern international community.

Generally, global climate change is manifested in the following ways: by increase of the air temperature, fluctuation of pluviometric regime, reduction of precipitation, increase of the intensity and frequency of periods of drought, floods and fires.

According to IPCC (Intergovernmental Panel for Climate Change) and their climate models (e.g. SRES), by the end of the year 2100, the global temperature could increase from 1.4 to 5.8 °C (IPCC 2012), which will cause a number of changes in the environment, its ecosystems and opportunities for sustainable development (Trbić and Bajić 2011).

Study of the air temperature for the period 1981–2010 showed evident increase in almost the entire territory of the Republic of Srpska. The highest increase has been recorded in the northern part of the Republic of Srpska (in the area of Posavina and Semberija) and in the southern part of Eastern Herzegovina. In the central region, the increase of temperature is insignificant, while in the high mountain area of Herzegovina, the trend of a slight decrease of temperature has been detected (Trbić and Bajić 2011).

In the period of 14–19 May of 2014, disastrous floods affected wide area of the Sava River basin in Bosnia and Herzegovina, Republic of Croatia and Republic of Serbia. The floods affected entire B&H area belonging to the River Sava basin and caused the loss of 23 lives and high material damages. In total, 70 administrative units (municipalities/cities) of B&H (the Federation of B&H, the Republic of Srpska and Brčko District of B&H) were affected by the floods (Council of Ministers of Bosnia and Herzegovina 2014).

The extent of the disaster in 2014 revealed vulnerability of Serbia and B&H, and emphasized the need to strengthen flood control management systems, forecasting and prevention, especially considering negative impact of climate change. Although meteorologists issued appropriate warnings regarding the expected weather condition, the municipalities were not able to foresee an exact height of water levels or the speed. In addition, the evacuation order was issued too late. Therefore, it could be argued that conditions were aggravated because defense system had not been upgraded in 25 years, flood ways were not adequately maintained, proper forestation of drainage canals had been ignored and therefore canals could not drain excess water (EU Commission 2015).

Due to complex geopolitical circumstances and "turbulent" geopolitical processes at the end of 20th century, which affected B&H and the Western Balkans region, B&H was included late in the possibilities of choosing an adequate method and approach for the social-economical scenarios to mitigate climate change. Because of that, the First National Report of Bosnia and Herzegovina in accordance with the UNFCCC was not enacted until October 2009 (UNFCCC 2009).

It took more than 10 years since the end of the B&H conflict to finally produce optimal political conditions for coordinated work in the field of environment and protection from climate change effects in B&H geospace. During the last 10 years, a great effort has been made in this field by initiating appropriate mitigation to climate change.

Therefore, since the end of the armed conflict and after signing the "Framework Agreement for Peace in Bosnia and Herzegovina", all issues related to the environment and the effects of global climate change have been assigned to three entity governmental institutions: the Ministry of Environment and Tourism of the Federation of B&H, Ministry of Spatial Planning, Civil Engineering and Ecology of the Republic of Srpska, and the Department of Public Utilities of Brčko District. However, there were many difficulties in cooperation between these institutions.

Luckily, at the beginning of the 21st century the coordinated work was initiated by solving the environmental problems and passing legal acts, so that B&H would actively engage in solving the negative effects of climate change. The work of the Entity Ministries and the Department of Brčko District was primarily based on the adoption of the following laws: the Law on Environmental Protection, the Law on Air Protection, the Law on Nature Protection, the Law on Waste Management, the Law on Waters and the Law on the Environmental Protection Fund.

This group of Laws has been prepared with the financial and technical assistance of the European Commission and the PHARE Program, with the intention of developing laws that would be in line with the relevant EU directives and which would be harmonized for both Entities and the Brčko District. The Laws were adopted in RS in 2002 (Official Gazette of RS, No. 50, 51 and 53/02), FB&H in 2003 and 2006 (Official Gazette FB&H, 33/03 and 70/06) and in the Brčko District 2004 (Official Gazette of Brčko District No. 24/04). In December 2005, the Ministry of Spatial Planning, Civil Engineering and Ecology of the Republic of Srpska prepared amendments to the Law on Environmental Protection, which were published in the Official Gazette of the RS no. 109/05 (UNFCCC 2009).

By adopting a set of laws, B&H has united all legal aspects of environmental protection, and the Government of B&H is a signatory of a large number of international agreements and environmental conventions and is fully committed to meeting the conditions prescribed in these agreements. The most important ratified international agreements include the UNFCCC, the United Nations Convention on Biological Diversity, the United Nations Convention to Fight against Land Desertification, the Vienna Convention on the Protection of the Ozone Layer, the Convention on Long-Range Transboundary Air Pollution, Aarhus Convention and First National Report of Bosnia and Herzegovina in accordance with United Nations Framework Convention on Climate Change (UNFCCC 2009).

The Ministry of Spatial Planning, Civil Engineering and Ecology of the Republic of Srpska is responsible for the overall quality of environmental protection and improvements through research, planning, management and protection measures, including the protection of resources of general interest, natural resources and natural and cultural heritage. In accordance with the Law on Meteorological and Hydrological Activities of the Republic of Srpska (Official Gazette of the Republic of Srpska, 20/2000), the Republic Hydro-meteorological Institute of the Republic of Srpska is a governmental organization responsible for monitoring climate change, climate data exchange and database management, applied research and climate forecasts within various WMO (World Meteorological Organization) scientific and technical programs (UNFCCC 2009).

As a result of constant activities in addressing the problem of negative impacts of climate change and adaptation possibilities in Bosnia and Herzegovina, and in addition to the aforementioned state and entity laws, as well as ratified international agreements, special highlight should go to draft the First National Report of Bosnia and Herzegovina in accordance with the UNFCCC, Second National Report of Bosnia and Herzegovina in accordance with the United Nations Framework Convention on Climate Change, from October 2013, the Adjustment Strategy for Climate Change and Low-Emission Development for Bosnia and Herzegovina from 2013, the Third National Report and the Second Biennial Report on Greenhouse Gas Emission of Bosnia and Herzegovina in accordance with the UNFCCC from July 2016.

The First National Report of Bosnia and Herzegovina in accordance with the UNFCCC pointed to the vulnerability of B&H to climate change and significant potential exposure to threats from climate change. B&H also has a high sensitivity to these threats because the high economic role of the "climate sensitive" sectors, such as agriculture and forestry; and the role of hydroelectric power plants in the energy sector to a lesser extent. Finally, it was concluded that B&H has very limited adaptation capabilities to address climate risks.

In particular, when water resources are concerned, the First Report identifies the basic problems arising from climate change, such as: change in seasonal flows of the river, reduction in the amount of water flow in rivers and difficulties in supplying water to households and industry. Also, primary and secondary measures of adaptation to these problems are proposed: "*construction of dams and reservoirs for production of electricity in hydropower plants, agriculture, water supply, tourism, fish farming, etc., then, training on efficient water usage and reduction of losses* *in distribution, strengthening the monitoring system and predicting the amount of water, and developing a hydrological information system*" (UNFCCC 2009).

The Second National Report of Bosnia and Herzegovina in accordance with the United Nations Framework Convention in 2013, among other things, clearly defined the sectors that are most vulnerable to climate change (agriculture, water resources, human health, forestry, biodiversity and sensitive ecosystems).

In that sense, detailed analyzes of long-term climate change in these sectors have been carried out. Estimations are based on SRES climate scenarios A1B and A2 developed for Bosnia and Herzegovina for the needs of the Second National Report (SNC). For each sector, the proposed adaptation measures have been identified on the basis of expert consensus, consultations with parties of interest and analysis of relevant research (UNFCCC 2013).

Regarding water resources, both scenarios for the periods 2001–2030 and 2071–2100 (A1B 2001–2030; A1B 2071–2100; A2 2071–2100) predict the increase in air temperature in B&H and decrease of precipitation. Changes in precipitation regime will be manifested in terms of the occurrence time, frequency and intensity of extreme events - floods and droughts. The Report concluded that "*additional and more complex research on climate change and its impact on water resources is needed, together with the development of a sector strategy of climate change adaptation and with the accompanying action plan and concrete measures*" (UNFCCC 2013).

Potential measures to protect water resources would refer to:

1. A detailed vulnerability assessment, and an assessment of the ability to adapt to climate change for water resources;
2. Creation of vulnerability maps and flood risk diagrams developed using GIS techniques;
3. Construction of several functional reservoirs and river regulations (In accordance with the strategy "Support to water policy in B&H"—project financed by EU IPA for 2007);
4. Improvement in hydrological monitoring and measurement systems, and in early warning systems for high water levels;
5. Improvement of the flood protection system;
6. Development of a sectoral plan for adapting to climate change;
7. Incorporate the impact of climate change in sectoral strategies and action plans;
8. Strengthening research activities regarding the impact of climate change on water resources and modeling of hydrological processes;
9. Developing capacity of competent institutions and local communities, raising awareness of the impact of climate change on water resources and adaptability;
10. Promoting Integrated Sustainable Development and Efficient Water Management. (UNFCCC 2013)

"*Adaptation strategy for climate change and low-emission development for Bosnia and Herzegovina (B&H)*" was prepared simultaneously with the Second National Report on Climate Change (SNC) of Bosnia and Herzegovina in accordance with the UNFCCC and in coordination with the United Nations Development Program (UNDP) in Bosnia and Herzegovina.

The strategy was developed based on the First National Report (INC) and as part of ongoing activities on the development of the Second National Report (SNC). The Strategy defines guidelines for mitigating the effects of climate change, which relate to:

1. Building the necessary capacity;
2. Determining a general policy course for low-emissions development that is resistant to climate change;
3. Integrating more specific policies, measures and projects into sectoral strategies;
4. Identifying already existing options for adapting to climate change and mitigating measures, in order to ensure their international support. (Council of Ministers of Bosnia and Herzegovina 2013)

"The Third National Report and the Second Biennial Report on the Greenhouse Gas Emissions of Bosnia and Herzegovina" by the UNDP in B&H, in accordance with the United Nations Framework Convention on Climate Change (2016), analyzed the series of annual precipitation from the previous reports, and complemented by the values for the period 2011–2014, for the Sava River basin and the Adriatic Sea basin as well. The study found that the median value did not change much.

However, the value of the range (distribution) is significantly higher for both basins. In the period of 1961–2014, annual precipitation was 44 mm higher in the Sava River basin than in the period 1961–1990, which was slightly lower increase value than in the period 1991–2010. However, the range has increased significantly (769 mm in relation to 407 mm), i.e. the minimum value is 100 mm smaller and the maximum is 262 mm higher. Accordingly, the value of the variance was significantly higher in the period 1991–2014 (UNFCCC 2016).

Water, as a resource, does not represent the limiting factor for development of Bosnia and Herzegovina, on the contrary, it represents the most important natural resource. However, its vulnerability to climate change is every day more significant. Therefore, the need for monitoring and detecting changes due to the impact of climate change is of great importance.

The Third National Report and the Second Biennial Report on Greenhouse Gas Emissions of Bosnia and Herzegovina provide clear guidelines/adaptation measures for climate change when talking about water potentials;

1. Regular maintenance of watercourse riverbeds;
2. Pre-flood warning;
3. Structural measures for flood protection (embankments);
4. Prevention of losses on pipelines;
5. Measures to reduce the specific use of water in industry, irrigation, etc.;
6. Melioration;
7. Construction of reservoirs;
8. Ensuring conditions for the sustainable use of groundwater (monitoring, estimation of available quantities, protection of sources);
9. Improving monitoring and other measures related to the fight against drought;
10. Rainwater collection. (UNFCCC 2016)

4 Management of Water Resources Affected by Climate Change

The water became the priority in "geopolitics of resources". It is estimated that in the past century, the total quantity of drinking water on Earth was reduced for about 40%. If this trend continues, which is in accordance with global climate change, it can cause various forms of crises and ecological disaster.

Therefore, the impact of climate change and the possibility of adaptation has become the center of attention of international policy, as a factor in direct relation with modern political and geographical, economical, demographical and other flows. The possibilities to mitigate these impacts are minimal, but there are many possibilities to adapt, and that includes defining new models of the environment, defining sustainable development strategies and cooperation of all political and geographical units from the environment at the local, state and regional level.

Previous statements point to the necessity of developing an adaptation strategy for climate change. The importance of drafting the strategy is particularly emphasized in the field of water resources protection and water management systems, since the events of 2014 (catastrophic floods) and 2017 (wildfires) are more than enough (Fig. 4). Although total and average precipitation remains the same during the vegetation period, the more frequent variability in precipitation quantity leads to necessity and demand for solving irrigation problems.

When developing strategies, analysis and monitoring, it is necessary to engage science experts from different fields and professions, with particular emphasis on: flood risk management, drought and wildfire protection, construction of irrigation

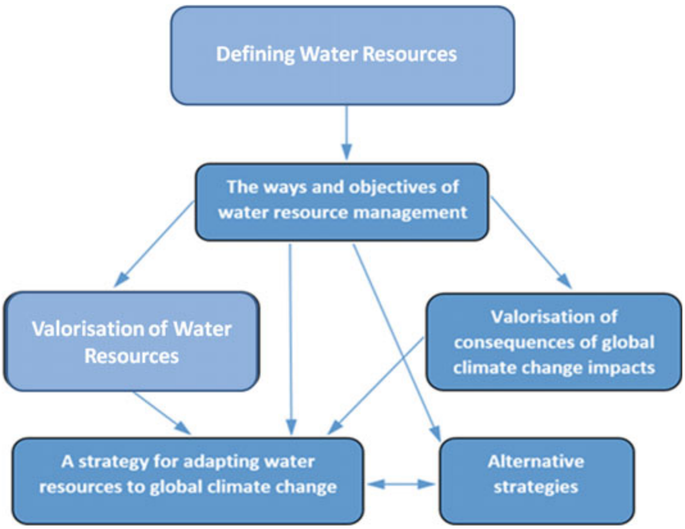

Fig. 4 Management of water resources highly affected by climate change. *Source* Author

systems and, in general, rational use of water resources, with the aim of making the most effective adaptation to global climate change. Among other things, strategy and continuous monitoring is necessary as a scientific basis for assessment and response to the question of whether certain changes in water potentials are caused by human activities or just a result of global climate change.

Also, the International Treaties, (in particular, the UN Framework Convention on Climate Change and the Kyoto Protocol), obligate B&H, and therefore the Republic of Srpska, to work continuously in the field of mitigation and adaptation to climate change.

The Third National Report and the Second Biennial Report on the Greenhouse Gas Emissions of Bosnia and Herzegovina in accordance with the United Nations Framework Convention on Climate Change, from July 2016, defined the limitations and pointed out future directions and prospects, regarding political and socio-economic adaptation component to climate change.

More attention should be paid to education, informing and awareness raising in the population about climate change through education systems in B&H and RS, with clearly designed goals. It is necessary to continue intensively with international cooperation in the framework of global environmental agreements and to intensify regional cooperation that takes place within the countries of Southeastern Europe and the Western Balkans, because climate change issues cannot be solved individually by states or without coordination between the countries in the region.

Also, it is necessary that the Republic of Srpska and B&H, considering the political and geographical dimension of watercourse and water resources, which are of transitional character and pass through more than one country, establish cooperation with all countries in the region, primarily on regulating the river flows, and coordination for creation of mechanisms for solving the problem of water management.

Geopolitical conditions and historical and geographical development, stemming from the disintegrative processes in the geographical space of the former SFRY, are not possible to ignore and discard, as well as negative political and geographical processes that have marked this geospace at the end of 20th century. But, cooperation and joint action, regarding the adaption to climate change, would lead, in a political and political-geographical context, to easing tensions between the countries of the former SFRY, as well as to improvement of inter-ethnic cooperation.

5 Conclusions

Bosnia and Herzegovina pointed its vulnerability to climate change and significant potential exposure to threats from climate change because of the high economic role of the "climate sensitive" sectors, such as agriculture and forestry; and the role of hydroelectric power plants in the energy sector to a lesser extent. Due to the fact that B&H has very limited adaptation capabilities to address climate risks more attention should be paid to education, informing and awareness rising in the population about climate change through education systems in B&H and RS, with clearly designed goals. In addition, it is necessary to intensively continue with international cooperation in the framework of global environmental agreements and to intensify regional cooperation that takes place within the countries of Southeastern Europe and the Western Balkans.

Joint action on the issue of planned and rational exploitation of natural potentials, seen through the prism of perspective trans-border cooperation, would represent one of the guidelines not only for revitalization in the economical and geographical terms, but also the guideline of the future concept of ethnic tolerance and political and geographical stability of the Republic of Srpska, Bosnia and Herzegovina, and also the countries of former SFR Yugoslavia and the entire region.

Among other things, joint action on prevention and adaptation to climate change would become a "geopolitical connecting tissue" of all political-geographical subjects in the region and would have a huge impact—that the nations of South-eastern Europe realize that the time of conflicts and wars is past, while the time of euro integration is the future.

References

Council of Ministers of Bosnia and Herzegovina (2013) Adaptation strategy for climate change and low-emission development for Bosnia and Herzegovina, p 9. https://doi.org/10.13140/rg.2.1.1235.5443

Council of Ministers of Bosnia and Herzegovina (2014) Action plan for protection from floods and river management of Bosnia and Herzegovina 2014–2017. Sarajevo

European Commission (2015) Flood Prevention and Management Gap analysis and needs assessment in the context of implementing EU Floods Directive, p 2

Gligorić M (2008) Water as the Republic of Srpska resource. In: Scientific conferences, vol XIII: The Republic of Srpska resources, Academy of Science and Arts Republic of Srpska, Banja Luka, pp 187-201

Grčić M (1989) General political geography. Faculty of Geography. University of Belgrade, Belgrade, p 46

IPCC (2012) Summary for Policymakers. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York, pp 1–19

Jokanović J (2016) Korišćenje hidroenergetskog potencijala Gornje Drine i Sutjeske na teritoriji Republike Srpske. Zbornik radova: Prvi kongres o vodama B&H, ACE BH, UKI B&H, Sarajevo

Ministry of Agriculture, Forestry and Water Management of RS (2012) Strategy of integral water management of the Republic of Srpska until 2024, Draft—first iteration. Agency for Waters of Regional Basin of the River Sava, Agency for Waters of Regional Basin of the River Trebišnjica, Bijeljina, p 46

Rajčević V, Crnogorac Č (2011) Rijeka Vrbanja – fiziogena svojstva sliva i riječnog sistema. "ART-PRINT", Banja Luka, B&H

Republic of Srpska Institute of Statistics (2017a) Census of population, households and dwellings in Republic of Srpska 2013, Banja Luka, B&H

Republic of Srpska Institute of Statistics (2017b) This is Republic of Srpska 2017. Banja Luka, B&H

Republic of Srpska Institute of Statistics (2017c) Statistical yearbook of Republika Srpska 2017. Number 9, Banja Luka, B&H
Trbić G, Bajić D (2011) Specifics of climate change in the Republic of Srpska and the possibility of adaptation. In: Proceedings: Third Congress of Serbian geographers with international participation, Geographical Society of Republic of Srpska. Faculty of Science, University of Banja Luka, Republic of Srpska, Bosnia and Herzegovina, Banja Luka, pp 149–157
UNFCCC (2009) First National Report of Bosnia and Herzegovina in accordance with United Nations, p 23
UNFCCC (2013) Second National Report of Bosnia and Herzegovina in accordance with United Nations Framework Convention on Climate Change, p 75
UNFCCC (2016) Third National Report and Second Biennial Report on greenhouse gasses of Bosnia and Herzegovina in accordance with United Nations Framework Convention on Climate Change, p 26
Zekanović I (2011) Ethno-demographic basis of the political-geographic position of the Republic of Srpska. Geographical Society of Republic of Srpska, Banja Luka
Zekanović I, Živković M (2015) The revelance of natural resources in the evaluation of political-geographical position of Republic of Srpska. Proceedings: - book 1: 4. srpski kongres geografa sa međunarodnim učešćem - dostignuća, aktuelnosti i izazovi geografske nauke i prakse, Faculty of Geography, University of Belgrade, Belgrade, Serbia, pp 237–241

Good Practices for Disaster Risk Reduction in Agriculture in the Western Balkans

Tamara van 't Wout, Reuben Sessa and Vlado Pijunovic

Abstract The Western Balkan region is prone to various natural hazards, including earthquakes, floods, landslides, droughts and forest fires, due to its location, climatic and topographic characteristics. The agriculture sector is adversely impacted by these hazards, through the damage of agricultural facilities and equipment as well as losses in the crops, livestock, fisheries, aquaculture and forestry subsectors. Climate change is expected to increase the frequency and severity of hydro-meteorological hazards, and smallholder farmers in these countries are therefore especially vulnerable as they mainly depend on the sector and its activities for their food and livelihoods. This paper presents the findings from interviews with farmers, extension officers and agriculture experts regarding 12 identified good practices that can help to reduce the adverse impacts of natural hazards, in particular, floods, landslides and droughts, on agriculture in Albania, Bosnia and Herzegovina, the Former Yugoslav Republic of Macedonia, Montenegro and Serbia. The differences between these stakeholders' perspectives will be illustrated and the requirements needed for the uptake and upscaling of these practices in the Western Balkan region will be discussed.

Keywords Agriculture · Disaster risk reduction · Good practices
Western Balkans

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1 Introduction

The Western Balkan region is located in the South-Eastern part of Europe and includes the countries of Albania, Bosnia and Herzegovina, the Former Yugoslav Republic (FYR) of Macedonia, Montenegro and Serbia, among others. The region is among the most seismically active in Europe, and borders the Adriatic Sea in the northwest and the Ionian Sea in the southwest, while the Danube-Sava river is flowing through several countries. Due to its location, climatic and topographic characteristics, the area is prone to various natural hazards, including earthquakes, floods, landslides, storms, droughts and forest fires.

According to the international disaster database of the Université Catholique de Louvain, it is estimated that between 1990 and 2017, a total of 98 natural hazards occurred, which affected approximately 9,761,557 people and caused total economic losses of around USD 3.534 billion in these five Western Balkan countries.[1] In terms of climate related hazards, floods occur quite regularly. Nevertheless, the heavy rainfall that led to the extensive inundation in May 2014 was considered among the worst in 120 years and particularly affected various sectors in Bosnia and Herzegovina and Serbia. In addition, droughts and forest fires often occur during the summer months, as a result of e.g. reduced precipitation and high temperatures.

The agriculture sector is one of the most climate sensitive sectors, and smallholder farmers in these countries are especially vulnerable as they mainly depend on agriculture for their food security and livelihoods. Climate change will provide another challenge to ensuring and enhancing agricultural production in the near future, as an increase in the frequency and severity of extreme weather events is expected, which will lead to further damages and losses to crops, livestock, forestry and fisheries (IPCC 2014; World Bank 2009). Temperature rises and precipitation decreases are expected throughout the South-East European region, with the largest drought risks during the summer months particularly in the FYR of Macedonia (Ministry of Environment and Physical Planning 2008). The region is also experiencing environmental challenges, such as land degradation, soil erosion, deforestation, water scarcity and biodiversity loss, due to unsustainable natural resource use (Mitkova and Cvetkovska 2006; Spalevic et al. 2014; Alfthan et al. 2015; EEA 2017; FAO 2017). This also reduces the ability of these ecosystems to reduce the effects of e.g. floods, landslides and storms, as healthy and diverse ecosystems are more resilient to climate variability and change and also help to build more resilient livelihoods (Sudmeier-Rieux and Ash 2009).

Despite an increasing number of studies, which document farmers' perspectives on climate variability and change as well as different agricultural practices, including those that can help to reduce the impact of natural hazards, like floods, droughts and storms (Habiba et al. 2012; Hitayezu et al. 2017; Waldman et al. 2017), little has been published on the perception of extension officers on such practices, how their

[1] It must be noted that global disaster databases, such as EM-DAT cannot be adequately substituted for national data, as small disasters are often not included. Moreover, the EM-DAT database does not include any agriculture sector damage and loss data.

advice may facilitate the promotion of these measures (Backus et al. 1995; Brown et al. 2018). There is also a lack of research comparing farmers' and experts' views regarding good practices for disaster risk reduction in agriculture (Halbrendt et al. 2014).

Furthermore, various factors can play a key role in the adoption of a practice or technology by farmers and differences in terms of perceptions between experts, extension officers and farmers can thus prevent adoption (Halbrendt et al. 2014). However, at present no study that analyses the views of these three stakeholder groups has so far been conducted for several good practices and technologies that can reduce the impact of natural hazards, in particular for the South-East European region.

2 Agriculture Sector in the Western Balkans

In terms of land area, Serbia and Bosnia and Herzegovina are the largest among the five Western Balkan countries, with 8.7 and 5.1 million hectares respectively. The size of the agricultural land area of all five countries varies between 40 and 50%, except for Montenegro where only 17% of its total land surface is agricultural land. In almost all countries, this agricultural land consists particularly of arable land and meadows and pastures, with a small area where permanent crops are cultivated, although in Montenegro, the majority of its agriculture land area consists of meadows and pastures as shown in Table 1.

The region is diverse in terms of landscapes and climates, which in turn affects farming and the types of crops produced. In general, cereals are cultivated on plains and in river valleys, while orchards and vineyards are found on the lower slopes of mountainous areas. Livestock, particularly sheep and goats, is raised in the upland areas and olives are traditionally grown along the Adriatic coast (EFNCP 2010).

The most important field crops in the region are cereals and oilseeds; sugar beets are also produced in high volumes in Serbia, while tobacco is important in the FYR of Macedonia, Bosnia and Herzegovina and Montenegro. Fruits and vegetables are also among the leading crops in all five countries. Cattle rearing (i.e. beef or milk production) seems to be the leading subsector in most Western Balkan countries, followed by pig farming in Serbia and sheep and goat husbandry in the other countries (IAMO 2010). Since 2005, positive trends have been observed in both agriculture production and trade in the region, in particular regarding apples, raspberries, cherries and plums as well as from time to time e.g. peaches, nectarines, and apricots. The dairy sector has maintained its production levels, despite a decrease in the number of dairy cows and dairy farmers. As a result, productivity has risen and processing has improved (FAO 2013). In terms of agricultural exports and imports, the share of Albania's agricultural exports as part of their total exports are the lowest in the region with 9%, whereas Serbia's agricultural exports are the highest with 24%. The share of agricultural imports as part of total imports, are lowest in Serbia (7%) and highest in Montenegro (21%) (Mizik 2012).

The Western Balkan countries share similarities with regard to the small average size of farm land, which ranges from around 1.2 ha in Albania, to less than 4 ha in Serbia (IAMO 2010). Land is highly fragmented into small plots throughout the region, which are often not connected or adjacent to each other. Thus, a smallholder farmer may have on average 2–3 plots located in different areas. However, in the northern parts of Serbia, in the Vojvoldina province, the average farmland ranges up to 10.9 ha, with the largest area of land (20 ha or more) belonging to only 3.1% of the farmers, which are the companies (the former collective farms) established through the privatisation process after the Socialist Federal Republic of Yugoslavia (Bogdanov 2015). This indicates the typical dual structure of agricultural holdings with small family farms on the one hand and the relatively large holdings on the other hand, which contributes to the diversity and inequality in society.

The agriculture sector and its activities play an important role in the economies of these five Western Balkan countries. The share of agriculture as a percentage of GDP varies from 22% in Albania, 11% in the FYR of Macedonia, 10% in Montenegro, 9% in Serbia to 7% in Bosnia and Herzegovina in 2015 (FAO 2016a).

The importance of the sector for the economy is also visible with regard to agriculture employment. The percentage of employment is the highest in Albania, with 42.3% and lower in the other countries, such as 19.4% in Serbia, 18.5% in Bosnia and Herzegovina, 16.4% in the FYR of Macedonia and 7.8% in Montenegro. In some countries, such as in Albania and Montenegro, the employment of women in agriculture is higher, while in all countries the projections for 2021 indicate a lower

Table 1 Overview of total land area, percentage and types of agriculture land in the Western Balkans

	Total land area, million hectares	Agricultural land area, % of total land area	Composition of agricultural land area		
			Arable land,	Permanent crops,	Meadows and pastures
			% of agricultural land area	% of agricultural land area	% of agricultural land area
Albania	2.7	42.9	52.4	6.8	40.7
Bosnia and Herzegovina	5.1	42.2	46.8	4.9	48.3
The FYR of Macedonia	2.5	50.1	32.8	3	64.2
Montenegro	1.3	17.1	3.8	2.2	94
Serbia	8.7	40.1	74.3	5.3	20.3

Note This data is mainly based on FAO questionnaires from countries and/or official country publications, websites or trade country files
Source FAO (2017)

Table 2 Agriculture employment as part of total employment and by sex in the Western Balkan countries, 2015 and 2021 (%)

	2015 (Total)	2021 (Total)	2015 (M)	2021 (M)	2015 (F)	2021 (F)
Albania	42.3	39.4	37.5	34.7	49.4	46.2
Bosnia and Herzegov-ina	18.5	16.9	19.2	17.5	17.5	16.0
FYR of Macedonia	16.4	15.7	18.7	17.8	13.0	12.6
Montenegro	7.8	7.1	7.3	6.6	8.3	7.6
Serbia	19.4	18.6	21.8	20.9	16.3	15.5

Source ILoSTAT, http://www.ilo.org/ilostat/faces/oracle/webcenter/portalapp/pagehierarchy/Page3.jspx?mBI_Id=33

percentage of total agricultural employment among both men and women as shown in Table 2.

A general decrease in population is expected in all countries between 2015 and 2020, varying from a 19.4 and 17.2% decrease in Bosnia and Herzegovina and Montenegro respectively, to 9.6% in the FYR of Macedonia, 6.7% in Serbia and 6.6% in Albania (United Nations 2014). Moreover, urbanization is also expected to increase in all countries in the coming years (United Nations, Department of Economic and Social Affairs, Population Division 2014), while the agriculture labor force is expected to decrease. According to FAO (2012) data, in 2005/07 the number of people working in this sector was approximately 5.6%, while in 2030 this is expected to decrease to 2.2 million and in 2050 to 1.0 million.

There is also significant aging of the current rural populations in the majority of the countries in the region, which will lead to a smaller agriculture labor force in the future, especially when taking into account the expected reduction in the number of younger people residing in rural areas. These demographic changes will need to be considered in the development of future sustainable and climate resilient production systems.

3 Environmental Challenges

Despite the fact that the Western Balkan region has substantial land and water resources, several countries are experiencing various environmental challenges, such as land degradation, soil erosion, water scarcity, deforestation, and biodiversity loss, as a result of the depletion and overexploitation of natural resources, which in turn undermines the sustainability of agricultural production and ecosystems' resilience. These environmental issues are adversely impacting the countries' food security and rural livelihoods, reducing the productive capacity of land and decreasing ecosystem functions, thereby diminishing the ability to enhance resilience in the face of future extreme weather events and climate change.

Soil degradation that leads to land degradation and desertification are also issues in the Southeastern Europe region. For instance, it has been estimated that in the FYR of Macedonia in 1993 land degradation and erosion affected approximately 96.5% of the total land area of the country (Mitkova and Cvetkovska 2006). This is also a key environmental challenge in Montenegro and has affected 13,135 km^2 or 95% of the country (Spalevic et al. 2014). Erosion is also estimated to impact around 25% of Albania (Alfthan et al. 2015) and has caused annual agricultural losses of around USD 138.2 million or around 5.5% of its agricultural GDP in 2011 (Binaj et al. 2014).

Deforestation and overgrazing have also led to biodiversity and habitat loss and soil erosion. The unregulated logging for timber and fuel wood have caused massive wood cutting and damaged forests in many parts of the region. Poverty and political changes in the 1990s have increased illegal logging, which is threatening the remaining forests in the Western Balkans. For instance, approximately a quarter of the timber that is cut in the FYR of Macedonia is primarily used for fuel (European Environmental Agency 2010). Albania has also seen extensive logging in its national parks, including the Lura and the Valbora. This is primarily due to demand for fuel for poor rural families, as well as for export. Fortunately, it is believed that illegal logging has decreased during the last few years. In addition, in the coastal areas, tourism development has also adversely affected both marine life, natural habitats and land and water use. Some planned/proposed investments into hydropower plants as well as the draining of wetlands to be used as agricultural land, such as those in Vojvodina in Serbia and Maliq in Albania, can also negatively impact ecosystems in the region.

Water is an indispensable agricultural input for the development and growth of crops. Due to the limited precipitation in the Western Balkans especially during the summer months, supplementary irrigation is often needed. Although sustainable irrigation and water use management is crucial for the sustainability of food systems, water withdrawal for agricultural use remains unsustainable in Albania, which is considered 'water stressed' as it withdraws over 25% of its renewable freshwater resources (FAO 2017). This results in higher water stress levels that can lead to a deterioration of fresh water resources with regard to quantity (e.g. aquifer overexploitation, dry rivers) and quality (e.g. eutrophication, organic matter pollution, saline intrusion) (EEA 2017). Similarly, it is expected that, as a result of climate change, the FYR of Macedonia is likely to experience "extremely high water stress levels"[2] for agriculture [over 80%] by 2020, 2030 and 2040. Albania will experience medium to high [20–40%] water stress levels by 2020, 2030 and 2040 (Luo et al. 2015). As a result, supplemental irrigation is projected to be required.

[2]Water stress measures total annual water withdrawals (municipal, industrial and agricultural) expressed as a percentage of the total annual available blue water.

4 Impact of Natural Hazards on Agriculture in the Western Balkans

The agriculture sector is highly impacted by natural hazards, due to its climate sensitivity and its dependence on e.g. precipitation, temperature and sunlight for the growth and development of crops, livestock, forestry and fisheries. It is, therefore, easily affected as natural hazards can cause damage to agricultural infrastructure, facilities and equipment as well as lead to partial and totally agricultural losses, thereby disrupting agricultural production cycles, trade flows and livelihoods. In addition, the food and nutrition security, especially that of the most vulnerable people, for whom agriculture is often used for subsistence only, may be negatively affected. As a result, these disasters may undermine and slow the overall economic growth, particularly in developing countries where the majority of the population depend on the sector and its activities for their food, employment and incomes.

A study undertaken by the Food and Agriculture Organization of the United Nations (2015), estimated that around 22% of the total damage and losses from natural hazards in developing countries were incurred by the agriculture sector. In addition, from 2003–2013, different agriculture sub-sectors seem to have been specifically impacted the most by a certain type of hazard, such as crops by floods, livestock by droughts, forestry by storms and fisheries by tsunamis.[3]

Floods and droughts have affected many people in Southeastern Europe, including smallholder farmers, who were substantially impacted by the May 2014 floods and landslides that occurred in Serbia and Bosnia and Herzegovina. These extraordinarily heavy rains caused extensive flooding and affected 24 and 81 municipalities in these countries respectively, resulting in total damage and losses to the agricultural sector of EUR 228 million (or 19% of total damage and losses) in Serbia and EUR 187 million (or 9% of total damage and losses) in Bosnia and Herzegovina (United Nations/EU/World Bank 2014a, b). Due to these floods and landslides, newly planted crops were inundated, storage facilities were destroyed and livestock was killed.

For the Western Balkan region, the impact of droughts, which generally occur during the summer months, is considered to cause the highest damage and losses to the agriculture sector compared to any other hazard. For instance, during the period of 1990–2014, it has been estimated that droughts (32.1%) have resulted in more economic losses than floods (30.2%) in Serbia and, in terms of the mean annual economic losses as a result of floods on agriculture, this has been valued at €38.75 to €106.25 million, while the impact of droughts on the sector has been estimated at around €500 million (WMO, UNCCD, FAO & UNW-DPC 2013). However, accurate and reliable post-disaster agricultural damage and loss data for specific countries and the region are lacking, due to the lack of or limited human, technical and financial resources to undertake systematic assessments for the agriculture sector.

[3]This study was undertaken by assessing the Post-Disaster Needs Assessment reports developed by the Global Facility for Disaster Risk and Recovery (GFDRR), as a result, the figures are likely to be underestimated as only the data from these medium to large-scale droughts events were included.

Nevertheless, some damage and loss data is available, which indicates the adverse impact of natural hazards on the agriculture sector and its activities. The Western Balkan region is especially prone to droughts during the summer months when there is limited rainfall. In some countries, such as Montenegro, the occurrence of droughts has been adequately recorded. According to Montenegro's Second National Communication on Climate Change (2015), 17 drought years have been recorded between 1950 and 2010[4] (Ministry of Sustainable Development and Tourisms 2015). In other countries, the impact of a drought on the economy is expressed in terms of economic costs or as a percentage. For instance, it is estimated that the 1989–1991 drought in Albania costed its economy USD 24 million (UNDP 2015) and the 1993 drought in the FYR of Macedonia led to a crop failure that has been estimated at 7.6% of the total national income (WMO 2012).

Some specific information on the reduction in agricultural production and specific damage and losses is also accessible for Bosnia and Herzegovina and Serbia. For instance, the 2002 drought in Bosnia and Herzegovina is considered the worst in 120 years and resulted in a 60% reduction in agricultural production that led to a serious food crisis and agricultural damages of EUR 200 million. The 2007 drought destroyed over 40% of the country's crop production and 250 ha of land were impacted by forest fires, resulting in high food prices (WMO 2012; ICPDR 2015). The drought in 2012 particularly affected Bosnia and Herzegovina, and caused over USD 1 billion in agricultural production losses in the region and reduced yields of grains and vegetables of up to 70% (Zurovec et al. 2015).[5] Available data indicate that in Serbia this drought resulted in agricultural production losses of around USD 2 billion; it particularly affected corn (USD 1 billion), sugar (USD 130 million), soybeans (USD 117 million), fruits and vegetables (USD 100 million), sunflowers (USD 55 million) and other crops (USD 600 million) (Maslac 2012).

At present, the systematic collection of specific agriculture pre-disaster and post-disaster damage and loss data is often lacking. However, understanding the exact impact of natural hazards on agriculture and people's livelihoods is of utmost importance in order to better understand people's vulnerabilities and risks as well as to better inform decision-making and undertake effective risk reduction measures and investments. This is also crucial as natural hazards may not only impact the agriculture sector, but also pose serious risks to food security and health, through the unavailability of drinking and irrigation water and may lead to slow and chronic forms of malnutrition.

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[4]The drought years that were observed included, 1953, 1962, 1967, 1969, 1978, 1981, 1982, 1985, 1988, 1989, 1993, 1994, 1996, 1999, 2003 (agricultural drought), 2007 (hydrological drought), 2008 and 2011 (social and economic drought).

[5]The most affected was maize production, which is the primary raw material for the production of animal feed, while other losses were experienced regarding the cultivation of e.g. barley, soybeans, alfalfa, clover, beans, meadows and pastures, which resulted in a lack of fodder. This adversely affected the number of livestock, livestock and milk production as well as the supply of meat for the domestic market, which increased food prices and reduced the export of agricultural products.

5 Climate Change Projections and the Expected Impacts on Agriculture

It is projected that global average annual temperatures will increase due to climate change, which may lead to more frequent and longer heat waves, more hot days and nights, fewer days with frost and fewer cold days and nights. Average annual precipitation is also expected to decrease. It is anticipated that climate change will increase the frequency and severity of many types of extreme weather events, including not only droughts and forest fires, but also climate-related hazards like floods and storms. Moreover, seasonal patterns may shift, which will lead to greater variability that may adversely affect the agriculture sector (IPCC 2014).

Similar trends in terms of expected temperature rises and reductions in precipitation are also anticipated in the Western Balkan region. For instance, temperature projections conducted for Albania indicate variations in average annual increases of +1.0 to +3.2 °C between 2030 and 2100 and seasonal changes of +0.8 to +5.3 °C between 2030 and 2100, with the highest increases expected to occur during summer (Ministry of Environment 2016). Other calculations have been undertaken for Bosnia and Herzegovina with expected temperature rises from +1 to +2.4 °C and from +3.8 to +5.6 °C during the periods of 2011–2040 and 2041–2070 respectively (UNDP in Bosnia and Herzegovina 2016).

Precipitation patterns are anticipated to change due to climate change, with excess rainfall at times, which may lead to flooding and physiological and direct physical stress on plants and animals, as well as the occurrence of dry spells and droughts. General annual precipitation reductions are expected in Albania of up to −8.5% by 2050 and by up to −18.1% by 2100 (Ministry of Environment 2016). Similar projections have been made for Bosnia and Herzegovina (UNDP in Bosnia and Herzegovina 2016) as well as for the FYR of Macedonia, with reductions in rainfall anticipated at 10–20% with a 19% decrease in the summer by 2100 (Ministry of Environment and Physical Planning 2008).

Since warmer air can hold more water vapor, increases in temperature affect hydrology and can lead to more intense rainstorms and a higher risk of flooding. The result is thus more extreme weather events and changing precipitation patterns, leading also to more storms and more dry spells and droughts (World Bank 2009). Projections have been made for Montenegro, which indicate that the extension of dry periods is expected to be on average 1–5 days until 2030 and 3–8 days for the 2071–2100 period (Ministry of Sustainable Development and Tourism 2015).

As a result of the changes in the climate of the Western Balkan region, it is expected to become hotter and moderately drier, particularly during the summer, combined with more frequent and severe extreme weather events, like droughts and floods (Ministry of Sustainable Development and Tourism 2015). This will negatively impact the agriculture sector, as temperature rises will lead to greater evaporation from soil, which will result in less water being available for plants. There is also an increased risk of erosion, which will adversely affect the fertility of the land and reduce agricultural yields. For instance, the yield of winter wheat in Vojvodina region, the most important agriculture area in Serbia, could be reduced by 5–8% and 4–10% in 2040 and 2080 respectively, compared to the average yield during the 1981–2005 period (WMO 2012). Some positive impacts are expected on the yield and quality of winter crops, such as winter wheat and fruits, including grapes, due to the longer growing periods as very cold winters and late spring frosts may disappear.

The vulnerability of spring crops, to increasing temperatures together with summer water shortages, is likely to reduce the growing season for these crops. It is also projected that there will be a decline in the yield and quality of pastures and feed, particularly for spring crops, which may reduce livestock production (e.g. milk, meat, etc.) as well as the expected depletion of pastures due to heavy rains and strong winds. In addition, the outbreak of plant pests and diseases may occur, due to the longer growing period as a result of the increasing temperatures in winter and early spring as well as the emergency of animal pests and diseases.

6 Disaster Risk Reduction

Due to the expected increase in the frequency and severity of natural hazards as a result of climate change, enhancing the resilience of a country's communities is highly important. All five countries in the region are signatories of the international disaster risk reduction agreement, such as the Sendai Framework for Disaster Risk Reduction 2015–2030.

Disaster risk reduction (DRR) focuses on moving away from a reactive emergency response to a more proactive DRR approach, which entails that governments aim to 'prevent', 'mitigate' and 'enhance preparedness for response', thereby reducing the impact of natural hazards and building the resilience of people and their livelihoods. FAO defines resilience as "the ability to prevent disasters and crises as well as to anticipate, absorb, accommodate or recover from them in a timely, efficient and sustainable manner. This includes protecting, restoring and improving livelihoods systems in the face of threats that impact agriculture, nutrition, food security and food safety" (FAO 2014).

In order to shift towards a more proactive approach, an enabling policy and institutional environment is required, such as the development and adoption of national DRR plans, policies and strategies and an institutional system that consists of all relevant stakeholders that are coordinated by a national organization, which ensures collaboration and communication at all levels. In addition, an effective early warning and information system is crucial, as is improvement of preparedness for response and agricultural DRR measures that focus on prevention and mitigation of the adverse impacts of natural hazards and climate change.

7 Agricultural Good Practices and Technologies to Reduce Impact of Natural Hazards

FAO promotes prevention and mitigation options for agriculture to reduce adverse impacts of natural hazards, like floods, storms and droughts on agriculture, through Farmer Field Schools (FFS). This approach has been developed by the organisation and its partners in the late 80s in Southeast Asia as an alternative to the prevailing top-down extension method. A typical FFS consists of a group of 20–25 farmers, which meet once a week in a local field setting and under the guidance of a trained facilitator (FAO 2016b). In small groups, they observe and compare two plots over the course of an entire cropping season, where one plot follows local conventional methods, while the other is used to experiment with what could be considered “best practices”. This learning-by-doing approach promotes farm-based experimentation, innovative, participatory and interactive learning, problem solving, group organization and decision-making, thereby increasing the likelihood that farmers will eventually “own” and adopt the demonstrated and validated practices that are most suitable to their farming systems (FAO, JICA and KFS 2011).

The process of identification, selection, testing/demonstration, validation, replication and upscaling of the good practices and technologies that will reduce the impacts and build agriculture-dependent communities’ resilience to natural hazards and climate change is outlined in Fig. 1.

Through desk research that was conducted during the period of May–July 2016, 12 good practices and technologies were identified that can potentially reduce the impact of natural hazards, in particular floods, landslides and droughts, in the Western Balkan region as outlined in Table 3.

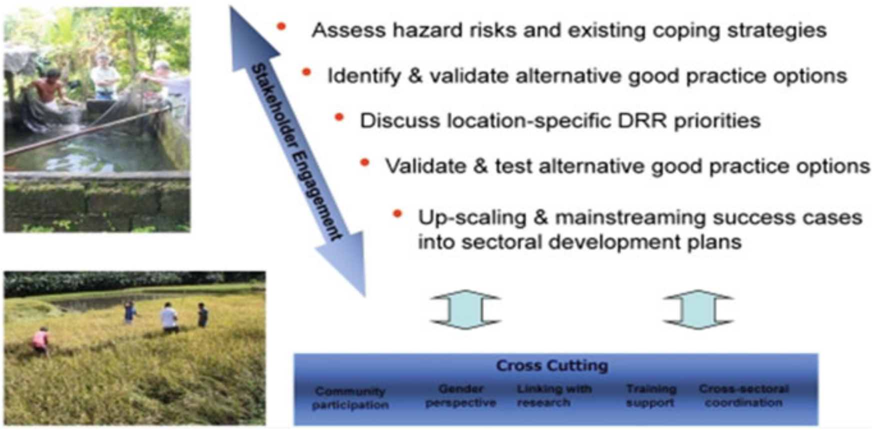

Fig. 1 Overview of the identification, testing, validation and upscaling of good practices. *Source* http://www.fao.org/climatechange/ph/bicol/66749/en/

Table 3 Overview of the 12-identified good practices for DRR in agriculture for the Western Balkan region

Good practice	Description	DRR aim	Implemented at farm level	Implemented at landscape level
Buffer strips and hedges	Buffer strips are areas of natural (permanent) vegetation cover (e.g. grass, bushes or trees) at the margin of fields, arable land, transport infrastructures and water courses. They can have several different vegetation varying from simply grass to combinations of grass, trees, and shrubs, for instance, in the form of hedges	Floods and soil erosion	√	√
Strip cropping and contour farming	Strip cropping and contour farming is the practice of growing two or more crops in alternating strips along the contour of the land. In this system, a row crop more susceptible to erosion, like corn or soybeans, is planted alternating with a cover crop less susceptible to erosion, such as grass meadow, clover, or oats. Similar to contour cropping, crops are planted perpendicular to the wind or water flow	Floods and soil erosion	√	√
Mulching	A mulch is a layer of material applied to the surface of an area of soil. It can be organic and non-organic in nature as well as permanent (i.e. plastic sheeting) or temporary (e.g. bark chips, grass clippings, leaves, straw). It may be applied to bare soil or around existing plants. Mulches of manure or compost will be incorporated naturally into the soil by the activity of worms and other organisms	Soil erosion and droughts	√	
Crop rotation	Crop rotation is the practice of growing a series of different types of crops in a specified order on the same fields. It is implemented so that the crop is not depleting only one type of nutrient in the soil. Crop rotation focuses on the cultivation of different successive crops in a defined order on the same area of land, in contrast to a one-crop system or succession planting	Droughts	√	
Stone walls	Stone walls can be built against embankments or even vertical terraces and are often structures constructed from stones without any mortar or cement to bind them together. These walls were traditional especially developed in the past to mitigate the risk of soil erosion and floods due to high intensity rainfall	Soil erosion and floods	√	√
Intercropping	Intercropping is the cultivation of two or more crops simultaneously on the same field, which can help to reduce the impact of droughts. It also means that the second crop is planted after the first one has completed its development	Droughts	√	
No till/low till	No-till farming (also called zero tillage or direct drilling) is a way of growing crops or pasture from year to year without disturbing the soil through tillage. Low till agriculture, also known as conservation or reduced till applies to arable land. It consists of a combination of a crop harvest, which leaves at least 30% of crop residue on the soil surface, during the critical soil erosion period and some surface work (low till)	Soil erosion and droughts	√	

(continued)

Table 3 (continued)

Good practice	Description	DRR aim	Implemented at farm level	Implemented at landscape level
Early/late sowing	Early or late sowing allows for an earlier and quicker or later establishment of winter crops that can provide cover during the winter and a root network that can help to protect the soil. Early sowing can also help to mitigate summer drought impacts on spring sown crops. However, early sown plants are frost sensitive	Droughts	√	
Afforestation	Afforestation is the establishment of a forest or the planting of trees in an area where there was no previous tree cover, which can help to reduce the impacts of floods and soil erosion. It is the process of conversion of land from other uses into forest and is the opposite of deforestation. Afforestation often includes areas that are converted from other land uses into forest through silvicultural measures. It also includes natural transitions into forest of e.g. agricultural land that has been abandoned or burnt areas that have not been classified as forest during the barren period	Floods, droughts and soil erosion		√
Terraces	A terrace is an earthen embankment, ridge or ridge-and-channel built across a slope (on the contour) to intercept runoff water and reduce soil erosion. Terraces are usually built in a series parallel to one another, with each terrace collecting excess water from the area above. The practice can be designed to channel excess water into grass waterways or direct it underground	Floods, droughts, soil erosion		√
Drip irrigation	Drip irrigation is the slow, precise application of water and nutrients directly to the plant root zone in a predetermined pattern, which can help to reduce the impact of droughts. Also, known as micro or trickle irrigation, drip irrigation helps to maintain the root zone at ideal moisture level, encouraging the formation of deeper roots and more abundant foliage, at the same time saving water through reduced evaporation and runoff	Droughts	√	
Agroforestry	Agroforestry is a land use management system in which trees or shrubs are grown around or among crops or pastureland, which can help to reduce the impacts of floods and soil erosion. It combines shrubs and trees in agricultural and forestry technologies to create more diverse, productive, profitable, healthy, ecologically sound, and sustainable land-use systems	Floods and erosion	√	√

8 Results of Experts' and Farmers' Feedback on the Good Practices

Feedback from agricultural experts, which included researchers, practitioners and extension officers, in the five Western Balkan countries has been obtained on the 12 identified good practices. A survey, including, among others, the following two questions, was administered to agricultural experts from August to November 2016 and their answers have been analysed in this paper:

– Is the good practice applicable to the country? Yes/No.
– Is the good practice currently implemented in the country? Yes/No.

Moreover, another questionnaire was prepared and feedback from farmers was collected from September 2016 until April 2017 regarding the 12 identified good practice options, which included the following three questions:

– Do you know/are you familiar with the good practice? Yes/No.
– Are you currently implementing the good practice? Yes/No.
– If you are not currently implementing it, would you still be willing to test it? Yes/No.

8.1 Experts' Feedback

Feedback has been obtained about the 12 good practices that can help to reduce the impacts of natural hazards, in particular, floods, landslides and droughts, from agricultural experts, extension officers and researchers, in terms of whether the practice is applicable to the country and whether it is currently implemented in the country. In total, two national experts provided feedback from Albania, twelve from Bosnia and Herzegovina, three from the FYR of Macedonia, two from Montenegro and five from Serbia. This feedback was received in both aggregated and non-aggregated form obtained from one or several experts. Tables 4 and 5 provide an overview of the answers provided by the experts, with a "+" indicating a positive and a "−" a negative answer on whether the practice is applicable to the country or currently implemented in the country and sometimes a "no answer" was provided. When two or three answer sheets all provide a positive answer only one '+' is provided in the table, but if, for instance, there are three different answers on each of the three different answer sheets, then each of the response is stated in the table, such as "±/no answer", in order to avoid losing valuable information.

Table 4 shows that experts consider most of the 12 good practices applicable to the five Western Balkan countries and experts in Albania, Bosnia and Herzegovina and Serbia appeared to be quite uniform about it, except for drip irrigation and agroforestry, where often no answer was provided. Experts in the FYR of Macedonia and Montenegro were somewhat divided where some indicated that strip cropping

Table 4 Experts' feedback on the applicability of the 12 good practices

	Albania (2 answer sheets—2 experts)	BiH (1 answer sheets—12 experts)	FYR of Macedonia (3 answer sheets—3 experts)	Montenegro (2 answer sheets—2 experts)	Serbia (2 answer sheets—5 experts)
Buffer strips and hedges	+	+	+	+/No answer	+
Strip cropping along the contours	+	+	+/−/−	No answer	+
Mulching	+	+	+	+	+
Crop rotation	+	+	+	+	+
Stone walls	+	+	+/+/−	+	+
Intercropping	+	+	+	+/No answer	+
No till/low till	+	+	+/+/−	+/No answer	+
Early/late sowing	+	+	+/No answer (2)	+/−	+
Afforestation	+	+	+/+/No answer	+	+
Terraces	+	–	+/+/No answer	+	+/No answer
Drip irrigation	+	No answer	No answer	+/No answer	+
Agroforestry	+	No answer	No answer	No answer	+/No answer

Source FAO collected data

along the contours is not so applicable as well as different opinions for e.g. stone walls, no till/low till for the FYR of Macedonia as well as divisions with regard to early/late sowing in Montenegro.

According to agricultural experts, of the 12 good practices shown in Table 5, mulching, crop rotation and more or less buffer strips and hedges, afforestation, intercropping and terraces are considered to be currently implemented in the five countries. The opinions are divided with regard to the current implementation of strip cropping along the contours, no till/low till, early/late sowing as well as drip irrigation and agroforestry among the countries as some experts did not provide their feedback.

8.2 Farmers' Feedback: Albania

In Albania, the questions were discussed with 470 participants, as part of climate change awareness raising trainings. In Fig. 2, it is apparent that from the 12 identified

Table 5 Experts' feedback on current implementation of the 12 good practices

	Albania (2 answer sheets—2 experts)	BiH (1 answer sheets—12 experts)	FYR of Macedonia (3 answer sheets—3 experts)	Montenegro (2 answer sheets—2 experts)	Serbia (2 answer sheets—5 experts)
Buffer strips and hedges	+	+	+	+/−	+
Strip cropping along the contours	+/−	+	+/+/−	–	+/−
Mulching	+	+	+	+	+
Crop rotation	+	+	+	+	+
Stone walls	+	–	+	+	+
Intercropping	+	+	+	+/No answer	+
No till/low till	+/−	–	+/+/−	+/−	+
Early/late sowing	+/−	+	+/−/No answer	+/No answer	+
Afforestation	+/−	+	+	+	+
Terraces	+	+	+	+	+/−
Drip irrigation	+	No answer	No answer	+/No answer	+
Agroforestry	−/No answer	No answer	No answer	−/No answer	+/No answer

Source FAO collected data

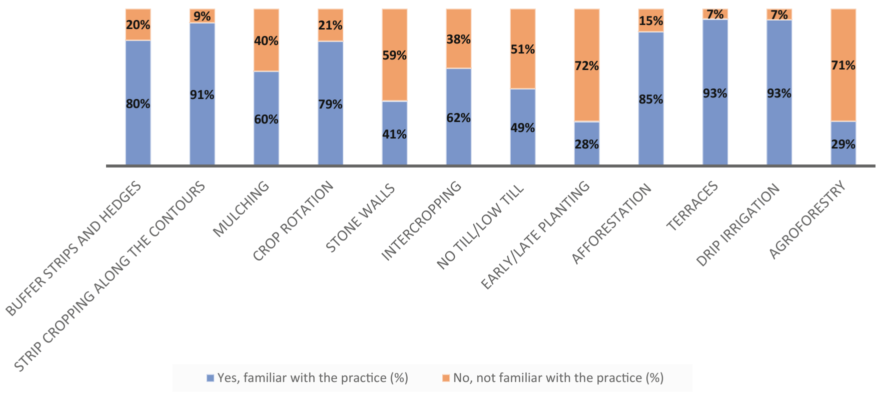

Fig. 2 Farmers' familiarity with the 12 good practices in Albania. *Source* FAO collected data

good practices, drip irrigation, strip cropping along the contours and terraces are measures that farmers are most familiar with compared to agroforestry and early/late planting.

Moreover, less than 10% of farmers mentioned that out of the twelve good practices, they are currently implementing agroforestry, afforestation and stone walls as

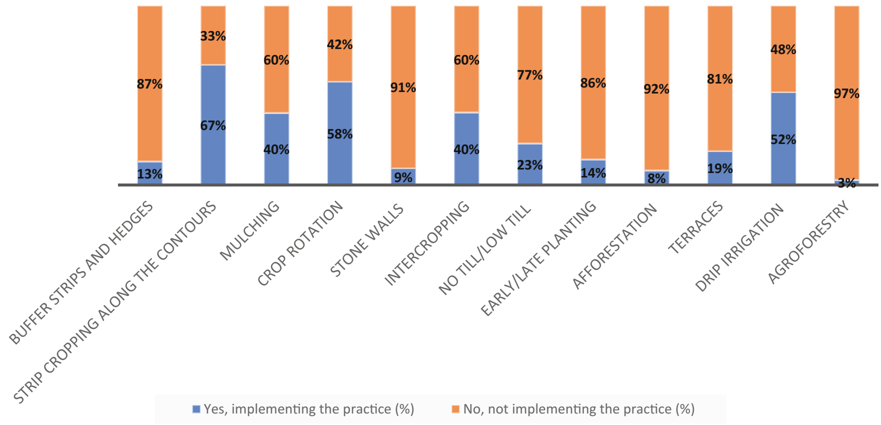

Fig. 3 Current implementation of the 12 good practices by farmers in Albania. *Source* FAO collected data

shown in Fig. 3. In addition, 40% of the farmers indicated that they have applied mulching, crop rotation and drip irrigation, which may mean that these latter measures are perhaps the most commonly used. Terraces, although a well-known measure by farmers, is currently hardly implemented.

Although farmers do not currently implement afforestation and buffer strips and hedges, more than 20% of the participants are willing to test afforestation and about 49% are willing to test buffer strips as outlined in Fig. 4. Approximately 10–20% of the participants were in favour of using stone walls, strip cropping and agroforestry. Mulching and drip irrigation are measures they are most willing to test, but these are also measures they know and are familiar with, as 40% of the participants are currently applying mulching and 50% are using drip irrigation. Despite the fact that most of the farmers are familiar with terraces, only 30% are willing to demonstrate this practice, which could be due to the high construction and maintenance costs.

8.3 Farmer's Feedback: Bosnia and Herzegovina

In total, 48 farmers' responses were collected. Figure 5 shows that drip irrigation (100%), crop rotation (100%), early/late planting (81%) and terraces (81%) are practices that farmers are most familiar with, while, agroforestry (29%) and intercropping (35%) are practices that farmers are less familiar with and have therefore applied to a lesser extent.

Figure 6 provides an overview of the good practices that farmers are currently implementing in the BiH. Crop rotation and drip irrigation are the only practices that farmers are very familiar with; 71 and 94% of the farmers responded that they are currently implementing them. While 46% of farmers are familiar with 'no tillage',

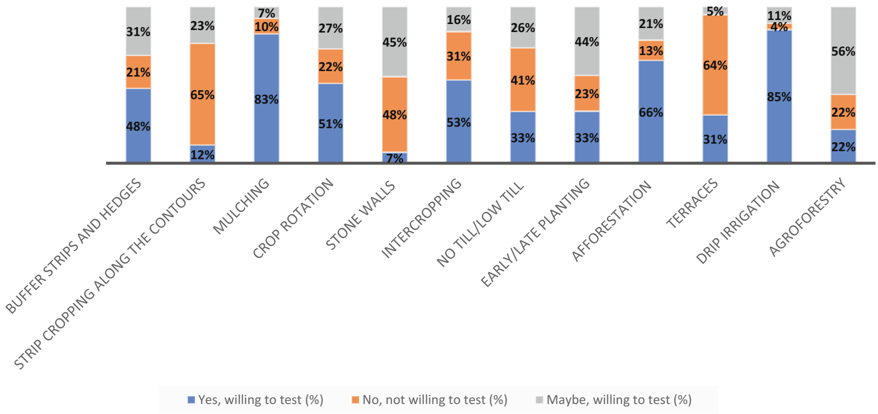

Fig. 4 Farmers' willingness to test the 12 good practices in Albania. *Source* FAO collected data

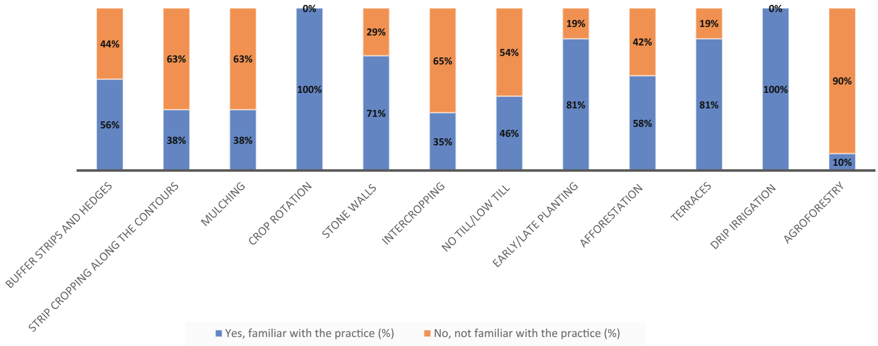

Fig. 5 Farmers' familiarity with the 12 good practices in BiH. *Source* FAO collected data

only 6% are applying it on their fields. Seventeen percent of the farmers are implementing early/late planting and 10% of farmers indicated that they are currently implementing stone walls and intercropping, while farmers are currently not implementing the practices of 'agroforestry', 'terraces', 'afforestation', 'strip cropping' and 'buffer strips'.

Optimistically, although farmers do not currently implement agroforestry, 52% of farmers responded that they are willing to test it, in contrast to 27% who are not willing and a further 21% who are not sure whether they want to test it as shown in Fig. 7. However, from the farmers' responses it is clear that they are willing to test those good practices that they already know and are currently applying, such as drip irrigation (100%) and crop rotation (57%).

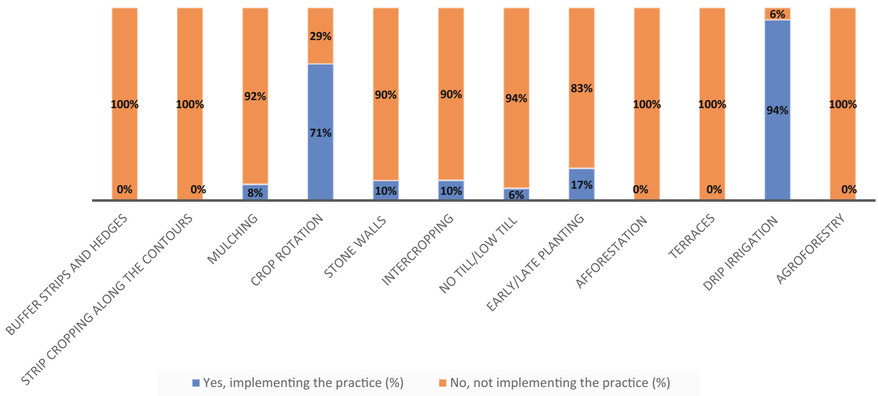

Fig. 6 Current implementation of the 12 good practices by farmers in BiH. *Source* FAO collected data

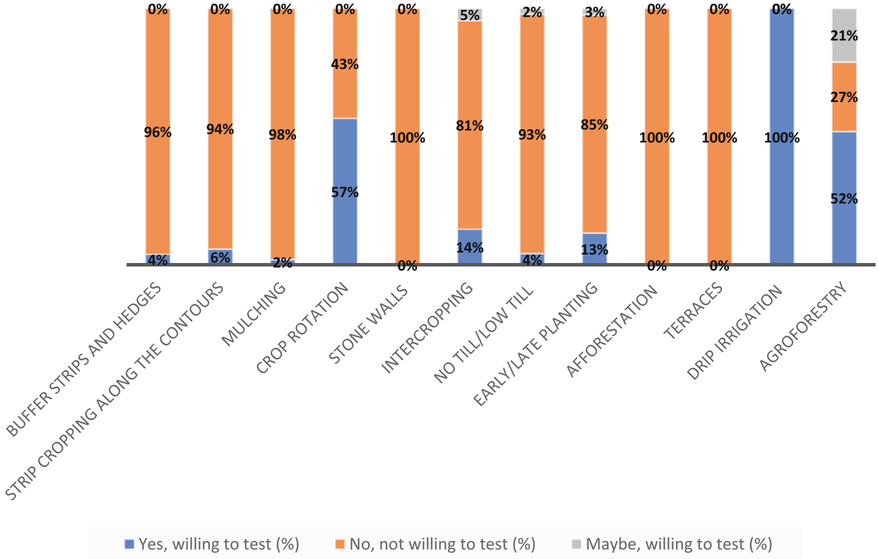

Fig. 7 Farmers' willingness to test the 12 good practices in BiH. *Source* FAO collected data

8.4 Farmers' Feedback: Serbia

In total, 256 farmers provided their feedback during various capacity building and awareness raising trainings on climate change conducted in Serbia from October 2016 to March 2017.

Figure 8 shows that measures that participants are most familiar with, include crop rotation, intercropping, early/late planting, afforestation, terraces and drip irrigation,

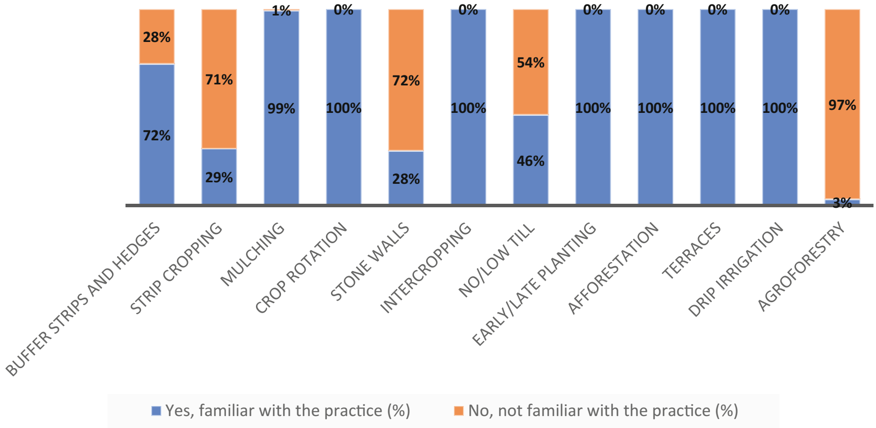

Fig. 8 Farmers' familiarity with the 12 good practices in Serbia. *Source* FAO collected data

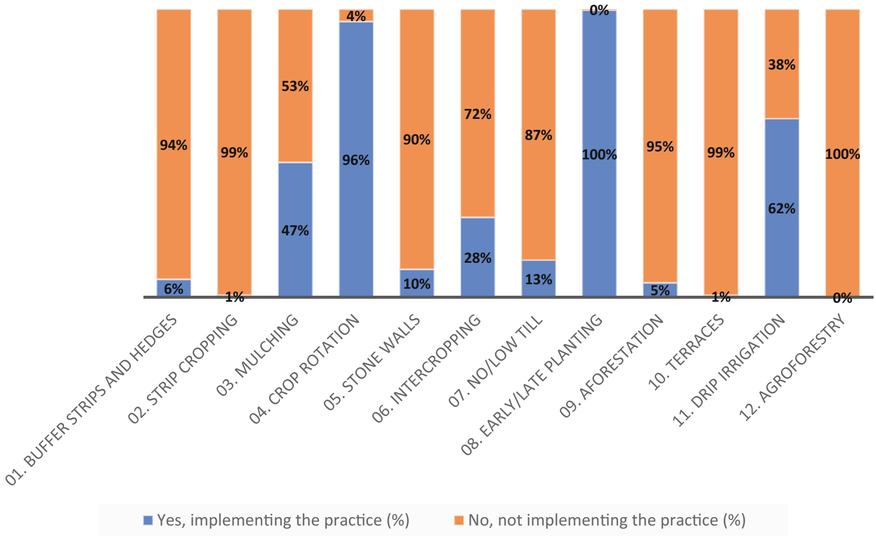

Fig. 9 Current implementation of the 12 good practices by farmers in Serbia. *Source* FAO collected data

while agroforestry is a practice that only 3% of participants are familiar with and it is currently hardly implemented as can be observed in Fig. 9. Although 100% of farmers responded that they know afforestation, intercropping and terraces, only 5, 28 and 1% respectively are currently implementing these practices.

In addition, less than 10% of farmers were willing to test practices, such as buffer zones (5%), strip cropping (1%), stone walls (0%), afforestation (10%), terraces (0%)

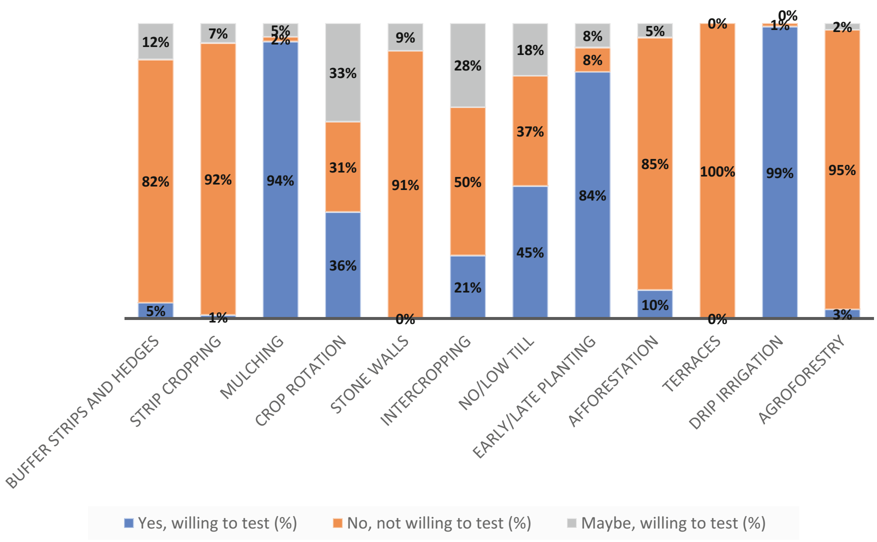

Fig. 10 Farmers' willingness to test the 12 good practices in Serbia. *Source* FAO collected data

and agroforestry (3%). However, participants showed that they are willing to test drip irrigation (99%), mulching (94%) and early/late planting (84%).

When Figs. 8, 9 and 10 are compared, it shows that participants are willing to test measures, which they are more familiar with and are currently implementing, such as drip irrigation (62%) and early/late planting (100%). Moreover, it is encouraging to see that even though only 13% of the farmers are already using the practice of 'no tillage', 45% are willing to test it. The results are similar for agroforestry, with which farmers are generally not familiar, although only 3% are willing to test it. In addition, it should be noted that for crop rotation and intercropping, although farmers stated that they are currently using these practices, they are less willing to continue or test them.

9 Conclusions

Natural hazards significantly impact the agricultural sector. With climate change, the frequency and severity of natural hazards are expected to increase. The sector is highly climate sensitive and thus vulnerable to the negative effects of natural hazards. Implementing good practices can help to reduce the impact of natural hazards on agriculture. Testing and validation of these practices and eventual adoption as well as replication and upscaling in different regions and countries is crucial, because it can help to enhance food security and build the resilience to natural hazards and climate change of people, whose livelihoods are dependent on the agriculture sector and its activities.

This chapter has provided an overview of the agriculture sector in the five Western Balkan countries of Albania, Bosnia and Herzegovina, the FYR of Macedonia, Montenegro and Serbia. It has also described how various natural hazards have adversely impacted the sector as well as the expected negative effects of the anticipated climatic changes. The region is currently facing environmental challenges, ageing rural populations and a reduced agriculture labour force, which also need to be taken into account in the development of future sustainable and climate resilient production systems.

Within this context, striving to reduce disaster risks, particularly in agriculture, is highly important, not only for ensuring food and nutrition security, but also for sustainable agricultural livelihoods. In order to achieve this, a shift from reactive emergency response to a more proactive disaster risk reduction approach is required, which includes creating an enabling policy and institutional environment, establishing effective early warning and information systems, improving preparedness for response and applying agriculture DRR practices and technologies that aim to prevent and mitigate the adverse impacts of natural hazards and climate change.

This study has investigated the perceptions of both agricultural experts and farmers on 12 identified good practices, including buffer strips and hedges, strip cropping along the contours, mulching, crop rotation, stone walls, intercropping, no till/low till, early/late planting, afforestation, terraces, drip irrigation and agroforestry, which can help to reduce the impacts of natural hazards in the Western Balkans.

According to agricultural experts, most of the 12 identified good practices are applicable to the five Western Balkan countries, except for drip irrigation and agroforestry, where often no answer was provided. The opinions of experts were divided regarding the applicability of strip cropping along the contours, stone walls, no till/low till in the FYR of Macedonia and regarding early/late sowing in Montenegro. As for mulching, crop rotation, buffer strips and hedges, afforestation, intercropping and terraces, they are considered to be currently implemented in the five countries. This strong variation in opinions may also be caused by the absence of feedback from certain experts. The lack of clarity on whether the lack of feedback indicates that these good practices are not applicable or are currently not implemented is one of the limitations of this study.

In Albania, Bosnia and Herzegovina and Serbia, farmers are all quite familiar with drip irrigation, crop rotation and terraces and less familiar with agro-forestry. Farmers in BiH are more familiar with stone walls than in the other two countries, while in Albania they are more familiar with strip cropping along the contours, but less familiar with early-late planting than in BiH and Serbia. In all three countries farmers are implementing crop rotation and drip irrigation. Mulching and intercropping is applied in Albania quite extensively, but not so much in Serbia and even less in BiH, while the other practices are hardly implemented. Farmers in all three countries are willing to test drip irrigation, crop rotation, mulching with which they are already familiar and/or already implement. They also showed a strong interest in testing, for instance, afforestation and intercropping in Albania, agro-forestry in BiH and early-late planting in Serbia, all practices with which they are less familiar and/or do not yet implement.

The views of agricultural experts, extension officers and farmers may differ in terms of e.g. familiarity, suitability, extent of implementation, and effectiveness of the DRR practices and technologies as mentioned above. Taking into account these varying views can help governments, NGOs, donors and practitioners when raising awareness and building up the capacity of farmers to test and validate these options. With expected changes in climate already being felt, combining local/traditional/indigenous knowledge with scientific knowledge can help communities highly dependent on agriculture to mitigate the risks of natural hazards and climate change. As a result, it is important that there is enhanced collaboration among these stakeholders, as well as the existence of mutual understanding in terms of ownership of the practices farmers may be willing to implement. Ensuring that there is a common understanding between stakeholders about the constraints and challenges that farmers may face is crucial if these good practices are to be tested and validated so as to be eventually replicated and up scaled in other areas that are similarly prone to natural hazards.

Given the limitations of this study with regard to the limited number of agricultural experts and extension officers that were able to provide their insights, it is recommended that further in-depth qualitative research in these countries is conducted. In addition, further research of farmers' perceptions in the FYR of Macedonia and Montenegro would also be useful to make a comparison between the five Western Balkan countries possible.

References

Alfthan B, Krilsasevic E, Venturini S, Bajrovic S, Jurek M, Schoolmeester T, Sandei PC, Egerer H, Kurvits T (2015) Outlook on climate change adaptation in the Western Balkan Mountains, Mountain adaptation outlook series. United Nations Environment Programme, GRID-Arendal and Environmental Innovations Associations, Vienna, Arendal and Sarajevo. http://eecca.recpnet.org/uploads/resource/4eea05ae360d56154dbcd344a79ec6de.pdf

Backus GBC, Timmer GTh, Dijkhuizen AA, Eidman VR, King RP (1995) The impact of a decision support system for strategic pig farm planning on the advice of extension officers. Comput Electron Agric 12(1):51–64

Binaj A, Veizi P, Beqiraj E, Gjokai F, Kasa E (2014) Economic losses from soil degradation in agricultural areas in Albania. Agric Econ 60(6):287–293

Bogdanov N (2015) Serbia: Agricultural Policy Brief (CAPB). Joint Research Centre. Institute for Prospective Technological Studies (IPTS), Seville. http://app.seerural.org/wp-content/uploads/2016/11/2015-10_Country-policy-brief-Serbia-Final.compressed.pdf

Brown B, Nuberg I, Llewellyn R (2018) Constraints to the utilization of conservation agriculture in Africa as perceived by agricultural extension service providers. Land Use Policy 73:331–340

EFNCP (2010) High nature value farming in the Western Balkans. Current status and key challenges—a scoping document. EFNCP, Lampeter. http://www.efncp.org/download/HNVF_SEE_v1.pdf

EMDAT: The OFDA/CRED international disaster database. Université Catholique de Louvain, Brussels, Belgium. www.emdat.be

European Environmental Agency (2010) Environmental trends and perspectives in the Western Balkans: future production and consumption patterns. EEA, Copenhagen

European Environmental Agency (2017) Glossary. EEA, Copenhagen
FAO, JICA and KFS (2011) Farmer field school implementation guide. Farm forestry and livelihood development. FAO, Rome. http://www.fao.org/docrep/016/i2561e/i2561e00.pdf
FAO (2012) European and Central Asian agriculture towards 2030 and 2050. Policy studies on rural transition no. 2012-1. N.p: FAO. http://www.fao.org/docrep/017/aq341e/aq341e.pdf
FAO (2013) Association of farmers in the Western Balkan countries. FAO Regional Office for Europe and Central Asia. Policy studies on rural transition no. 2013-1. N.p: FAO. http://www.fao.org/3/a-ar592e.pdf
FAO (2014) Disaster risk reduction for food and nutrition security. Key practices for DRR implementers. FAO, Rome. http://www.fao.org/3/a-i3775e.pdf
FAO (2015) The impact of disasters on agriculture and food security. FAO, Rome. http://www.fao.org/3/a-i5128e.pdf
FAO (2016a) Aquastat. FAO, Rome
FAO (2016b) Farmer field school guidance document. Planning for quality programmes. FAO, Rome. http://www.fao.org/3/a-i5296e.pdf
FAO (2017) The state of food security and nutrition in Europe and Central Asia. FAO, Budapest. http://www.fao.org/3/a-i8194e.pdf
Habiba U, Shaw R, Takeuchi Y (2012) Farmer's perception and adaptation practices to cope with drought: perspectives from Northwestern Bangladesh. Int J Disaster Risk Reduction 1:72–84
Halbrendt J, Gray SA, Crow S, Radovich T, Kimura AH, Tamang BB (2014) Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. Global Environ Change 28:50–62
Hitayezu P, Wale E, Ortmann G (2017) Assessing farmers' perceptions about climate change: a double-hurdle approach. Climate Risk Manag 17(2017):123–138
IAMO (2010) Agriculture in the Western Balkan Countries. Studies on the Agricultural and Food Sector in Central and Eastern Europe. IAMO, Halle (Saale)
ICPDR (2015) The 2015 droughts in the Danube River Basin. ICPDR, Vienna. https://www.icpdr.org/flowpaper/viewer/default/files/nodes/documents/icpdr_report_on_2015_droughts_in_the_danube_river_final.pdf
IPCC (2014) Climate change 2014 synthesis report summary for policymakers. IPCC, Geneva. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SyR_FiNAL_SPM.pdf
Luo T, Young R, Reig P (2015) Aqueduct projected water stress rankings. Technical note. World Resources Institute, Washington, DC. http://www.wri.org/publication/aqueduct-projected-water-stress-country-rankings
Maslac T (2012) Drought driven declines in serbian crops increased food prices. Global agricultural information network. USDA, Belgrade. https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Drought%20Driven%20Declines%20in%20Serbian%20Crops%20Increased%20Food%20Prices%20_Belgrade_Serbia_8-15-2012.pdf
Ministry of Environment (2016) Third national communication of the Republic of Albania under the United Nations framework convention on climate change. Ministry of Environment, Tirana
Ministry of Environment and Physical Planning (2008) Second national communication on climate change. Ministry of Environment and Physical Planning, Skopje. http://www.adaptation-undp.org/sites/default/files/downloads/macedonias_snc.pdf
Ministry of Sustainable Development and Tourism (2015) The second national communication on climate change. Ministry of Sustainable Development and Tourism, Podgorica
Mitkova T, Cvetkovska M (2006) Presentation on: overview of soil information and soil protection policies in Republic of Macedonia. Ministry of the Environment and Physical Planning, Skopje
Mizik T (2012) A snapshot of Western Balkan's agriculture from the perspective of EU accession. Stud Agri Econ 114(2012):39–48. https://ageconsearch.umn.edu/record/122450/files/A_snapshot_of_Western_Balkan_s_agriculture_from_the_perspective_of_EU_accession.pdf
Spalevic V, Curovic M, Simunic I, Behzadfar M, Tanaskovic V (2014) Land degradation, land use and soil erosion: the case of Montenegro. CIHEAM, Watch Lett: Land Issues Mediterr Countries 28(1):58–62

Sudmeier-Rieux K, Ash N (2009) Environmental guidance note for disaster risk reduction. Health ecosystems for human security. IUCN, Gland. https://cmsdata.iucn.org/downloads/healthy_ecosystems_for_human_security.pdf

UNDP (2015) Climate change and disaster risk reduction snapshot. Albania. UNDP, Istanbul. http://reliefweb.int/sites/reliefweb.int/files/resources/UNDP-snapshot-Albania%28web%29.pdf

UNDP in Bosnia and Herzegovina (2016) Third national communication and second biennial update report on greenhouse gas emissions of Bosnia and Herzegovina under the united framework convention on climate change. UNDP in Bosnia and Herzegovina, Sarajevo. http://www.ba.undp.org/content/bosnia_and_herzegovina/en/home/presscenter/articles/2017/07/19/usvojen-tre-i-nacionalni-izvje-taj-bih-i-drugi-dvogodi-nji-izvje-taj-o-emisiji-stakleni-kih-plinova-bih/

United Nations/EU/World Bank (2014a) Serbia Floods 2014. N.p., Belgrade. http://www.ilo.org/wcmsp5/groups/public/—ed_emp/documents/publication/wcms_397685.pdf

United Nations/EU/World Bank (2014b) Bosnia and Herzegovina Floods 2014. N.p.: N. p. http://europa.ba/wp-content/uploads/2015/05/delegacijaEU_2014090308560389eng.pdf

United Nations, Department of Economic and Social Affairs, Population Division (2014) World urbanization Prospects: The 2014 revision. Cd-rom Edition. UN DESA, New York. https://esa.un.org/unpd/wup/Cd-rom/

United Nations (2015) Probabilistic population projections based on the world population prospects: the 2015 revision. Population division. United Nations, New York

Waldman KB, Blekking JP, Attri SZ, Evans TP (2017) Maize seed choice and perceptions of climate variability among smallholder farmers. Global Environ Change 47:51–63

World Bank (2009) Adapting to climate change in Europe and Central Asia. World Bank, N.p. http://siteresources.worldbank.org/ECAEXT/Resources/258598-1243892418318/ECA_CCA_Full_Report.pdf

WMO (2012) Strengthening multi-hazard early warning systems and risk assessment in the Western Balkans and Turkey: assessment of capacities, gaps and needs. WMO, Geneva. https://www.wmo.int/pages/prog/drr/projects/SEE/documents/SEEPhase%20I%20-%20FinalReport.pdf

WMO/UNCCD/FAO and UNW-DPC (2013) Country report. Drought conditions and management strategies in Serbia. Initiative on "Capacity development to support national drought management policy". N.p., N.p. http://www.droughtmanagement.info/literature/UNW-DPC_NDMP_Country_Report_Serbia_2013.pdf

Zurovec O, Vedeld OP, Kumar Situala BK (2015) Agricultural sector of Bosnia and Herzegovina and climate change—challenges and opportunities. Agriculture 5(2):245–266. https://pdfs.semanticscholar.org/4e8a/c633d46182f02f25633fe83903453065805e.pdf